DEVELOPMENT OF MATHEMATICAL MODELS FOR PREDICTION OF COMPRESSIVE STRENGTH OF SANDSTONE CONCRETE

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20104834518

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ENGINEERING, (M.ENG.) DEGREE IN CIVIL ENGINEERING (STRUCTURES)

JANUARY, 2015

CERTIFICATION

This is to certify that this work "Development Of Mathematical Models For Prediction Of Compressive Strength Of Sandstone Concrete" was carried out by Igbojiaku A. U. (B. Eng) with Reg. No. 20104834518 in partial fulfillment of the requirements for the award of Master of Engineering (M. Eng.) degree in Civil Engineering (Structures) in the School of Engineering and Engineering Technology, Federal University of Technology, Owerri, Nigeria.

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DEDICATION

I dedicate this research work to my parents Engr. and Mrs. C. O. Igbojiaku.

ACKNOWLEDGEMENTS

I wish to express my appreciation, gratitude and indebtedness to my Supervisor, Engr. Dr. J.C Ezeh for initiating and supervising this research project. I am also grateful to my second supervisor Engr. Dr. O. M. Ibearugbulem for his assistance, guidance, unending encouragement and kind co-operation throughout the period of this work, which has been instrumental in the success of this research work, may GOD bless you sir.

I would also like to appreciate the efforts of my lecturers Engr. Prof. O. O. Ugwu, Engr. Dr. D.O. Onwuka, Engr. Dr. B. Mama, Engr M.S. Mbajiorgu, Engr. Dr. B.C. Okoro, Engr. Dr. C. Okere, Engr. Dr .B.U. Dike, Engr. Dr. Rev. L.O. Ettu, Engr. U.C. Anya, Engr. Dr. J. Osuagwu,Engr. Dr. H. Nwoke and the entire staff of Civil Engineering Department, FUTO for preparing me to undertake this research. I acknowledge the Dean of School of Engineering and Engineering Technology Engr. Prof. E.E. Anyanwu and the Dean of postgraduate school Engr. Prof. K.B. Oyoh for their tireless work to uphold academia.

I would like to appreciate and thank my parents Engr. and Mrs. C. O. Igbojiaku for their support morally, financially and their heartfelt encouragement may GOD continue to guide them in their endeavor, amen. I would like to thank in a special way my very good friends, Mr. Agbo S.I., Chinedu N., and Kola who helped me by providing the necessary resources in various ways for the completion of my work. I also recognize the friendliness, support and encouragement from my brothers and sisters, Mr. Stanley O. K. I., Mrs. Assumpta C., Master Valintine C.I., Miss. Thelma .O. I. and Miss. Jenifer N. I.

Finally, I thank God Almighty, whose love for me is more than words can express may his name be glorified for ever Amen.

ABSTRACT

This project presents development of mathematical models for prediction of compressive strength of sandstone concrete. In doing this, three models were formulated. The new models were derived mathematically from first principle. Concrete cubes of various mix ratios were cast and cured for 28 days. Materials for the concrete included water, Ordinary Portland Cement (OPC), river sand and sandstone aggregate. A total of 60 mix ratios were used and four cubes were cast for each mix ratio, giving a total of 240 cubes. The compressive cube strengths at 28 day of curing were used to develop the models. The models are designated as models 1, 2 and 3.The first one is a mathematical model with two degree polynomial; the second is a mathematical model with a truncated three degree polynomial consisting of twenty three coefficients while the third is a model with a complete three degree polynomial consisting of twenty six coefficients. These models were subjected to adequacy test using Fisher F test. The adequacy test proved that the three models were adequate for predicting compressive cube strength of concrete used herein at 95% confidence level. Compressive cube strengths predicted by regression model 1, were close to the results from the experiment. Those predicted by model 2, were closer to the experimental results. However, there exist no clear difference on the accuracy of predictions between models 2 and 3, in other words results predicted by both models have very little or no difference. The highest and lowest experimental compressive cube strengths recorded in this work are 33.33 Nmm^{-2} and 0.78 Nmm^{-2} respectively. These values correspond to mix ratio of water, cement, sand and stone of 0.45:1:2.25:0.75 and 0.45:1:6.75:2.25respectively.The corresponding values for model 1 are 32.40 Nmm^{-2} and 0.84 Nmm^{-2}. For model 2 the values are 30.85 Nmm^{-2} and 0.62 Nmm^{-2}, in the case of model 3 the values are 32.10 Nmm^{-2} and 0.89 Nmm^{-2}. Thus, the developed mathematical models are suitable for the prediction of compressive strength of sandstone concrete and should be used by structural engineering analysts accordingly.

KEYWORDS: Compressive strength; Sandstone; Concrete; Regression; Mathematical Model.

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$\sum$ $summation$
$\leq$ $less\ or\ equal\ to$
$-$ $subtraction$
$+$ $addition$
$\times$ $multiplication$
$\sqrt{}$ square root
α $coefficient$
b $constant\ coefficient$
$[$ $bracket$
$($ $parenthesis$
m $number\ of\ components\ of\ a\ mixture$
x_i $proportion\ of\ the\ ith\ component\ in\ the\ mixture$
$F(z) or\ R$ $responds\ function$
s_i $actual\ portions$
z_i $psudo\ variables (fractional\ portion)$
α_i $coefficients\ of\ model\ equation$
$[CC]$ $cc\ matrix$
Z $z\ matrix$
Y_i $responds\ (concrete\ compressive\ strength)$
$\widetilde{Y}$ $mean\ of\ responds$
n $number\ of\ responds$
S_y $standard\ error\ of\ replicates$
S_1^2 $variance\ at\ each\ point$
N $number\ of\ points$
ϵ $estimated\ standard\ deviation\ or\ error$
t $t - statistics$
s_y $replication\ error$
Y_p $Experimental\ results$
Y_m $Predicted\ results$
F $Fisher\ test\ statistics$

CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND OF STUDY

The use of statistics for analyzing and seeking solution to problems in the social, biological and physical sciences have been proved to be essential. This is because all these sciences make use of observations of natural phenomena, through sample surveys or experimentation, to develop and test new theories.

The continuing triple trends of increasing industrialization, urbanization, population growth and especially cost of construction due to high cost of concrete materials and its production, is on the high side. The quest to provide less expensive or cost efficient methods of concrete production, has brought about an increasing application of knowledge based on existing survey techniques and scientific study designs. It has also fuelled the development of new techniques with more advanced mathematics and probability theory to provide a good guide to good methods. Recent trends in the development of concrete mix design indicate an increasing use of probability and statistical inferences in the study of experiments and evaluation of concrete mix results, to formulate models for concrete mix optimization or response prediction. Among these models, Scheffe's and Osadebe's models are two common statistical methods of concrete mix design in civil engineering (Scheffe, 1958 & 1963, Obam, 1998 & 2006, Ibearugbulem, 2006, Osadebe and Ibearugbulem, 2008, 2009). Simon et al. (1997) also used a method that is close to Scheffe's method in concrete mix design. These methods have been found to be working well for mix optimizations. However, they have inherent problems. Both Scheffe's and Osadebe's methods have predetermined number of experiments to be carried out in order to formulate them. Apart from having predetermined number of observation points, they determine the mix ratios that can be used in them. Hence, one cannot use them to optimize an already conducted laboratory tests. If you want to optimize with them the laboratory tests will be predetermined by them. This has led to the search for alternative, more flexible and still efficient methods with modifiable amount of materials. This in turn is to help bring about more affordable assembling of materials or substitute experiment, in the formulation of models for concrete mix optimization or responds prediction and for use in concrete production. It is in the same spirit of the search for an alternative that this research work tried to see the applicability of sandstone and a mathematical model to help guide its use (a material hitherto considered less in construction) in concrete production.

1.2 Statement of problem

High cost of concrete production due to inefficient concrete mix design that would give variety of concrete mix ratio options (alternatives) for a desired response (compressive strength, tensile strength, flexural strength etc) led to evolution of statistical experiment concrete mix designs like Scheffe's lattice design and Osadebe regression. However, both Scheffe's and Osadebe's models have inherent limitations. They determine the minimum number of observation points (mix ratios in this case) that must be used to formulate them. Where the available mix ratios are less than this specified minimum number, it becomes impossible to use either Scheffe or Osadebe models.

This problems discussed here prompted the search for alternative models for concrete mix ratio prediction.

1.3 Objectives of study

The main objective of this study is the development of mathematical models for prediction of compressive strength of sandstone concrete.

The specific objectives are;

i. To develop mathematical model with two degree polynomial.

ii. To develop mathematical model with complete three-degree polynomial.

iii. To develop mathematical model with truncated three-degree polynomial.

iv. To compare the accuracies of the mathematical models obtained in i, ii and iii above.

v. To test the adequacy of the models using fisher's F test.

1.4 Justification of the study

One of the significance of this research work is creating modifiable, cheaper and affordable concrete mix design models, to help as a substitute for regression models with predetermined demand for expensive experimental process and or very complex assembling of experimental mix constituents. This will in turn help increase the pace of research development to bring about more economic breakthrough in the construction industry.

Another significance of this research work is creating more usefulness for readily available local materials like sandstone and more experimental understanding and guide for its use in concrete production. The third significance is the study of the application of alternative and cheaper course aggregate material other than granite to enable the construction of more economic structures.

1.5 Scope of study

The following will be covered in this research work: A review of related literatures on Normal Weight and Lightweight Concrete will be done to create some more background on the behavior of concrete. The study will also look at the influence of aggregates properties on concrete both in its fresh and hardened state.

The study will also look at existing works on statistical-regression concrete mix design, and their method of analysis, this will help to create the back ground of study for chapter two and also set and present the objective of the study.

Materials and methods adopted in the experiment will be stated in chapter three,also the models will be developed here. In chapter four the results of the experiments will be discussed and analysed, then the study will also test the models for accuracy. Chapter five will form the conclusion of this research where it will be stated if the objectives of this research have been met while expressing a contribution to knowledge after which a set of recommendations will be made.

CHAPTER TWO

LITERATURE REVIEW

2.0 NORMAL WEIGTH CONCRETE

According to Hassoun and AL-Manaseer (2008),the first modern record of concrete is as early as 1760 ,when john smeaton used it in Britain , the first lock on the river Calder ,the wall of the lock were made of stones filled in with concrete .Concrete is a man-made stone made by mixing sand, broken stones and cement in predetermined proportions, with sufficient water to enable the setting action of the cement content to take place. Concrete can be good or bad and surprisingly the ingredients of both concrete are exactly the same and it’s only the method of preparation often without addition of extra labour.Bad concrete often a substance of soup, hardening into a honey combed, non-homogeneous mass after simply mixing its components. But the overall criteria for good concrete is that it has to be satisfactory in its fresh state ,and also in its hardened state in order to bring about a satisfactory compressive strength .This is aimed not only to ensure that the concrete can withstand a prescribed compressive strength but also because many other desired properties of concrete are concomitant with high strength such as density ,impermeability ,tensile strength etc. With possible variation in such concrete properties concrete can be said to be classified as normal weight if the density (unit weight) is appreciably within a usual range of 2200-2600kg/m^3 (140 to 160 ib/ft^3) . According to National Concrete Masonry Association (2008) Normal Weight – units have an average density of 125 lb/ft3 (2,000 kg/m^3) or more. Hassoun and AL-Manaseer (2008) also stated that for the value of final shrinkage for normal weight concrete a value of $300x10^{-6}$ may be used. Normal weight High strength concrete (HSC) in the United States is generally considered to be concrete with a compressive strength of 6000 psi (41 MPa) or greater. In a 1984 ACI Committee 363 report, revised and reissued in 1992, 6000 psi (41MPa) was selected as a lower strength limit for high strength concrete. But ACI 318-02 explicitly states that there is no upper limit on the strength of normal weight concrete that can be used in structures, including those exposed to high seismic risk. According to a research work by Ghosh (2001) on Limit on Strength of Normal Weight Concrete , adjustments have been made on an ongoing basis in the ACI 318 code provisions to account for sometimes differing properties of high strength concrete, The consensus is that local imposition of arbitrary limits on the strength of normal weight concrete is unwarranted and unjustified, Stating that ACI 318 has never imposed an upper limit on the strength of normal weight concrete that can be used in construction, even for structures located in high seismic zones or assigned to high seismic performance or design categories. No such limit has ever existed in any other U.S. standard, in any of the model building codes, or in the building code of any legal jurisdiction within the United States. Except for the findings that application of concrete having specified compressive strengths in the range of 8 to 10 ksi (56 to 70 MPa) is now considered routine and commonplace in cities like Seattle (UBC Seismic Zone 3) and San Francisco (UBCSeismic Zone 4).

Normal weight concrete can be achieved by using ordinary aggregates whose specific gravity is approximately 2.6 and by avoiding the presence of voids ,either in the aggregate, or in the mortar or in the interstices between the coarse particles for these reduce both the strength and density and affect other properties of the concrete.

Properties of normal weight concrete are affected by many factors, from its own composition, production process, method of transport and processing, to its setting and hardening conditions. In terms of composition there is a tendency to use different waste materials to replace some of the fundamental components with new types of additives and ingredients to alter their properties. In other words normal weight concrete ability to answer the required parameters can be affected by low quality supply of concrete may be from mixing plant or other sources and a defect resulting from construction process. One of the reasons can be attributed to insufficiencies in the curing of concrete in construction or storage due to conditions that are different from those required by the relevant technical standard. According to a research carried out by Brožovský (2010) On :“Way of Concrete Storing (Curing) of Some Common Normal Weight Concrete Classes Along with Impact on its Physic-Mechanical Properties”, a study of storing(curing) as a cause of variation in normal weight concrete properties was done. In this research a test was done considering the characteristic storing environment of a standard environment (t=20+2 ^{0}c, relative air humidity ≥95%), laboratory environment (t=20+23 ^{0}c, relative air humidity ≡ 30-35%), climatogical station (variable parameters of relative humidity and air temperature and precipitation).In storing test specimens in these environments immediately after manufacturing and monitoring parameters such as compressive strength , density of hardened concrete, ultrasonic pulse velocity, dynamic modulus of elasticity ,resistance of frost and thawing alterations and to defrosting chemicals, the resulting findings of the analysis indicated that environment of normal weight concrete influences its characteristics under monitoring such as

- Compressive strength of concrete :

Highest strength was observed in concrete stored in standard environment (relative air humidity at least 95%, ambient temperature with the range of 20+2 ^{0}c). The most pronounced decrease in strength was observed for concrete stored
in climatological station (variable parameters of relative humidity and air temperature and precipitation followed by that for laboratory environment.

- Density of hardened concrete:

Presented findings demonstrated that highest mass density became evident in concrete stored in standard environment (i.e. Water), as to environment of climatological station, strength declines, concrete in laboratory shows most dramatical reduction.

Dynamic modulus of elasticity:

Highest strength was observed in concrete stored in standard environment, concrete stored in laboratory environment and climatological station showed lower Dynamic modulus of elasticity with differences in range of 2 to 3%.Another factor that influences the dynamic modulus of elasticity reduction is in the fact that concrete under testing indicates lower mass density by reason (among others) lower moisture contained in concrete which impacts on the ultrasonic pulse velocity due to material drying ,water is replaced by air and the speed of ultrasonic pulse in the air under normal condition is 340m/s which is about four to five times smaller than in water (v=1500m/s).

Concrete surface scaling:

The most resistant concrete was the one stored in the standard environment, inadequate or inappropriate curing of concrete leads to a reduction in concrete surface durability and early defect creation, and this normally leads to the operating parameters deterioration of the final structure.

According to ACI Committee 221 (2001), other factors like processing and handling of aggregate can also affect the properties of freshly mixed and hardened concrete. Basic physical and chemical characteristics of aggregates cannot generally be altered by processing although the quantities of certain deleterious particles can be reduced.

Aggregates properties that can be altered through processing which can affect concrete quality include grading ,moisture content ,cleanliness, removal of abnormally light particles ,and to some degree, particle shape. The extent to which exact specification are applied to aggregate is directly proportional /equals how refined a concrete should be for an expected critical end use. Aggregate processing for a better quality of normal weight concrete may be divided into two broad classifications.

The basic processing; to achieve suitable grading, uniformity and cleanliness.

Handling of aggregates; faulty or excessive handling of processed aggregate may result in one or all three principal problems that may affect the properties of concrete mixtures.

The first is segregation, which destroys the grading uniformity.

The second is contamination ,or inadvertent inclusion of deleterious materials

A third problem, lack of successful maintenance of uniform and stable moisture content in the aggregate as batched which further complicates the production of uniform concrete.

Degradation of material, which produce more fines has a detrimental effect on the properties of concrete is a forth problem.

2.1 LIGHTWEIGHT CONCRETE

Hassoun and AL-Manaseer (2008) states that Light weight concrete is a concrete that has been made lighter than conventional normal-weight concrete and , consequently ,it has a relatively lower density. ACI Committee E-701(2007) states that Structural lightweight concretes have densities ranging from 1360 to 1920 kg/m3 (85 to 120 lb/ft3) and minimum compressive strengths of 17.0 MPa (2500 psi). ACI 213 (1987), Structural lightweight aggregate concrete is a concrete whose 28-day compressive strength is equal to or greater than 17 N/mm^2 with air-dry density less than or equal to 1850kg/m^{2}Structural lightweight concrete and associated aggregates. Spratt (1974) is of the opinion that some lightweight concrete has air-dry density of up to 2000kg/m^3. Any concrete whose

air-dry density is below 1850kg/m^3 (about $^2/_3$ of the density of normal weight concrete) is regarded as lightweight concrete. Three means are available to achieve lightweight concrete. One way to do this is by deliberately removing the fines (fillers) from concrete mix to create large interstitial voids in the concrete. Another way is by entraining air to create large air voids within the concrete mix. The third means is by simply using lightweight aggregate (LWA) in the place of normal aggregate in a concrete mix.

Lightweight concrete is concrete of substantially lower bulk density than that made from gravel or crushed stone. The lower bulk density is produced by using lightweight aggregates that may be naturally occurring or processed materials. According to New York city building code (2008) section BC1902, light weight aggregates are aggregates with a dry, loose weight of 70 pounds per cubic foot(pcf) (1120kg/m^3) or less, Ries et al. (2010) states that Structural lightweight aggregates are aggregates produced in manufacturing plants from raw materials, including suitable shales, clays, slates, fly ashes, or blast-furnace slags. Naturally occurring light- weight aggregates are mined from volcanic deposits that include pumice and scoria. The lightweight aggregate concrete may be made of entirely lightweight aggregate or a combination of lightweight aggregate and normal weight aggregate. However, it has been a common practice to use normal sand as the filler, (fine aggregate). According to ACI Committee E-701(2007), the bulk density of structural lightweight coarse aggregate is normally from 480 to 1040 kg/m3 (30 to

65 lb/ft3), significantly lower than that of normal weight aggregates, and that the bulk density of structural lightweight fine aggregate is normally from 720 to 1120 kg/m3 (45 to 70 lb/ft3). The use and design of lightweight aggregate concrete is not as well accepted as normal weight concrete. As such no generally acceptable guideline is available for use and design of lightweight aggregate concrete. As normal weight aggregate concrete, lightweight aggregate concrete is often manufactured at site in fluid state. The properties of

concrete (both normal weight and lightweight) vary with time. Properties can be classified as fresh (fluid) properties and hardened concrete properties. Properties of fresh concrete can be used to predict, to some extent, the properties of hardened concrete. These characteristics in both fine and coarse aggregates affect the workability, water requirement, and cement content of lightweight-aggregate concrete, just as they affect concrete made with normal weight aggregates.This is why careful consideration should be given to fluid concrete, as any error at this stage will become a problem to hardened concrete. The major fresh concrete properties include workability and wet unit weight. On the other hand properties of hardened concrete include strength, dry density, durability and others.

2.2 AGGREGATES FOR NORMAL WEIGHT CONCRETE;

As mentioned in the clause 2.1. Above aggregate whose specific gravity are approximately 2.6 can be said to be normal weight aggregate, and can be used to produce normal weight concrete. University of Massachusetts (2002) studied water of absorption of some aggregates and the results showed that normal weight aggregates have water of absorption of less than 2%. Also according to University of Massachusetts (2002), normal weight aggregates have a bulk density and specific gravity not less than 1120km/m^3 and 2.2 respectively.

ACI Committee E-701(2007) also states that normal weight aggregates have absorption of 0.5 to 4%, Bulk specific gravity (relative density) 2.30 to 2.90, Dry-rodded bulk density of coarse aggregate 1280 to 1920 kg/m^3(80 to 120 lb/ft3), Surface moisture content for coarse aggregate 0 to 2% and for fine aggregate 0 to 10%.

Aggregates used in concrete ranges from several inches down to particles of a few thousands of an inch in cross-section .In practical the aggregates are best put into use by obtaining it in at least two size groups. The main division being between fine aggregates, often called sand not larger than 5mm or 3/16in., and coarse aggregates which comprises material at least 5mm or 3/16in. in size. In the United States the division is made at no.4 sieve, which is 4.76mm (3/16in.) in size. According to ACI Committee E-701(2007),for normal weight aggregate fineness modulus of fine aggregate is from 2.0 to 3.3and Nominal maximum size of coarse aggregate is from 9.5 to 37.5 mm (3/8 to 1-1/2 in.). A further distinction can be made between aggregates reduced to its present size by natural agent and crushed aggregate obtained by a deliberate fragmentation of rock. According to BS 812:1967 natural aggregates could also be classified through petrological view into different groups basalt group ,flint group, gabbro group ,granite group ,gritestone group, hornfels group, limestone group, porphyry group and quartzite group. Sandstone is classified as a gritstone. In addition aggregates could also be classified according to external characteristics such as particle shape and surface texture, aggregates could be irregular flaky, angular, elongated etc in shape while they could also be granular, glassy smooth, crystalline, rough etc in texture but properties that define normal weight aggregates tend to be related to its density. Sandstone is considered to be angular in shape and granular in texture. Natural materials and also materials that can be recycled or produced from waste products are potential sources of normal weight aggregates, however special evaluation may be necessary.

In addition to serving as an inexpensive filler normal weight aggregate the major constituent of normal weight concrete influences the properties of both freshly mixed and hardened normal weight concrete as follows

2.2.1 INFLUENCE OF NORMAL WEIGHT AGGREGATE PROPERTIES ON HARDENED CONCRETE PROPERTIES

2.2.1.1 DURABILITY

- *Wetting and drying*—The influence of aggregate on the durability of concrete subjected to wetting and drying is also controlled by the pore structure of the aggregate. According to Neville (1996),the porosity of aggregate, its permeability, and absorption ,influence such properties of aggregate as bond between it and the cement paste, resistance of concrete to freezing and thawing, as well as its chemical stability and resistance to abrasion. This problem, occurring alone, is usually not as serious as damage caused by freezing and thawing. Differential swelling accompanying moisture gain of an aggregate particle with a fine-textured pore system may be sufficient to cause failure of the surrounding paste and result in the development of a pop out. The amount of stress developed is proportional to the modulus of elasticity of the aggregate. Many times friable particles or clay balls in aggregate, which are detected by ASTM C 142, are weakened on wetting and may degrade on repeated wetting and drying.
- *Heating and cooling*—Heating and cooling induce stresses in any non homogeneous material. If the temperature range is great, damage may result. For aggregates commonly used and for temperature changes ordinarily encountered, this is not usually a critical factor in concrete. However, it has been reported by (Willis and DeReus, 1939; Callan, 1952;Pearson, 1942; Parsons and Johnson, 1944; and Weiner,1947), that large differences in the coefficient of expansion or thermal diffusivity between the paste and the aggregate can result in damaging stresses in concrete subject to normal temperature change. In interpreting laboratory tests and field observations, it is difficult to isolate thermal effects from other effects such as moisture changes and freezing and thawing. Although the usual practice is not to restrict the expansion coefficient of aggregate for normal temperature exposure, aggregates with coefficients that are extremely high or low may require investigation before use in certain types of structures. Normally, concrete containing aggregate with a low modulus of elasticity withstands temperature strains better than that containing aggregate with a high modulus (Carette et al.1982).

- *Abrasion resistance*—Abrasion resistance and localized impact resistance of concrete is a property that is highly dependent on the quality of both the cement paste and the aggregate at and near the surface receiving localized impact and abrasive stresses which in turn is dependent on the roundness of the aggregates, According to Neville (1996), roundness of the aggregates is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In those cases where the depth of wear is not great, there will be little exposure of coarse aggregate, and only the presence of a hard and strong fine aggregate in a good quality cement paste may be necessary to provide needed surface toughness.

- *Reactive aggregates*—The use of some aggregates may result in deleterious chemical reaction between certain constituents in the aggregates and certain constituents in the cement, usually the alkalies. According to Neville (1996), the most common reaction is that between the active silica constituents of the aggregate and the alkalis in cement. All aggregates are generally believed to be reactive to some degree when used in portland cement concrete, and some reaction evidence has been identified petrographically in many concretes that are performing satisfactorily. It is only when the reaction becomes extensive enough to cause expansion and cracking of the concrete that it is considered to be a deleterious reaction. Moisture condition and temperature range of the concrete in service may significantly influence the reactivity and its effects. In most cases, it is not necessary to further consider aggregate reactivity if aggregates have a known good service record when used with cement with similar alkali levels. Two principal deleterious reactions between aggregates and cement alkalies have been identified. These are:
    - ·Alkali-silica reaction, and
    - Alkali-carbonate reaction

In both cases, a deleterious reaction may result in abnormal expansion of the concrete with associated cracking, popouts, or loss of strength. Other damaging chemical reactions involving aggregates can also occur

- *Alkali-silica reaction*—Deterioration of concrete due to the expansive reaction between siliceous constituents of some aggregates and sodium and potassium oxides from cements has occurred in numerous locations in the U.S. and elsewhere (Helmuth et al. 1993; Mid-Atlantic Regional Technical Committee, 1993 and 1993a; Portland Cement Association, 1994; Stark et al. 1993). Typical manifestations of alkali-silica reaction are expansion, closing of joints, dislocation of structural elements and machinery, cracking (usually map or pattern cracking), exudations of alkali-silicate gel through pores or cracks which then form jellylike or hard beads on surfaces, reaction rims on affected aggregate particles within the concrete, and occasionally pop outs. It should be noted that some of these manifestations also can occur from other phenomena such as sulfate attack. Petrographic examination must be used to identify the causes of the reaction. Rock materials identified as potentially deleteriously reactive are opal, chalcedony, microcrystalline to cryptocrystalline quartz, crystalline quartz that is intensely fractured or strained, and latitic or andesitic glass, or cryptocrystalline devitrification products of these glasses. All of these materials are highly siliceous. Some of the principal rock types that may contain the reactive minerals are cherts, siliceous limestones and dolomites, sandstones, quartzites, rhyolites, dacites, andesites, shales, phyllites, schists, granite gneisses, and graywackes. However, these rock types do not necessarily contain any of the reactive minerals. Manufactured glass, such as bottle glass, may be reactive when present as a contaminant in otherwise suitable aggregate. Recycled crushed glass aggregate should not be used in concrete. The principal factors governing the extent of expansive reactivity of the aggregates are:

i. Nature, amount, and particle size of the reactive material,
ii. The amount of soluble alkali contributed by the cementitious material in the concrete, and

Water availability.

- *Alkali-carbonate rock reaction*—Certain dolomitic limestone aggregates found in the U.S. and elsewhere are susceptible to this reaction. However, most carbonate rocks used as concrete aggregate are not expansive. All of the expansive reactive carbonate rocks are generally thought to have the following features:

i. They are dolomitic but contain appreciable quantities of calcite.
ii. They contain clay and/or silt.

iii. They have an extremely fine-grained matrix.

iv. They have a characteristic texture consisting of small isolated dolomite rhombs disseminated in a matrix of clay or silt and finely divided calcite.

The clay may contribute to expansion by providing mechanical pathways to the reacting dolomite rhombs by disrupting the structural framework of the rock, thus weakening the carbonate matrix. Research on this reaction (Buck, 1975) has been performed, and control measures have been developed to use potentially expansive rocks (U.S. Army Corps of Engineers, 1985). These include selective quarrying to eliminate the deleterious rock or to restrict its amount and use of cement with not more than 0.40 percent alkali as equivalent sodium oxide.

- *Fire-resistance*—Aggregate type has an influence on the fire resistance of concrete structures according to ACI 216R. Laboratory tests (Selvaggio and Carlson, 1964, and Abrams and Gustaferro, 1968) have shown concrete with lightweight aggregate to be more fire-resistant than concrete with normal weight aggregate. This lighter material reduces the thermal conductivity of the concrete and thus insulates the concrete better from the heat source. Also, blast furnace slag is more fire-resistant than are other normal weight aggregates (Lea, 1971) because of its lightness and mineral stability at high temperature.

Carbonate aggregates are generally more resistant to fire than are certain siliceous aggregates. Dolomites calcine at 1110-1290 F (600-700 C) and the calcite in limestone calcines at about 1650 F (900 C) in a 100 percent carbon dioxide atmosphere. As the calcined layer is formed, it insulates the concrete from the heat source and reduces the rate at which the interior of the concrete becomes heated. Aggregates containing quartz such as granite, sandstone, and quartzite are susceptible to fire damage. At approximately 1060 F (570 C), quartz undergoes a sudden expansion of 0.85 percent caused by the transformation of “alpha” quartz to “beta” quartz. This expansion may cause concrete to spall and lose strength.

- *Acid resistance*—Siliceous aggregates (quartzite, granite, etc.) are generally acid resistant. The opposite is true of carbonate aggregates (limestone and dolomite) which, under most conditions, react with acids. However, the cement paste of concrete will also react with acid, and under mild acid conditions a concrete with carbonate aggregates may be more acid-tolerant than if made with siliceous aggregates. This is because under these conditions the sacrificial effect of the carbonate aggregate can significantly extend the functional life of the concrete. Where concrete is routinely exposed to severe acid environments

an appropriate protective coating or non-portland (such as epoxy) cement concrete with acid resistant aggregate may be required.

2.2.1.2 Strength

Perhaps the second most important property of concrete and the one for which values are most frequently specified, is strength. The types of strength usually considered are compressive and flexural strength depends largely on the strength of the cement paste and on the bond between the paste and aggregate. According to Neville (1996),the bond between aggregate and cement paste is an important factor in the strength of concrete especially flexural strength ,stating that bond is due, in part to the interlocking of the aggregate and the paste owing to the roughness of the surface of the aggregate. The strength of the aggregate also affects the strength of the concrete, even though most normal weight aggregates have strengths much greater than the strength of the cement paste with which they are used. Neville (1996) also states that it is possible that the influence of aggregate on the strength of concrete is due only to the mechanical strength of the aggregate but also, to a considerable degree to its absorption and bond characteristics. The bond between the paste and aggregate tends to set an upper limit on the strength of concrete that can be obtained with a given set of materials, particularly in the case of flexural strength. Bond is influenced by the surface texture, mineral composition, particle size and shape, and cleanliness of the aggregate.Cement paste normally bonds better to a rough-textured surface than a smooth surface. Surface texture is more important for coarse aggregates than for fine aggregates. Fine aggregate, grading, particle shape, and amount all have a major influence on the strength of concrete because of their effect on water requirements

There is experimental evidence (Walker and Bloem, 1960) to show that at a fixed water-cement ratio, strength decreases as maximum size of aggregate increases, particularly for sizes larger than 11/2 in. (38 mm). However, for the same cement content, this apparent advantage of the smaller size may not be shown because of the offsetting effects of the required increased quantity of mixing water. For high-strength concretes, optimum maximum aggregate size will usually be less than 11/2 in. (38 mm), and this size tends to decrease with increasing strength (Cordon and Thorpe, 1975).

2.2.1.3 Shrinkage

According to Hassoun and AL-Manaseer (2008) the smaller the size of aggregate particles, the greater the shrinkage, the greater the aggregate content, the smaller the shrinkage. Aggregate has a major effect on the drying shrinkage of concrete. With cement paste having a high shrinkage potential, aggregate is introduced into the paste to make mortar or concrete reduces paste shrinkage due to the restraint provided by the aggregate, and to the dilution effect (less paste). The resulting shrinkage of the concrete is a fraction of the shrinkage of the paste due to these effects. Therefore, the shrinkage of concrete under given drying conditions is dependent on the shrinkage potential of the paste and the properties and amount of the aggregate. The relative importance of these factors will vary. Factors associated with the aggregate that affect drying shrinkage of concrete are as follows:

a. Stiffness, compressibility, or modulus of elasticity of the aggregate.
b. Properties of the aggregate such as grading, particle shape, and maximum aggregate size that influence the amount of water required by the concrete and the amount of aggregate used in the concrete.
c. Properties of the aggregate (texture, porosity, etc.) that affect the bond between the paste and aggregate.
d. Clay on or within the aggregate that contributes to an actual shrinkage of the aggregate on drying or that contributes clay to the paste.

Some aggregates which shrink on drying have high absorption values. Tests were made under identical exposure conditions. Aggregates containing quartz or feldspar and limestone, dolomite, granite, and some basalts can generally be classified as low shrinkage-producing aggregates. Aggregates containing sandstone, shale, slate, graywacke, or some types of basalt have been associated with high-shrinkage concrete. However, the properties of a given aggregate type, such as limestone, granite, or sandstone, can vary considerably with different sources. This can result in significant variation in shrinkage of concrete made with a given type of aggregate.

According to Hassoun and AL-Manaseer (2008), the more cement and water content in the concrete mix, the greater the shrinkage. Drying shrinkage of concrete is influenced by the water content of the concrete. Therefore, the various aggregate properties that influence the amount of water used are a factor in the amount of drying shrinkage. These factors are particle shape, surface texture, grading, maximum aggregate size, and percentage of fine aggregate.Neville (1996), reports that some Scottish dolerites shrink on drying. Some South African aggregates have considerable shrinkage on drying (Stutterheim, 1954). Aggregate with high absorption should be a warning sign that the aggregate may produce concrete with high shrinkage. If one needs to know the drying shrinkage potential of concrete made with a given aggregate, drying shrinkage tests made under carefully controlled conditions are required. The magnitude of the shrinkage obtained is dependent on the test procedure and specimen.

2.2.1.4 Thermal properties

According to Neville (1996), the properties of aggregate that have an effect on the thermal characteristics of concrete are the specific heat, coefficient of thermal expansion, thermal conductivity, and thermal diffusivity. Thermal conductivity varies directly with the unit weight of the concrete. Generally, the denser the aggregate used, the higher the value of the thermal conductivity. Cement paste has a lower thermal conductivity than most aggregates. Therefore, the more aggregate used in the mixture the higher the value of thermal conductivity.

2.2.1.5 Unit weight

The unit weight of the concrete depends on the specific gravity of the aggregate, the amount of air entrained, mix proportions, and the properties previously discussed that determine water requirement. Since the specific gravity of cement paste is less than that of normal weight aggregate, unit weight normally increases as the amount of paste decreases.

2.2.1.6 Modulus of elasticity

Due to the nonlinear behavior of the cement paste and formation of bond cracks and slipping at the aggregate-paste interface, there is no simple relationship between aggregate and concrete modulus of elasticity. LaRue (1946) found that for a given cement paste the modulus of elasticity of the aggregate has less effect on the modulus of elasticity of the concrete than can be accounted for by the volumetric proportions of aggregate in concrete. Hirsch (1962) gives data where aggregates with modulus of elasticity values of about 2, 5, 9, 11, and 30 x 106 psi (13, 34, 62, 76, and 207 GPa) did indicate “that the modulus of elasticity of concrete is a function of the elastic moduli of the constituents.” In general, as the modulus of elasticity of the aggregate increases so does the modulus of elasticity of the concrete, and as the volume of the aggregate increases, the modulus of the concrete will approach the modulus of elasticity of the aggregate. However, where the modulus of elasticity of the concrete must be known fairly accurately, tests of the concrete are recommended instead of the computation of modulus of elasticity from the properties of the aggregate based on empirical or theoretical relationships.

2.2.1.7 Surface frictional properties

The coefficient of friction or slipperiness of concrete surfaces is influenced by the properties of the aggregates used at the surfaces. Initially the finished texture of the surface and hardness of the fine aggregate are important.The coarse aggregate will become involved only if there is enough loss of surface material to expose a significant amount of the coarse particles.

2.2.2 INFLUENCE OF NORMAL WEIGHT AGGREGATE PROPERTIES ON FRESHLY MIXED CONCRETE PROPERTIES

Compositional differences in the aggregates may be geologic factors involved in the formation, subsequent deformation, and mineralogy of the source material or due to the processes used in crushing, sizing, and cleaning. There can be a wide range in the various physical and chemical properties of aggregates .Differences in properties among aggregate sources as well as variation in the properties of an aggregate from a single source can also affect the performance of freshly mixed concrete.

Physical properties of the aggregate affecting freshly mixed concrete proportions include grading, maximum size, particle shape and texture, bulk unit weight, absorption, specific gravity, and amount of clay fines. Also the properties of freshly mixed concrete can be affected by aggregates with all such variations as follows

2.2.2.1 Mix proportions

The grading and particle shape of aggregates influence the proportions needed to obtain workable freshly mixed concrete and at the same time provide needed hardened concrete properties with reasonable economy. ACI 211 provides guidance on the use of maximum density curves to determine the optimal combined aggregate grading. The amount of mixing water needed to obtain a desired slump or workability depends on the maximum size of the coarse aggregate, particle shape and texture of both the fine and coarse aggregates, and particle size range of coarse aggregate. Significant differences in the water requirement of concrete using fine aggregates from different geographic areas were noted by Blanks (1952). In comparable concrete mixtures, one fine aggregate needed 80 lb/yd^3 (48kg/m^3) more mixing water. Examination of these fine aggregates under magnification revealed that one was smooth and rounded and the other was rough and very angular. The angular fine aggregate required the greater amount of mixing water and also needed more Portland cement to maintain the water-cement ratio. There are many aspects of concrete durability, and practically all are influenced by properties of the aggregate.

2.2.2.2 Slump and workability

Slump is a measure of concrete consistency and can be affected by aggregate in that changes in the aggregate grading or particle shape affect mixing water requirement. According to Neville (1996), an increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increased. Another cause would be a change in the grading of the aggregate, such as deficiency of sand. So, on the long run a change in particle shape or grading changes the consistency of the concrete if the amount of mixing water is held constant. Normal weight aggregates can also affect normal concrete by being a source of slump loss, this may be due to the absorption of mixing water into porous aggregate that has been batched dry or at a moisture content less than its absorption. However, it is not, by itself, a measure of workability. Other considerations such as cohesiveness, harshness, segregation, bleeding, ease of consolidation, and finishability are also important, and these properties are not entirely measured by slump. Workability speaks mostly of the effective placement and consolidation of freshly mixed concrete without undesirable voids and honeycombing. Concrete must be workable enough for the given formwork, reinforcement spacing, placement procedure, and consolidation technique to completely fill spaces around the reinforcement and flow into corners and against form surfaces to produce a reasonably homogeneous mass without undue separation of ingredients or entrapment of macroscopic air or water pockets in the concrete. According to Neville (1996), if the water content and the other mix proportions are fixed , workability is governed by the maximum size of aggregate, its grading, shape and texture.One important aspect of workability, particularly if mixtures of plastic or flowable consistency are being placed, is the tendency of the mix to segregate—the separation of coarse particles from the mortar phase of the concrete and the collection of these mortar-deficient particles at the perimeter or toe of a concrete placement. The effect of aggregate on the cohesive properties of a concrete mixture depends on factors such as the maximum size of the coarse aggregate, if larger than 3/8 in. (9.5 mm), the overall combined grading fine and coarse aggregate (and percentage of fine aggregate on the basis of total aggregate), and the amount of clay-size fines present.It is difficult to evaluate workability on an objective basis because of the lack of a good test method. Normally, workability problems only become apparent during a concrete placement requiring either a change in the placement equipment, or procedures, or an adjustment in the mixture proportions to provide better workability for prevailing conditions

2.2.2.3 Pumpability

With more angular or poorly graded aggregates in a mix, Concrete is expected to be more difficult to pump because of its higher internal friction. The particle shape of coarse aggregate will have a modest effect on pumpability and line pressure. The properties of fine aggregate play an important part in proportioning pumpable mixtures.ACI Standards 211.1 and 304R state that, for concrete that is to be pumped, the amount of coarse aggregate may be decreased by up to 10 percent. This means that the mortar-coarse aggregate ratio may be increased if necessary to provide for more workable concrete. For some fine aggregates, particularly poorly graded manufactured fine aggregate, close control of the fine aggregate may be needed to produce pumpable concrete. This may include improving particle shape, increasing the amount of finer sizes in the fine aggregate, using a natural blending fine aggregate, or the use of a higher cement content, (perhaps with fly ash or other pozzolans) to improve workability and decrease bleeding. Concrete that bleeds excessively is more difficult to pump

and may be unpumpable if the pumping pressure squeezes water out of the concrete.

2.2.2.4 Finishing characteristics of unformed Concrete

The angularity and grading of aggregate, the amount of bleeding, and mixture proportions of the concrete are factors that may influence finishing. Possible remedies to improve finishing of concrete include the use of additional fines in the fine aggregate, the use of a blending sand, more cement adjustments to the aggregate grading (both fine and coarse), or changes in mixture proportions. Neville (1996), states that the physical properties of fine aggregate, especially that smaller than a 150µm (No. 100) B.S. sieve, may also affect bleeding. Rich mixes are less prone to bleeding than lean ones. If the concrete is affected by excessive bleeding, its reduction may be accomplished according to Neville (1996) by addition of pozolanas or of aluminium powder.Less fines in the fine aggregate and also less cement, less pozzolan, adjustments of chemical admixtures, or reduction in air content might help in the reduction of stickiness in the finishing characteristics of unformed concrete

2.2.2.5 Air content

Air content in concrete can be reduced by a significant amount of material passing the 75 μm (No. 200) sieve, particularly in the form of clay,; therefore, more air-entraining admixture must be used. Sometimes this material results from the use of "dirty" fine or coarse aggregate and is quite variable, thereby causing problems in controlling the air content, as well as causing other problems, which include variations in water requirement, slump, and strength (Blick, 1964). Gaynor (1977) reports that increased minus 75 or 150 μm (No. 200 or No. 100) sieve size material in fine aggregate required an increased dosage of air-entraining admixture to obtain required air content but produced smaller bubbles and a better air-void system with a low spacing factor. Conversely, increased amounts of 600 to 300 μm (No. 30 to No. 50) sizes of the fine aggregate will decrease the dosage of air-entraining admixture required for the same air content.

2.2.2.6 Other properties

The presence of soluble salts or organic materials in the aggregate may influence the Setting time of concrete even though normally this property is not affected by aggregate. The resulting unit weight of the fresh concrete will be affected by the specific gravity and quantity of each aggregate used in concrete. With aggregates of fairly high porosity, the unit weight of concrete may vary depending on whether the absorption has been satisfied by premoistening the aggregate prior to batching. Concrete temperature, as mixed, is influenced by the temperatures and specific heat properties of the constituent materials. Aggregate, being present in the greatest amount, has a large effect on concrete temperature.

In hot weather, sprinkling or shading of stockpiles of aggregate reduces concrete temperature. In cases where very cool concrete is needed, coarse aggregate may be cooled by immersion in chilled water or by spraying the stockpile (ACI 305R). In cold weather the heating of the aggregate may be necessary to obtain desired concrete temperatures (ACI 306R). Frozen aggregates should not be used in concrete mixtures.

2.3 TRADITIONAL CONCRETE MIX DESIGN;

Mix design of concrete is a means of producing the most economical and durable concrete that meet with certain properties as consistency, strength and durability by properly and systematically combining the ingredients at relative proportions (Neville, 1996). Two categories of mix design method exist. One of them is the empirical method and the other is the statistical method (Simon et al. 1997).

2.3.1 EMPIRICAL MEHTOD

Here one will rely on information from historic data or laid down rules (codes) for mixture proportioning. Historic data is just about the rule of thumb. It will only work for the materials that were used for it in the past. The method will not incorporate new material other than the ones used in the past. The use of trial mixes and repeated mixes (further trials) to enable all specified criteria to be met is inevitable. Hence, it will be difficult if not impossible to achieve an optimal mixture for desired criterion with historic information method of concrete mixture design. The use of laid down rules or codes in concrete mix design is an improvement over the historic information method. This is so because there is a stepwise (though rigorous) approach and it can accommodate a wider range of materials. Some common laid down rules in concrete mix design are Road Note No.4, ACI standards 211.1 – 77 and 211.3 – 75 and 1975 British method. (Simon et al.(1997), Road Research (1950), ACICommittee 211 (1974) and Teychenne et al. (1975)).

2.3.2 STATISTICAL EXPERINMENTAL METHOD

This method makes use of theory of statistics and some specified laboratory results from practical experiments to formulate a mathematical model (equation), which will later be used to predict concrete mix ratio when a desired target strength is known. The long run advantage will always pay off or compensate the initial input and justifies it. Unlike the empirical method, there won't be any further trial mixes once the model has been formulated. The limitation to this method is the model is always particularised and cannot be used as a generalised model. For example, if a model is formulated for sandstone aggregate concrete, it cannot be used to predict the concrete mixture ratio involving aggregate other than the sandstone aggregate. Some statistical experimental methods are Simplex design (Obam, 1998), Axial design, Mixture experiments involving process variables, Mixture model with inverse terms (Draper et al. 1997) and K-model (Draper et al. 1999).

2.4 STATISTICAL-REGRESSION CONCRETE MIX DESIGN

According to Ott and Longnecker (2001) the objective of statistics is to make an inference about a population of interest based on information obtained from a sample of measurements from that population, also stating that the basic idea of regression analysis is to use data on a quantitative independent variable to predict or explain variation in a quantitative dependent variable. Radhakrishna (1970) showed that a set of parameters $X_1, X_2, X_3, \ldots, X_n,$ known as predictors can be used to predict the probable value of a dependent variable, Y with a particular degree of certainty. This means that so long as the values of the predictors are known in this case blend components of concrete such as water-cement ratio, sand-cement ratio etc. the corresponding value of the dependent variable can be predicted with some degree of certainty. In this method few points of observation will be used to formulate the model. Once the model has been formulated and tested for "goodness of fit", it can then be used to be predicting future values of the dependent variable. The details of the regression method of concrete mixture design will be considered in chapter three.

2.4.1 SCHEFFE SIMPLEX DESIGN

Scheffe (1958) was the first person to introduce simplex lattice design. Later in 1963 he also introduced simplex centroid design. Simplex is a factor space. The simplest factor space is a straight line comprising of two components at both ends. The points within a simplex lattice (space factor) are symmetrically arranged and equidistant from the centroid. In the design a suitable polynomial will be chosen to represent the response surface of the entire space. In the research work by Ibearugbulem (2006), in which Scheffe Simplex Design was adopted, it was demonstrated as stated by Scheffe that the number of points on the space corresponds to the number of parameters in the chosen polynomial equation. Scheffe (1958) showed that the response function (property) in multi-component system can be approximated by a polynomial, as demonstrated by Nwakonobi and Osadebe (2008) in their research on: “Optimization Model for Mix Proportioning of Clay-Ricehusk-Cement Mixture for Animal Buildings”, In which he carried out using Scheffe’s simplex lattice approach.

The difference between the simplex lattice and simplex centroid design is: in simplex lattice design the points considered either fall at the vertices of the factor space or at the edges, while in the centroidal design one of the points must fall at the centre of the factor space.

2.4.2 OSADEBE’S REGRESSION CONCRETE MIX DESIGN

It is similar to Scheffe’s simplex model lattice design because it is formulated with similar bases of initiation using simplex lattice as a structural representation of lines joining the components of a mixture, but it is an extension and an alternative to Scheffe’s simplex model. In Scheffe’s model according to Osadebe and Ibearugbulem (2009), the actual components of the mixture are related with the pseudo components of the same mixture, the two are related with coefficient of relation. The various quantities of the pseudo components of the mixture at each arbitrary point are determined depending on the number of component that make up the concrete mixture and its designated factor space.In Osadebe’s model, It is still required like the simplex model that the sum of the components must be one , and the actual components also represents values of the actual mixture proportions(ie the proportion of the ingredients), the pseudo components represent the corresponding Fractional portions (the proportion of the components of the ith component in the mixture) .In order words instead of pseudo components he introduced fractional portion and condensed the model equation in order to use matrix algebra. Osadebe (2003) also assumed that the response function is continuous and differentiable with respect to its predictors. This was demonstrated in the work of Okere et al. (2013), On: "Mathematical Model for Optimisation of Modulus of Rupture of Concrete Using Osadebe's Regression Theory" . The general polynomial model for the multiple linear regressions relating the responds y to a set of independent variables was the starting point from where the use of matrix notion was initiated.(model in linear parameters ,but in independent variables).A suitable combination of independent variable is obtained in order to form a suitable entity that would relate the coefficients and the responds. The first row of the combination contains the setting for the k independent variables for the first observation ,row 2 contains the corresponding settings of the independent variable for y_2 similarly the other rows contain settings for the remaining settings. This is substituted into the resulting normal equation, in matrix notation and its computation carried out, there by getting the desired vector of estimated coefficients. The resulting data is used to formulate a desirable prediction equation that relates the dependent variable and independent variables.

2.4.3 IBEARUGBULEM REGRESSION MODEL FOR OPTIMIZING CONCRETE MIXES;

Ibearugbulem's regression model was formulated as a further improvement and alternative to both Scheffe's model and Osadebe's alternative regression model. According to Ibearugbulem et al. (2013), the formulation started with the Osedebe's procedures, then Scheffe's model and Osadebe's model constraints were imposed on it. A number of modification were put into its formulation which made it quite different from both Scheffe's and Osadebe's model. The number of terms in the general polynomial equation is dependent on the degree of the polynomial and the number of independent variables.The regression models were formulated to have a combination of terms representing quantitative independent variables allowing for interaction between the independent variables.The independent variables used in the regression function are pseudo variables formed from a predetermined relationship with the actual variables. A suitable matrix algebra equation formulated from the multiple regression model relating the responds (y) to a given set quantitative independent variables and the coefficient for the total sample of n measurements containing the sum of every observation point was used to determine the vector coefficient estimates, which was now used in the formation of regression model equation

Other recent regression models like SBZ-model has been developed by Szilágyi et al. (2010), arising from the long time need for a model that can clarify the rebound surface hardness of concrete. This phenomenological constitutive model (SBZ-model) was introduced and formulated for the surface hardness of concrete as a time dependent material property.

2.5 STUDENT T – STATISTICAL TEST.

The need to understand variations in measurements led to important concepts in statistics such as bias, mean and standard deviation .The practice in statistics concerned with the meaning of measurement is known as the analysis of variance. This field formally developed only in the last century, beginning with a significant insight by a little –known chemist working in Ireland and writing under the pseudonym “student”. In most statistical works it turns out that mean suffices to characterize a physical property especially in such cases where tolerances are not of critical importance and it is not necessary to actually calculate error margins. This is especially true in that it is clear that the individual measurements do not display a significant range. With doubts about the value of the mean creeping into the picture in situations where a series of measurement show a good scatter /dispersion, a need to report the average but qualify it with some value reflecting the quality of the data. Standard deviation is the key to understanding the diversity of measurements that go into an average. It is useful in determining the intrinsic error inherent in any series of measurements. It is also useful in identifying any extremes that might exist in a set of data. According to Page (1995) in analyzing the relationship of mean of a population, the estimated mean, and the standard deviation, Gosset arrived at a new understanding under the name student, the rather unusual pseudonym “student” was chosen by Gosset in honor of Karl Pearson his “professor”. For publication, Gosset also assumed the name “student” According to Ziliak(2008**)** “Student” is the pseudonym used in 19 of 21 published articles by William Sealy Gosset, who was a chemist, brewer, inventor, and self-trained statistician, agronomer,and designer of experiments (Student, 1942).He devised an extensive experiment in an approach which was decidedly empirical, Gosset was perhaps lucky in quantifying the error in a way that was later demonstrated to be optimum. In a bid to relate the economic impact of changes in procedures to the cost of experimentation, Gosset tried to judge the certainty of results from very small sample, in order to reach supportable conclusion on the basis of so few measurements. So Page, (1995) reported that Gosset’s preoccupation with small sample size stressed existing statistical techniques and eventually led to improvement in handling the more customary large population. According to statistician Egon S. Pearson, son of Karl Pearson the existing imperfections were of “small consequence” with large samples but completely evident in the “absurdly small numbers” of Gosset’s.In this way, Gosset’s contributions extended greatly beyond small sample technique and truly set the foundation for analysis of variance. According to Lehmann (1993), the modern theory of testing hypotheses began with student’s discovery of the t test in 1908. Ziliak (2008**),** stated that the first presentation of “Student’s test of significance” came a century ago, in “The Probable Error of a Mean” (1908b), published by an anonymous “Student.” Also stating that the author’s commercial employer required that his identity be shielded from competitors, but it has been known for some decades that the article was written by William Sealy Gosset (1876 –1937). In 1908 Gosset expressed the original formulation of what has since become known as student‘s t test of statistical hypothesis .The technique pioneered by Gosset were eventually extended and popularized by Ronald fisher (1890-1962), writing to Gosset while still a student proposing some improvement in the definition of standard deviation. It was fisher in 1924, who first introduced the term "t test", Gosset immediately accepted the new formulation and published the extended values for t, as stated by Page (1995) from a work termed "Gosset's original work used a z constant, which Fisher later related to t as$\sqrt{n-1z}$." The new tables appeared in publication with a theoretical contribution by Fisher. Expressing it in modern form Gosset related a table of constants, t with the probability that a mean closely approximates the unknown value it attempts to describe. Student's t-test can be described as a statistical hypothesis test in which on forming a suitable test statistic, follows a Student's t distribution (or t distribution) if the null hypothesis is true.

According to Ziliak(2008**),** Gosset's contributions includes: small sample distribution theory (1904–1932); "Student's" *t* table and test of significance (1906–08, 1922–26, 1931–32); modern Monte Carlo analysis (1907–08); the efficient design of experiments (1908–1937) ; the economic approach to the logic of uncertainty ("net pecuniary value" and "real error" substituting for a 5 percent or other rule of statistical significance, 1904–1937); and alternative hypotheses and "power" (1926, in two letters he wrote to Egon Pearson).

In the light of this, t test was adopted and used in statistical hypotheses tests such as single population test for single parameter, and also for testing hypothesis about single population parameters or about the difference between two population parameters if certain assumption about the variable hold. T distribution is also used for determining confidence interval.

2.6 FISHER F – STATISTICAL TEST;

Fisher F–statistical test was invented by a British statistician and geneticist Sir Ronald Aylmer Fisher (Feb, 17, 1890-July29 1962) a pioneer in modern statistical tests and methods. Though at first eugenics sparked his interest in the practical application of statistics, his contribution to the discipline of statistics are clearly outstanding, as he contributed both to the mathematical theory of statistics and to its application and test. According to Stevan (2005), Ronald Fisher undoubtedly laid the foundation for modern statistical methods and their application, stating that his work contributed to statistics to become and develop in an independent scientific discipline. According to Stevan (2005), Fisher(1922) gave a new definition of statistics asserting that its purpose was the reduction of data. Briefly and in its most concrete form, the object of statistical methods is the reduction of data. A quantity of data, which usually by its mere bulk is incapable of entering the mind ,is to be replaced by relatively few quantities which shall adequately represent the whole ,or which, in other words ,shall contain as much as possible ,ideally the whole of the relevant information contained in the original data. In this context it is also the object of the statistical processes employed in the reduction of data to exclude this irrelevant information and to isolate the whole of the relevant information contained in the data .

Fisher provided a unified and general theory for analysis of data and laid the logical foundation for inductive inferences. Regarding statistical methods from the point of view of application, since he was always involved in solving biological problems which needed statistical methods. Many of his application techniques have become standard tools in statistics today. Due to the fact that some of these statistical methods required rather deep mathematical work it was characteristic of fisher to use elegant geometrical arguments in the derivation of his results. It is believed that fisher had this unexpected advantage of developing a keen geometrical sense due to fisher had a complicated condition of poor eye sight even at a young age. This prevented private reading and made him rely largely on being read to, which in turn involved doing mathematics without pencil, paper and other visual aids.

Ronald fisher undoubtedly laid the foundation for modern statistical methods and their application. His work contributed to statistics to become and develop in an independent scientific discipline.

Among his distinctive works on statistical tests and methods include

2.6.1 Sampling Distributions (F test)

According to Krishnan (1997), Fisher derived mathematically the sampling distribution of the Student's *t* statistic which Gosset (pen name: Student) had derived earlier by 'simulation'. Fisher also derived mathematically the sampling distributions of the *F* statistic, the correlation coefficient and the multiple correlation coefficient and the sampling distributions associated with the general linear model. This in turn is used in a research work for statistical test of sample(s) from one or more populations, such as paired sample in which the H_O (Null hypotheses) is tested with a two factor unreplicated ANOVA F-ratio test, random sample from two independent population tested through an ANOVA F–ratio test. They are used for testing whether a null hypotheses that the variances of two populations are the same is in line. In order words fishers f test is also a statistical hypothesis test in which on forming a suitable test statistics, follows a sampling distributions of F statistic, (or F distribution) if the null hypothesis is true.

According to Krishnan (1997), Fisher's derivation of the sampling distribution of the correlation coefficient from a bivariate normal distribution was the starting point of the modern theory of exact sampling distributions. Another useful and important contribution was the tanh –1 transformation he found for the correlation coefficient to make its sampling distribution close to the normal distribution, so that tables of the standard normal distribution could be used in testing significance of the correlation coefficient. Fisher made a modification in the degree of freedom of the Pearson's $\mathbf{X^2}$ when parameters are to be estimated.

Some other contributions by fisher include:

2.6.2 Analysis of Variance

Fisher was appointed as the only statistician with the Rothamsted Experimental Station in 1919, where one of his tasks was to analyze data from current field trials. It is in this context that he formulated and developed the technique of analysis of variance. The analysis of variance is really a convenient way of organizing the computation for analyzing data in certain situations. Although initially developed as a convenient means of testing hypotheses, it is a means that helps to throw light on sources of experimental error and helps set up confidence intervals for means, contrasts, etc. According to Lehmann (1993), Fisher with his series of papers culminating in his book "Statistical Methods for Research Workers(1925)" in which he created a new paradigm for hypothesis testing, greatly extended the applicability(to the two sample problem and the testing of regression coefficients) and generalized it to the testing of hypothesis in the analysis of variance.

According to Krishnan (1997) Fisher developed the analysis of variance initially for orthogonal designs such as randomized block designs and Latin square designs. Later, Frank Yates extended the technique to nonorthogonal designs such as balanced incomplete block designs, designs with a factorial structure of treatments, etc. The technique of analysis of variance developed rapidly and has come to be used in a wide variety of problems formulated in the set-up of the linear model.

2.6.3 Maximum Likelihood

According to Stevan (2005), a great contribution of R.A Fisher is the development of likelihood as a fundamental concept of making inference about the state of system based on the outcome of a set of experiments of trials.

According to Krishnan (1997), Fisher's very first paper published in 1912 (at the age of 22) was on the method of maximum likelihood (although he did not call it so at that time). He developed this in view of his lack of satisfaction with the methods of moment estimators and least squares estimators. At that time the term 'likelihood' as opposed to probability or inverse probability caused some controversies. Although the basic idea of likelihood dates back to Lambert and Bernoulli and the method of estimation can be found in the works of Gauss, Laplace and Edgeworth, it was Fisher to whom the idea is credited, since he developed it and advocated its use. Fisher studied the maximum likelihood estimation in some detail establishing its efficiency. Fisher's mathematics was not always rigorous, certainly not by modern-day standards, but even then, his mathematical work, like in the case of his work on maximum likelihood estimation, provided a great deal of insight. According to Krishnan (1997), Fisher advocated maximum likelihood estimation as a standard procedure and since then it has become the foremost estimation method and has been developed for innumerable problems in many different sciences and contexts. It also has seen enormous ramifications and plays a central role in statistical theory, methodology and applications. Following his work on the likelihood, Fisher did a lot of work on the theory of estimation and developed the notions of sufficiency, information, consistency, efficiency and ancillary statistic and integrated them into a well-knit theory of estimation. His pioneering work on this is contained in two papers he wrote in 1922 and 1925.

2.6.4 Design of Experiments

According to Stevan (2005), Fisher during his analysis and examination of data on agricultural field data trial with the Rothamsted Experimental Station and on his investigating the linkage of genes for different traits was the first statistician to consider the methodology for the design of experiment. In order to avoid unintentional bias in selection of materials used in his investigation he studied the design of experiment in more detail, evolved it as a science and enunciated clearly and carefully the basic principles of experiments as randomisation, replication and local control (blocking, confounding, etc.). According to Krishnan (1997), the theory of design of experiments he formulated was intended to provide adequate techniques for collecting primary data and for drawing valid inferences from them, and extracting efficiently the maximum amount of information from the data collected. Randomisation guarantees validity of estimates and their unbiasedness. Replication helps provide a source of estimate of error, which can be used to compare treatments and other effects, test hypotheses and set up confidence limits. Local control helps to reduce sampling variations in the comparisons by eliminating some sources of such variations. According to Krishnan (1997), Fisher formulated randomised block designs, latin square designs, factorial arrangements of treatments and other efficient designs, he also worked out the analysis of variance structures for them. The subject of design of experiments then developed rapidly both in the direction of formulation and use of efficient designs, especially in agricultural experiments, in the direction of statistical theory he formulated useful and efficient designs and working out of their analyses. In the direction of interesting and difficult combinatorial mathematics investigating the existence of designs of certain types and their construction.

2.6.5 Discriminant Analysis

According to Krishnan (1997), from the time Fisher derived the sampling distributions of correlation coefficient and the multiple correlation coefficient, he was interested in the study of relationships between different measurements on the same individual and the use of multiple measurements for the purposes of classification and other problems. Fisher formulated the problem of discriminant analysis (what might be called a statistical pattern recognition problem today) in statistical terms and arrived at what is called the linear discriminant function for classifying an object into one of two classes on the basis of measurements on multiple variables. He derived the linear discriminant function as the linear combination of the variables that maximises the between-group to within-group squared distance. Since then the same function has been derived from considerations such as a Bayes decision rule and has been applied in many fields like biological taxonomy, medical diagnosis, engineering pattern recognition and other classification problems. Statistical and other pattern recognition methods and image processing techniques have made considerable progress in the last two or three decades, in theory and in applications, but Fisher's linear discriminant function still has a place in the pattern recognition repertoire.

2.7 WORKING METHOD

The methods to be used in light of the methods reviewed in this chapter for the purpose of this research work is Ibearugbulem's regression models for optimizing concrete mixes**;** the first model will have a fixed degree of accuracy while the second model will have as many degrees as the number of its concrete mix components. The simplicity of the model formulation and numbers of experimental mixes required made these methods interesting. Also the methods are selected because of the accuracy of the results and ease in testing adequacy of model. More so, these methods can easily be transformed into a computer program in the form of interactive software models. The details of these methods as mentioned in clauses 2.4.3 above will be discussed in chapter three and finalised in chapter four.

CHAPTER THREE

MATERIALS AND METHODS

3.0 GENERAL

Concrete mix components were tested for their characteristic properties and their characterisation, also concrete test was presented in detail in this chapter .Regression as a statistical technique was used in the formulation of concrete mixture design models. Two different but related models was formulated in detail also in this chapter

3.1 MATERIALS

Concrete component materials were used in this project in order to produce concrete for concrete tests to be carried out.Care was also taken to avoid faulty results and to avoid addition of non component materials. This was done by eliminating deleterious substances that may be found in its components such as impurities, which interfere with the processes of hydration of cement; coating which prevents the development of good bond between aggregates and the cement paste and certain individual particles which are unsound in themselves.

3.1.1 MATERIALS FOR CONCRETE TEST

The fine aggregate used in this research work was sand taken from Otamiri River. It was free from deleterious matters and has a specific gravity of 2.60 and bulk density of 1675kg/m^3 (compacted) and 1429kg/m^3 (non-compacted) and was well graded in the size range of 0.15mm $\leq x \leq$ 4.75mm . The coarse aggregate which is sandstone used in this study was a normal weight aggregate from a local market in Owerri, the capital city of Imo State Nigeria. It was also free from deleterious matters. The compacted bulk density of the sand stone is 1613kg/m^3 and the non-compacted bulk density is 1398kg/m^3. Both the sand and the sandstone are in accordance with BS 1881 (1970). The cement used for this study was “Dangote” cement, a brand of Ordinary Portland Cement and conforms to BS 12 (1978). The water used for this work was taken from bore-hole tap also fit for drinking from Federal University of Technology, Owerri.

3.2 CHARACTERISTIC TEST OF THE MATERIALS

3.2.1 PHYSICAL CHARACTERISATION TESTS OF FINE AND COARSE AGGREGATE

Bulk density, specific gravity, water absorption, void ratio and sieve analysis of both fine and coarse aggregate were tested. The apparatus used were a 20kg weighing machine, four plastic baths, a flat table, a calibrated cylindrical glass jar, hydrometer and scoop. Others were 16mm steel rod, a 150mm x 150mm steel cube container, three plastic buckets, three plastic baskets and four standard sieves (19.5mm, 14mm, 10mm and 5.6mm).

3.2.1.1 BULK DENSITY

The bulk density test was conducted for compacted and non-compacted samples. For non-compacted sample, the aggregates were loosely poured into the steel cylinder container that measured 150mm length x100mm Dia till it became over filled. The 16mm (5/8in) steel rod was used to level the sample by rolling it over the container. At this point the content of the container was discharged into the tray of the weighing machine, which had been set to the zero point already. The mass of the sample was weighed and recorded. This was repeated two more times and masses recorded.

For the compacted samples, the container was filled in three layers using the scoop. Each layer is about one - third of the volume of the container, when the first layer was poured in, the 16mm rod was used to tamp on it 25 times in accordance with ASTM C128-04a. This was done for the second and third layers. The container was then over filled and 16mm rod used to level the sample by rolling it over the container. The process was also repeated for two more times and masses recorded.

3.2.1.2 SPECIFIC GRAVITY

The test was conducted by collecting dry samples of aggregates using three plastic baths.

The weighing machine with its tray was set to the zero point. At this point the weighing machine was used to weigh the three samples contained in the plastic baths. The masses of the samples were recorded. The hydrometer was used to measure the specific gravity of the water. The water was poured into the calibrated cylinder after recording its specific gravity. Water level in the cylinder was noted and recorded. After recording the water level, the first sample was gradually poured into the cylinder containing water. The final level of water was also noted and recorded. The content of the cylinder was now discharged into one of the plastic baskets. The process was repeated for the remaining two samples.

3.2.1.3 WATER ABSORPTION

During this test, three dry samples of coarse aggregates were collected using three plastic baths. The weighing machine with its tray was set zero point. After setting the weighing machine, the masses of the three samples were weighed and recorded. The weighed samples were put back into the three plastic buckets and topped with distilled water of known specific gravity. The buckets were allowed to stay for 24hours, after which they were emptied into three different plastic baskets, which were allowed to stand for 1hour inside the laboratory. At the end of the 1hour the baskets were respectively emptied into the tray of the weighing machine and the respective masses weighed and recorded.

3.2.1.4 VOID RATIO

The procedure for void ratio was covered by the procedures of specific gravity and bulk density.

Void ratio = 1 - (Bulk density / Specific gravity)

3.2.1.5 SIEVE ANALYSIS

The test was done in general accordance with BS 812 (1975). The first thing done was to set the weighing machine with its tray to zero point. Then a dry sample of the aggregates were collected and poured into the tray of the weighing machine and the mass was weighed and recorded. At this point the weighed sample was poured into the 19.5mm sieve and by manual operation using hand the sample was sieved. The portion that passed through the sieve was collected in the 14mm sieve and also manually sieved using hand. This process continued with sieves 10mm and 5.6mm in that order. The portion that passed through 5.6mm sieve was collected using the receiver. In order words the sieves were arranged in ascending order with the sieve with the smallest pore hole size placed on the receiver to that with the largest pore size on top, then there were sieved one after the other. With Masses of the portions retained on 19.5mm, 14mm, 10mm, 5.6mm and the receiver were respectively weighed using the weighing machine. Their various masses were recorded.

3.3 CRUSHING STRENGTH TEST OF CONCRETE CUBES

The materials were batched by mass in their dried state. The bunker where the materials were mixed was wetted to avoid absorbing the mixing water. Mixing was done manually using spade and hand trowel. The moulds used for the concrete cubes were 150mm x150mm. After mixing properly to a consistent state the concrete was cast into the moulds. The concrete was tamped very well to ensure proper compaction. The cube moulds were covered with polythene papers and allowed to stand for 24 hours. After 24 hours, the cubes were de-moulded and transferred immediately to curing water at room temperature. The concrete cubes stayed in the curing water for 27 days to make up the 28 days after which they were tested for compressive strength using universal tensile / compressive testing machine to the requirement of Bs 1881: Part 115: 1986.The concrete cubes immediately after demoulding was left for some time to dry and then the masses were measured and recorded. The volume of the cube moulds were also measured and recorded. Then the SSD density was also measured as below. The mixture proportions of the tested samples are as shown in Table 3.1.

CALCULATIONS:

The compressive strength was obtained from the equation:

FC = Failure load (KN) / Nominal cross section area (m^2)

Where FC is the compression strength

The saturated-surface-dry density of the concrete cubes was obtained from the equation.

SSDD = Mass (kg) / Volume of cube (m^3)

Where SSDD means saturated-surface-dry density

TABLE 3.1: EXPERIMENTAL CONCRETE MIXTURE PROPORTIONS

Mixture Label	Water (kg)	Cement (kg)	Sand (kg)	Sandstone (kg)
U1	4.16	9.25	6.94	20.81
U2	4.16	9.25	13.88	13.88
U3	4.16	9.25	20.81	6.94
U4	3.03	6.73	7.57	22.70
U5	3.03	6.73	15.14	15.14
U6	3.03	6.73	22.70	7.57
U7	2.38	5.29	7.93	23.79
U8	2.38	5.29	15.86	15.86
U9	2.38	5.29	23.79	7.98
U10	1.96	4.35	8.16	24.49
U11	1.96	4.35	16.32	16.32
U12	1.96	4.35	24.49	8.16
U13	1.67	3.70	8.33	24.98
U14	1.67	3.70	16.65	16.65
U15	1.67	3.70	24.98	8.33
U16	4.63	9.25	6.94	20.81
U17	4.63	9.25	13.88	13.88
U18	4.63	9.25	20.81	6.94
U19	3.36	6.73	7.57	22.70
U20	3.36	6.73	15.14	15.14
U21	3.36	6.73	22.70	7.57
U22	2.64	5.29	7.93	23.79
U23	2.64	5.29	15.86	15.86
U24	2.64	5.29	23.79	7.93
U25	2.18	4.35	8.16	24.49
U26	2.18	4.35	16.32	16.32

TABLE 3.1 EXPERIMENTAL CONCRETE MIXTURE PROPORTIONS CONT.

U27	2.18	4.35	24.49	8.16
U28	1.85	3.70	8.33	24.98
U29	1.85	3.70	16.65	16.65
U30	1.85	3.70	24.98	8.33
U31	5.09	9.25	6.94	20.81
U32	5.09	9.25	13.88	13.88
U33	5.09	9.25	20.81	6.94
U34	3.70	6.73	7.57	22.70
U35	3.70	6.73	15.14	15.14
U36	3.70	6.73	22.70	7.57
U37	2.91	5.29	7.93	23.79
U38	2.91	5.29	15.86	15.86
U39	2.91	5.29	23.79	7.93
U40	2.39	4.35	8.16	24.49
U41	2.39	4.35	16.32	16.32
U42	2.39	4.35	24.49	8.16
U43	2.04	3.70	8.33	24.98
U44	2.04	3.70	16.65	16.65
U45	2.04	3.70	24.98	8.33
U46	5.55	9.25	6.94	20.81
U47	5.55	9.25	13.88	13.88
U48	5.55	9.25	20.81	6.94
U49	4.04	6.73	7.57	22.70
U50	4.04	6.73	15.14	15.14
U51	4.04	6.73	22.70	7.75
U52	3.17	5.29	7.93	23.79
U53	3.17	5.29	15.86	15.86
U54	3.17	5.29	23.79	7.93

TABLE 3.1 EXPERIMENTAL CONCRETE MIXTURE PROPORTIONS CONT.

U55	2.61	4.35	8.16	24.49
U56	2.61	4.35	16.32	16.32
U57	2.61	4.35	24.49	8.16
U58	2.22	3.70	8.33	24.98
U59	2.22	3.70	16.65	16.65
U60	2.22	3.70	24.98	8.33
TOTALS		**351.79**	**934.10**	**934.10**

3.4 MODELLINGS

Regression model was used to make inferences about concrete mix through the use of experimental design in other words experimental design as a statistical technique was adopted and used in detail in this project .The basic purpose of the experiment is to generate a model which is accomplished by another statistical technique, regression analysis. This is to bring about process optimization or in this case a significant basis for predicting concrete compressive strengths for different concrete mix proportions. It will be done for two different but related models, the first model has a fixed degree of accuracy while the second model has as many degrees as the number of its concrete mix components.

3.5 REGRESSION MODEL 1

3.6 INTRODUCTION OF THE POLYNOMIAL OF REGRESSION

Osadebe and Ibearugbulem (2008) quoted Osadebe (2003) that the response function F(z) is given as

$$F(z) = \sum F^m\,(z_0).(z_i - z_0)^m/m! \qquad (3.1)\ 0 \leq m \leq \infty$$

It should be noted that F^m (z_0) is the derivative of the function F (z_0) to m degree. Hence, equation(3.1)will be rewritten as

$$F(z) = \sum_{i=0}^{n} \frac{d^m \quad f(z_0)}{d{z_0}^m} \cdot \frac{(z_{i-}z_0)^m}{m!} \tag{3.2}$$

$0 \leq m \leq \infty$, $2 \leq m \leq \infty$

The number of terms in equation (3.2) is dependent on the degree of the polynomial, m and the number of independent variables, i. For instance let m be equal to one, hence

$$F(z) = \sum \frac{d^0 F(z_0)}{dz_0^0} \cdot \frac{(z_i - z_0)}{0!} + \sum \frac{dF(z_0)}{dz_0} \cdot \frac{(z_i - z_0)}{1!} \tag{3.3}$$

$0 \leq m \leq \infty$, $2 \leq m \leq \infty$

If m is equal to two, then equation (3.2) will read

$$F(z) = \sum \frac{d^0 F(z_0)}{dz_0^0} \cdot \frac{(z_i - z_0)^0}{0!} + \sum \frac{dF(z_0)}{dz_0} \cdot \frac{(z_i - z_0)}{1!} + \sum \frac{d^2 F(z_0)}{dz_0^2} \cdot \frac{(z_i - z_0)^2}{2!} + \sum \frac{d^2 F(z_0)}{dz_0^2} \cdot \frac{(z_i - z_0)(z_i - z_j)}{2!} \tag{3.4}$$

$0 \leq m \leq \infty$, $2 \leq m \leq \infty$

They assumed that the origin is z_0, which is equal to zero. Now taking the products and quotients of constants to give a new constant, and that z_0 is equal to zero, then equation(3.2) will be written as

$$f(z) = \sum b_m \cdot z_i^m \tag{3.5}$$

$0 \leq m \leq \infty$, $2 \leq m \leq \infty$

$$where\ if\ m = 0\ then\ b_m = b \tag{3.6}$$

$$if m = 1\ then\ b_m = b_i \tag{3.7}$$

$$i\ m = 2\ then\ b_m = \ b_{ii}\ for\ z_i^2\ term \tag{3.8}$$

$$b_m = b_{ij}\ for\ z_i\ z_j\ term \tag{3.9}$$

$$if\ m = 3\ then\ b_m = b_{iii}\ for\ z_i^3\ term \tag{3.10}$$

$$b_m = b_{ijk}\ for\ z_i z_j z_k\ term \tag{3.11}$$

$$b_m = b_{iij}\ for\ z_i^2\ z_j\ term \tag{3.12}$$

$$b_m = \ b_{iij}\ for\ z_i\ z_j^2\ term \tag{3.13}$$

$$b_m = b_{iik}\ for\ z_i^2 z_k\ term \tag{3.14}$$

$$b_m = \ b_{ikk}\ for\ z_i z_k^2\ term \tag{3.15}$$

$$b_m = \ b_{jjk}\ for\ z_j^2 z_k\ term \tag{3.16}$$

$$b_m = b_{jkk}\ for\ z_j z_k^2\ term \tag{3.17}$$

Now equation (3.5) can be written as

$$F(z) = b_0 + \sum b_m . z_i^m \tag{3.18}$$

$1 \le \mathrm{m} \le \infty$, $2 \le \mathrm{m} \le \infty$

$$For\ i = n, 1 \le m \le n \tag{3.19}$$

The implication of equation (3.19) is that the maximum degree of polynomial one can use is equal to the number of independent variables, i.

3.7 BOUNDARY CONDITIONS

Both Scheffe (1958) and Osadebe and Ibearugbulem (2008) restricted the summation of the independent variables to unity. That is

$$\sum z_i = 1 \tag{3.20}$$

Scheffe (1958) also restricted the value of each arbitrary independent variable to be between zero and one. That is

$$0 \le m \le 1 \tag{3.21}$$

3.8 MODEL EQUATION

Assuming this bases of boundary condition and

Multiplying equation (3.20) by b_0 will give

$$b_0 = \sum b_0\, z_i \tag{3.22}$$

It is worthy of note here that the independent variable, z_i is not the actual portion of the mixture component rather it is the ratio of the actual portions to the total quantity of concrete.

They could also be seen as fractional portion but would be given the term "pseudo variables". The actual portions of the mixture components are s_i.

For concrete of four components, $1 \leq i \leq 4$, if the total quantity of concrete is designated s, then

$$\sum s_i = s$$

That is to say, $s_1 + s_2 + s_3 + s_4 = s$ (3.23a)

If the total quantity of concrete required here is a unit quantity then it will be wise to divide equation (3.23a) through by s. Hence,

$$s_1/s + s_2/s + s_3/s + s_4/s = s/s \quad (3.23b)$$

So that $z_1 + z_2 + z_3 + z_4 + z_5 = 1$

However, a relationship can be seen to exist between the pseudo variables, z_i and the actual variables, s_i.

Pseudo variables, $z_i =$
s_i/s (3.24)

$$S = \sum s_i \quad (3.25)$$

Going back to the formulation of the regression equation, multiplying equation (3.20) by z_i will give on rearranging

$$Z_i^2 = z_i - z_1 z_i - z_2 z_i - \dots \dots - z_i z_n \quad (3.26)$$

Multiplying equation (3.20) by z_i^r will give on rearranging

$$Z_i^{r+1} = z_i^r - z_1 z_i^r - z_2 z_i^r - \dots \dots - z_i^r z_n \quad (3.27)$$

Taking the highest degree of the polynomial and substituting equations (3.22) and (3.27) into equation (3.18) and factorizing, making sure that every term has no independent variable of more than one degree will yield

$$F(z) = \sum \propto_i z_i + \sum \propto_{ij} z_i z_j + \sum \propto_{ijk} z_i z_j z_k + .. + \sum \propto_{ijk..\infty} z_i z_j z_k .. z_\infty \qquad (3.28)$$

$1 \le i \le \infty,\ 1 \le i \le j \le \infty,\ 1 \le i \le j \le k \le \infty,\ \ldots,\ 1 \le i \le j \le k \le \ldots \le \infty$

If i = 2 then equation(3.28) becomes

$$F(z) = \propto_1 z_1 + \propto_2 z_2 + \propto_{12} z_1 z_2 \qquad (3.29)$$

If i = 3 then equation(3.28) becomes

$$F(z) = \propto_1 z_1 + \propto_2 z_2 + \propto_3 z_3 + \propto_{12} z_1 z_2 + \propto_{13} z_1 z_3 + \propto_{23} z_2 z_3 + \propto_{123} z_1 z_2 z_3 \qquad (3.30)$$

If i = 4 then equation(3.28) becomes

$$F(z) = \propto_1 z_1 + \propto_2 z_2 + \propto_3 z_3 + \propto_4 z_4 + \propto_{12} z_1 z_2 + \propto_{13} z_1 z_3 + \propto_{14} z_1 z_4 + \propto_{23} z_2 z_3 + \propto_{24} z_2 z_4 + \propto_{34} z_3 z_4 + \propto_{123} z_1 z_2 z_3 + \propto_{124} z_1 z_2 z_4 + \propto_{134} z_1 z_3 z_4 + \propto_{234} z_2 z_3 z_4 + \propto_{1234} z_1 z_2 z_3 z_4 \qquad (3.31)$$

3.9 COEFFICIENTS OF THE REGRESSION FUNCTION

Summing equation (3.28) for n observation points gives

$$\Sigma_R F(Z) = \Sigma_R \Sigma \propto_1 z_1 + \Sigma_R \Sigma \propto_{1j} z_1 z_j \qquad (3.32)$$

$1 \le r \le n$

Multiplying equation (3.32) by z_w will give

$$\Sigma_r z_w . F(Z) = \Sigma_r \Sigma \propto_1 z_1 z_w + \Sigma_R \Sigma \propto_{1j} z_1 z_j z_w + \qquad (3.33)$$

Multiplying equation (3.32) by $z_q\ z_s\ z_t$ . . . will give

$$\Sigma_r z_q z_s z_t . F(Z) = \Sigma_r \Sigma \propto_1 z_{1.} z_q z_s z_t + \Sigma_R \Sigma \propto_{1j} z_1 z_j z_q z_s z_t + \ldots \qquad (3.34)$$

Adding equations (3.33) and (3.34) will give n simultaneous equations with n unknowns. This is represented in matrix form as shown in equation (3.35a).

$$\begin{vmatrix} \Sigma_r z_1 . F(Z) \\ \Sigma_r z_2 . F(Z) \\ \Sigma_r z_3 . F(Z) \\ \vdots \\ \Sigma_r z_1 z_2 . z_3 F(Z) \end{vmatrix} = \begin{vmatrix} \Sigma_r \Sigma z_{1}. z_1 & \Sigma_r \Sigma z_{2}. z_1 & \Sigma_r \Sigma z_{3}. z_1 & \ldots \\ \Sigma_r \Sigma z_{1}. z_2 & \Sigma_r \Sigma z_{2}. z_2 & \Sigma_r \Sigma z_{3}. z_2 & \ldots \\ \Sigma_r \Sigma z_{1}. z_3 & \Sigma_r \Sigma z_{2}. z_3 & \Sigma_r \Sigma z_{3}. z_3 & \ldots \\ \vdots & \vdots & \vdots & \vdots \\ \Sigma_r \Sigma z_1 z_1 z_2 . z_3 & \Sigma_r \Sigma z_2 z_1 z_2 . z_3 & \Sigma_r \Sigma z_3 z_1 z_2 . z_3 & \ldots \end{vmatrix} \begin{vmatrix} \propto_1 \\ \propto_2 \\ \propto_3 \\ \vdots \\ \propto_{123} \end{vmatrix} \qquad (3.35a)$$

Solving the simultaneous equation of equation (3.35a) will give the values of the coefficients of regression function equation. Equation (3.35a) can be written in a short form as [F(z)Z] = [CC] [$\propto$]

CC is always a symmetric matrix

For a mixture of three components, CC is a 7 x 7 matrix as shown below (3.35b)

$$\begin{vmatrix}
\Sigma\Sigma Z_1Z_1 & \Sigma\Sigma Z_2Z_1 & \Sigma\Sigma Z_3Z_1 & \Sigma\Sigma Z_1Z_2Z_1 & \Sigma\Sigma Z_1Z_3Z_1 & \Sigma\Sigma Z_2Z_3Z_1 & \Sigma\Sigma Z_1Z_2Z_3Z_1 \\
\Sigma\Sigma Z_1Z_2 & \Sigma\Sigma Z_2Z_2 & \Sigma\Sigma Z_3Z_2 & \Sigma\Sigma Z_1Z_2Z_2 & \Sigma\Sigma Z_1Z_3Z_2 & \Sigma\Sigma Z_2Z_3Z_2 & \Sigma\Sigma Z_1Z_2Z_3Z_2 \\
\Sigma\Sigma Z_1Z_3 & \Sigma\Sigma Z_2Z_3 & \Sigma\Sigma Z_3Z_3 & \Sigma\Sigma Z_1Z_2Z_3 & \Sigma\Sigma Z_1Z_3Z_3 & \Sigma\Sigma Z_2Z_3Z_3 & \Sigma\Sigma Z_1Z_2Z_3Z_3 \\
\Sigma\Sigma Z_1Z_1Z_2 & \Sigma\Sigma Z_2Z_1Z_2 & \Sigma\Sigma Z_3Z_1Z_2 & \Sigma\Sigma Z_1Z_2Z_1Z_2 & \Sigma\Sigma Z_1Z_3Z_1Z_2 & \Sigma\Sigma Z_2Z_3Z_1Z_2 & \Sigma\Sigma Z_1Z_2Z_3Z_1Z_2 \\
\Sigma\Sigma Z_1Z_1Z_3 & \Sigma\Sigma Z_2Z_1Z_3 & \Sigma\Sigma Z_3Z_1Z_3 & \Sigma\Sigma Z_1Z_2Z_1Z_3 & \Sigma\Sigma Z_1Z_3Z_1Z_3 & \Sigma\Sigma Z_2Z_3Z_1Z_3 & \Sigma\Sigma Z_1Z_2Z_3Z_1Z_3 \\
\Sigma\Sigma Z_1Z_2Z_3 & \Sigma\Sigma Z_2Z_2Z_3 & \Sigma\Sigma Z_3Z_2Z_3 & \Sigma\Sigma Z_1Z_2Z_2Z_3 & \Sigma\Sigma Z_1Z_3Z_2Z_3 & \Sigma\Sigma Z_2Z_3Z_2Z_3 & \Sigma\Sigma Z_1Z_2Z_3Z_2Z_3 \\
\Sigma\Sigma Z_1Z_1Z_2Z_3 & \Sigma\Sigma Z_2Z_1Z_2Z_3 & \Sigma\Sigma Z_3Z_1Z_2Z_3 & \Sigma\Sigma Z_1Z_2Z_1Z_2Z_3 & \Sigma\Sigma Z_1Z_3Z_1Z_2Z_3 & \Sigma\Sigma Z_2Z_3Z_1Z_2Z_3 & \Sigma\Sigma Z_1Z_2Z_3Z_1Z_2Z_3
\end{vmatrix}$$

(3.35b)

For a mixture of four components, CC is a 15 x 15 matrix as shown in (3.35c) below.

Matrix showing elements of CC matrix of a mix of four components

$\Sigma\Sigma Z_1$Z 1	$\Sigma\Sigma Z_1$Z 2	$\Sigma\Sigma Z_1$Z3	$\Sigma\Sigma Z_1$Z4	$\Sigma\Sigma Z_1$Z1Z2	$\Sigma\Sigma Z_1$ Z1 Z3	$\Sigma\Sigma Z_1$ Z1 Z4	$\Sigma\Sigma Z_1$Z2 Z3	$\Sigma\Sigma Z_1$ Z2 Z4	$\Sigma\Sigma Z_1$ Z3Z4	$\Sigma\Sigma Z_1$ Z1Z2Z3	$\Sigma\Sigma Z_1$ Z1Z2Z4	$\Sigma\Sigma Z_1$ Z1Z3Z4	$\Sigma\Sigma Z_1$ Z2Z3 Z4	$\Sigma\Sigma Z_1$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_2$Z1	$\Sigma\Sigma Z_2$Z2	$\Sigma\Sigma Z_2$Z3	$\Sigma\Sigma Z_2$ Z4	$\Sigma\Sigma Z_2$ Z1Z2	$\Sigma\Sigma Z_2$ Z1 Z3	$\Sigma\Sigma Z_2$ Z1 Z4	$\Sigma\Sigma Z_2$ Z2 Z3	$\Sigma\Sigma Z_2$ Z2 Z4	$\Sigma\Sigma Z_2$ Z3Z4	$\Sigma\Sigma Z_2$ Z1Z2Z3	$\Sigma\Sigma Z_2$ Z1Z2Z4	$\Sigma\Sigma Z_2$ Z1Z3Z4	$\Sigma\Sigma Z_2$ Z2Z3 Z4	$\Sigma\Sigma Z_2$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_3$ Z1	$\Sigma\Sigma Z_3$ Z2	$\Sigma\Sigma Z_3$ Z3	$\Sigma\Sigma Z_3$ Z4	$\Sigma\Sigma Z_3$ Z1Z2	$\Sigma\Sigma Z_3$ Z1 Z3	$\Sigma\Sigma Z_3$ Z1 Z4	$\Sigma\Sigma Z_3$ Z2 Z3	$\Sigma\Sigma Z_3$ Z2 Z4	$\Sigma\Sigma Z_3$ Z3Z4	$\Sigma\Sigma Z_3$ Z1Z2Z3	$\Sigma\Sigma Z_3$ Z1Z2Z4	$\Sigma\Sigma Z_3$ Z1Z3Z4	$\Sigma\Sigma Z_3$ Z2Z3 Z4	$\Sigma\Sigma Z_3$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_4$ Z1	$\Sigma\Sigma Z_4$ Z2	$\Sigma\Sigma Z_4$ Z3	$\Sigma\Sigma Z_4$ Z4	$\Sigma\Sigma Z_4$ Z1Z2	$\Sigma\Sigma Z_4$ Z1 Z3	$\Sigma\Sigma Z_4$ Z1 Z4	$\Sigma\Sigma Z_4$ Z2 Z3	$\Sigma\Sigma Z_4$ Z2 Z4	$\Sigma\Sigma Z_4$ Z3Z4	$\Sigma\Sigma Z_4$ Z1Z2Z3	$\Sigma\Sigma Z_4$ Z1Z2Z4	$\Sigma\Sigma Z_4$ Z1Z3Z4	$\Sigma\Sigma Z_4$ Z2Z3 Z4	$\Sigma\Sigma Z_4$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_5$ Z1	$\Sigma\Sigma Z_5$ Z2	$\Sigma\Sigma Z_5$ Z3	$\Sigma\Sigma Z_5$ Z4	$\Sigma\Sigma Z_5$ Z1Z2	$\Sigma\Sigma Z_5$ Z1 Z3	$\Sigma\Sigma Z_5$ Z1 Z4	$\Sigma\Sigma Z_5$ Z2 Z3	$\Sigma\Sigma Z_5$ Z2 Z4	$\Sigma\Sigma Z_5$ Z3Z4	$\Sigma\Sigma Z_5$ Z1Z2Z3	$\Sigma\Sigma Z_5$ Z1Z2Z4	$\Sigma\Sigma Z_5$ Z1Z3Z4	$\Sigma\Sigma Z_5$ Z2Z3 Z4	$\Sigma\Sigma Z_5$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_6$ Z1	$\Sigma\Sigma Z_6$ Z2	$\Sigma\Sigma Z_6$ Z3	$\Sigma\Sigma Z_6$ Z4	$\Sigma\Sigma Z_6$ Z1Z2	$\Sigma\Sigma Z_6$ Z1 Z3	$\Sigma\Sigma Z_6$ Z1 Z4	$\Sigma\Sigma Z_6$ Z2 Z3	$\Sigma\Sigma Z_6$ Z2 Z4	$\Sigma\Sigma Z_6$ Z3Z4	$\Sigma\Sigma Z_6$ Z1Z2Z3	$\Sigma\Sigma Z_6$ Z1Z2Z4	$\Sigma\Sigma Z_6$ Z1Z3Z4	$\Sigma\Sigma Z_6$ Z2Z3 Z4	$\Sigma\Sigma Z_6$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_7$ Z1	$\Sigma\Sigma Z_7$ Z2	$\Sigma\Sigma Z_7$ Z3	$\Sigma\Sigma Z_7$ Z4	$\Sigma\Sigma Z_7$ Z1Z2	$\Sigma\Sigma Z_7$ Z1 Z3	$\Sigma\Sigma Z_7$ Z1 Z4	$\Sigma\Sigma Z_7$ Z2 Z3	$\Sigma\Sigma Z_7$ Z2 Z4	$\Sigma\Sigma Z_7$ Z3Z4	$\Sigma\Sigma Z_7$ Z1Z2Z3	$\Sigma\Sigma Z_7$ Z1Z2Z4	$\Sigma\Sigma Z_7$ Z1Z3Z4	$\Sigma\Sigma Z_7$ Z2Z3 Z4	$\Sigma\Sigma Z_7$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_8$ Z1	$\Sigma\Sigma Z_8$ Z2	$\Sigma\Sigma Z_8$ Z3	$\Sigma\Sigma Z_8$ Z4	$\Sigma\Sigma Z_8$ Z1Z2	$\Sigma\Sigma Z_8$ Z1 Z3	$\Sigma\Sigma Z_8$ Z1 Z4	$\Sigma\Sigma Z_8$ Z2 Z3	$\Sigma\Sigma Z_8$ Z2 Z4	$\Sigma\Sigma Z_8$ Z3Z4	$\Sigma\Sigma Z_8$ Z1Z2Z3	$\Sigma\Sigma Z_8$ Z1Z2Z4	$\Sigma\Sigma Z_8$ Z1Z3Z4	$\Sigma\Sigma Z_8$ Z2Z3 Z4	$\Sigma\Sigma Z_8$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_9$ Z1	$\Sigma\Sigma Z_9$ Z2	$\Sigma\Sigma Z_9$ Z3	$\Sigma\Sigma Z_9$ Z4	$\Sigma\Sigma Z_9$ Z1Z2	$\Sigma\Sigma Z_9$ Z1 Z3	$\Sigma\Sigma Z_9$ Z1 Z4	$\Sigma\Sigma Z_9$ Z2 Z3	$\Sigma\Sigma Z_9$ Z2 Z4	$\Sigma\Sigma Z_9$ Z3Z4	$\Sigma\Sigma Z_9$ Z1Z2Z3	$\Sigma\Sigma Z_9$ Z1Z2Z4	$\Sigma\Sigma Z_9$ Z1Z3Z4	$\Sigma\Sigma Z_9$ Z2Z3 Z4	$\Sigma\Sigma Z_9$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{10}$ Z1	$\Sigma\Sigma Z_{10}$ Z2	$\Sigma\Sigma Z_{10}$ Z3	$\Sigma\Sigma Z_{10}$ Z4	$\Sigma\Sigma Z_{10}$ Z1Z2	$\Sigma\Sigma Z_{10}$ Z1 Z3	$\Sigma\Sigma Z_{10}$ Z1 Z4	$\Sigma\Sigma Z_{10}$ Z2 Z3	$\Sigma\Sigma Z_{10}$ Z2 Z4	$\Sigma\Sigma Z_{10}$ Z3Z4	$\Sigma\Sigma Z_{10}$ Z1Z2Z3	$\Sigma\Sigma Z_{10}$ Z1Z2Z4	$\Sigma\Sigma Z_{10}$ Z1Z3Z4	$\Sigma\Sigma Z_{10}$ Z2Z3 Z4	$\Sigma\Sigma Z_{10}$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{11}$ Z 1	$\Sigma\Sigma Z_{11}$ Z2	$\Sigma\Sigma Z_{11}$ Z3	$\Sigma\Sigma Z_{11}$ Z4	$\Sigma\Sigma Z_{11}$ Z1Z2	$\Sigma\Sigma Z_{11}$ Z1 Z3	$\Sigma\Sigma Z_{11}$ Z1 Z4	$\Sigma\Sigma Z_{11}$ Z2 Z3	$\Sigma\Sigma Z_{11}$ Z2 Z4	$\Sigma\Sigma Z_{11}$ Z3Z4	$\Sigma\Sigma Z_{11}$ Z1Z2Z3	$\Sigma\Sigma Z_{11}$ Z1Z2Z4	$\Sigma\Sigma Z_{11}$ Z1Z3Z4	$\Sigma\Sigma Z_{11}$ Z2Z3 Z4	$\Sigma\Sigma Z_{11}$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{12}$ Z1	$\Sigma\Sigma Z_{12}$ Z2	$\Sigma\Sigma Z_{12}$ Z3	$\Sigma\Sigma Z_{12}$ Z4	$\Sigma\Sigma Z_{12}$ Z1Z2	$\Sigma\Sigma Z_{12}$ Z1 Z3	$\Sigma\Sigma Z_{12}$ Z1 Z4	$\Sigma\Sigma Z_{12}$ Z2 Z3	$\Sigma\Sigma Z_{12}$ Z2 Z4	$\Sigma\Sigma Z_{12}$ Z3Z4	$\Sigma\Sigma Z_{12}$ Z1Z2Z3	$\Sigma\Sigma Z_{12}$ Z1Z2Z4	$\Sigma\Sigma Z_{12}$ Z1Z3Z4	$\Sigma\Sigma Z_{12}$ Z2Z3 Z4	$\Sigma\Sigma Z_{12}$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{13}$ Z1	$\Sigma\Sigma Z_{13}$ Z2	$\Sigma\Sigma Z_{13}$ Z3	$\Sigma\Sigma Z_{13}$ Z4	$\Sigma\Sigma Z_{13}$ Z1Z2	$\Sigma\Sigma Z_{13}$ Z1 Z3	$\Sigma\Sigma Z_{13}$ Z1 Z4	$\Sigma\Sigma Z_{13}$ Z2 Z3	$\Sigma\Sigma Z_{13}$ Z2 Z4	$\Sigma\Sigma Z_{13}$ Z3Z4	$\Sigma\Sigma Z_{13}$ Z1Z2Z3	$\Sigma\Sigma Z_{13}$ Z1Z2Z4	$\Sigma\Sigma Z_{13}$ Z1Z3Z4	$\Sigma\Sigma Z_{13}$ Z2Z3 Z4	$\Sigma\Sigma Z_{13}$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{14}$ Z1	$\Sigma\Sigma Z_{14}$ Z2	$\Sigma\Sigma Z_{14}$ Z3	$\Sigma\Sigma Z_{14}$ Z4	$\Sigma\Sigma Z_{14}$ Z1Z2	$\Sigma\Sigma Z_{14}$ Z1 Z3	$\Sigma\Sigma Z_{14}$ Z1 Z4	$\Sigma\Sigma Z_{14}$ Z2 Z3	$\Sigma\Sigma Z_{14}$ Z2 Z4	$\Sigma\Sigma Z_{14}$ Z3Z4	$\Sigma\Sigma Z_{14}$ Z1Z2Z3	$\Sigma\Sigma Z_{14}$ Z1Z2Z4	$\Sigma\Sigma Z_{14}$ Z1Z3Z4	$\Sigma\Sigma Z_{14}$ Z2Z3 Z4	$\Sigma\Sigma Z_{14}$ Z1Z2 Z3Z4
$\Sigma\Sigma Z_{15}$ Z1	$\Sigma\Sigma Z_{15}$ Z2	$\Sigma\Sigma Z_{15}$ Z3	$\Sigma\Sigma Z_{15}$ Z4	$\Sigma\Sigma Z_{15}$ Z1Z2	$\Sigma\Sigma Z_{15}$ Z1 Z3	$\Sigma\Sigma Z_{15}$ Z1 Z4	$\Sigma\Sigma Z_{15}$ Z2 Z3	$\Sigma\Sigma Z_{15}$ Z2 Z4	$\Sigma\Sigma Z_{15}$ Z3Z4	$\Sigma\Sigma Z_{15}$ Z1Z2Z3	$\Sigma\Sigma Z_{15}$ Z1Z2Z4	$\Sigma\Sigma Z_{15}$ Z1Z3Z4	$\Sigma\Sigma Z_{15}$ Z2Z3 Z4	$\Sigma\Sigma Z_{15}$ Z1Z2 Z3Z4

(3.35c)

Legend:

Z_1 = Z 1 Z_2 = Z 2 Z_3 = Z3 Z_4 = Z4 Z_5= Z1Z2 Z_6= Z1 Z3 Z_7= Z1 Z4 Z_8= Z2 Z3 Z_9= Z2 Z4 Z_{10}= Z3Z4

Z_{11}= Z1Z2Z3 Z_{12}= Z1Z2Z4 Z_{13}= Z1Z3Z4 Z_{14}= Z2Z3 Z4 Z_{15}= Z1Z2 Z3Z4

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The Table of mix ratios for compressive strength test was divided into five groups TEST A, TEST B, TEST C, TEST D, TEST E, these five groups were used separately for calculations and the determined values for each group were used finally in the formation of the model equations. This was done to reduce the cumbersome nature of the model formation, which could result from calculations involved when the whole mixes are used in bigger groups or as a whole group.

Table3.2:Mix ratios for compressive strength test used in formulating the model

TEST A					TEST B				
S/N	water	cement	sand	sandstone	S/N	water	cement	sand	sandstone
1	0.45	1	0.75	2.25	13	0.45	1	1.125	3.375
2	0.45	1	1.5	1.5	14	0.45	1	2.25	2.25
3	0.45	1	2.25	0.75	15	0.45	1	3.375	1.125
4	0.5	1	0.75	2.25	16	0.5	1	1.125	3.375
5	0.5	1	1.5	1.5	17	0.5	1	2.25	2.25
6	0.5	1	2.25	0.75	18	0.5	1	3.375	1.125
7	0.55	1	0.75	2.25	19	0.55	1	1.125	3.375
8	0.55	1	1.5	1.5	20	0.55	1	2.25	2.25
9	0.55	1	2.25	0.75	21	0.55	1	3.375	1.125
10	0.6	1	0.75	2.25	22	0.6	1	1.125	3.375
11	0.6	1	1.5	1.5	23	0.6	1	2.25	2.25
12	0.6	1	2.25	0.75	24	0.6	1	3.375	1.125

Table3.3:Mix ratios for compressive strength test used in formulating the model									
TEST C					TEST D				
S/N	water	cement	sand	sandstone	S/N	water	cement	sand	sandstone
25	0.45	1	1.5	4.5	37	0.45	1	1.875	5.625
26	0.45	1	3	3	38	0.45	1	3.75	3.75
27	0.45	1	4.5	1.5	39	0.45	1	5.625	1.875
28	0.5	1	1.5	4.5	40	0.5	1	1.875	5.625
29	0.5	1	3	3	41	0.5	1	3.75	3.75
30	0.5	1	4.5	1.5	42	0.5	1	5.625	1.875
31	0.55	1	1.5	4.5	43	0.55	1	1.875	5.625
32	0.55	1	3	3	44	0.55	1	3.75	3.75
33	0.55	1	4.5	1.5	45	0.55	1	5.625	1.875
34	0.6	1	1.5	4.5	46	0.6	1	1.875	5.625
35	0.6	1	3	3	47	0.6	1	3.75	3.75
36	0.6	1	4.5	1.5	48	0.6	1	5.625	1.875

Table3.4:Mix ratios for compressive strength test used in formulating the model				
TEST E				
S/N	water	cement	sand	sandstone
49	0.45	1	2.25	6.75
50	0.45	1	4.5	4.5
51	0.45	1	6.75	2.25
52	0.5	1	2.25	6.75
53	0.5	1	4.5	4.5
54	0.5	1	6.75	2.25
55	0.55	1	2.25	6.75
56	0.55	1	4.5	4.5
57	0.55	1	6.75	2.25
58	0.6	1	2.25	6.75
59	0.6	1	4.5	4.5
60	0.6	1	6.75	2.25

As shown in appendix 1 are the $Z^{(n)}$ matrix for model 1whose elements are gotten from the pseudo variables, $Z_i^{(n}$ (fractional portions) which was developed from the actual mixture proportions. They were separated into different groups representing the different concrete mix proportions for various range of observation points.

Knowing the values of [F(z)Z] and $[CC]^{-1}$, the values of the constant coefficients can be determined from equation (3.35a) by making $\propto_i$ the subject of the equation.

$$[\propto] = [\, F(z)Z] \, [CC]^{-1} \qquad (3.35b)$$

Expanding equation 3.35b gives

$$\begin{vmatrix} \propto_1 \\ \propto_2 \\ \propto_3 \\ : \\ : \\ : \\ : \\ \propto_{123} \end{vmatrix} .= \begin{vmatrix} \Sigma_r z_1 .\ F(Z) \\ \Sigma_r z_2 .\ F(Z) \\ \Sigma_r z_3 .\ F(Z) \\ : \\ : \\ : \\ : \\ \Sigma_r z_1\ z_2 .\ z_3\ F(Z) \end{vmatrix} \begin{vmatrix} \Sigma_r \Sigma\ z_{1.}\ z_1 & \Sigma_r \Sigma\ z_{2.}\ z_1 & \Sigma_r \Sigma\ z_{3.} z_1 & \ldots\ldots \\ \Sigma_r \Sigma\ z_{1.}\ z_2 & \Sigma_r \Sigma\ z_{2.}\ z_2 & \Sigma_r \Sigma\ z_{3.} z_2 & \ldots\ldots \\ \Sigma_r \Sigma\ z_{1.}\ z_3 & \Sigma_r \Sigma\ z_{2.}\ z_3 & \Sigma_r \Sigma\ z_{3.} z_3 & \ldots\ldots \\ : & : & : & : \\ : & : & : & : \\ : & : & : & : \\ : & : & : & : \\ \Sigma_r \Sigma\ z_1\ z_1\ z_2 .\ z_{3.} & \Sigma_r \Sigma\ z_2\ z_1\ z_2 .\ z_{3.} & \Sigma_r \Sigma\ z_3\ z_1\ z_2 .\ z_{3.} & \ldots\ldots \end{vmatrix}^{-1} \qquad (3.35c)$$

With equation (3.35a) and (3.35b) opened and solved mathematically ,the inverse of the CC matrix was calculated as can be seen in appendix 1for model 1. The solution of equation (3.35b) above will be completed by substituting the values of Z_i and the laboratory compressive strength into the equation .This was done in chapter five after the practical tests were done.

3.10 REGRESSION MODEL 2

Assuming the response function be represented by:

$R(x_i, x_j, x_k, \ldots) =$

$$R(x_i, x_j, x_k, \ldots) = \sum_{i=0}^{n} a_i x_1^i \, . \sum_{j=0}^{n} a_j x_2^i \, . \sum_{k=0}^{n} a_i x_3^i \; . \; . \; . \; \sum_{r=0}^{n} a_i x_m^i \qquad (3.36)$$

Where $x_1 + x_2 + x_3 + \; . \; . \; . \; x_m = 1$

(3.37)

$0 \leq x_i \leq 1;$ and $1 \leq i \leq m$

n is the degree of the response function, and

m is the number of mix components

For concrete mixes, physical components of the mix are different from the blend components of the mix.

For instance, a concrete mix has water, cement, sand and gravel as the physical components of the mix. However, the blend components may be taken as water-cement ratio, sand-cement ratio and gravel cement ratio.

Thus, x_i is the blend component of the concrete mix.

The least degree of the response function is 1 (one), and the least number of blend components is 2 (two).

A one degree – two blend component mixes has response function as:

$$R = (a_0 x_1^0 + a_1 x_1^1) \, . (b_0 x_2^0 + b_1 x_2^1)$$

$$= (a_0 \, . \, b_0) + (a_0 \, . \, b_1) \, . \, x_2^1 + (a_1 \, . \, b_0) \, . \, x_1^1 + (a_1 \, . \, b_1) \, . \, x_1^1 \, . \, x_2^1 \qquad (3.38)$$

Taking $x_1 + x_2 = 1$ (3.39)

And

then, $(a_0 \, . \, b_0) x_1 + (a_0 \, . \, b_0) x_2 = (a_0 \, . \, b_0)$. (3.40)

Substituting equation 3.40 into equation 3.38 the responds becomes

$$R = (a_0 \, . \, b_0) x_1 + (a_0 \, . \, b_0) x_2 + (a_1 \, . \, b_0) x_1 + (a_0 \, . \, b_1) x_2 + (a_1 \, . \, b_1) x_1 x_2 \qquad (3.41)$$

Upon collecting like terms equation 3.41 becomes

$$R = (a_0 . b_0 + a_1 . b_0)x_1 + (a_0 . b_0 + a_0 . b_1)x_2 + (a_1 . b_1)x_1 x_2. \quad (3.42)$$

Let $(a_0 . b_0 + a_1 . b_0) = \alpha_1$ (3.43a)

$(a_0 . b_0 + a_0 . b_1) = \alpha_2$ (3.43b)

and

$(a_1 . b_1) = \alpha_{12}$, (3.43c)

Substituting equations 3.43a-c into equation 3.42 it becomes

$$R = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_{12} x_1 x_2 \quad (3.44)$$

In similar manner, the response function for a two degree – two blend component mixes is:

$$R = (a_0 x_1^0 + a_1 x_1^1 + a_2 x_1^2) . (b_0 x_2^0 + b_1 x_2^1 + b_2 x_2^2). \quad (3.45a)$$

That is

$$R = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_{11} x_1^2 + \alpha_{12} x_1 x_2 + \alpha_{22} x_2^2 + \alpha_{112} x_1^2 x_2 + \alpha_{122} x_1 x_2^2 + \alpha_{1122} x_1^2 x_2^2 \quad (3.45b)$$

The values of blend components at various coefficients for a two degree – two component mixes are shown in table below:

Table 3.5 blend components at various coefficients for a two degree – two component mixes

Coefficient	Value of X_1	Value of X_2	$X_1 + X_2$
α_1	1/1 = 1	0/1 =0	1
α_2	0/1	1/1 = 1	1
α_{12}	1/2 = 0.5	1/2 = 0.5	1
α_{11}	2/2 =1	0/2 = 0	1
α_{22}	0/2 = 0	2/2 = 1	1
α_{112}	2/3 = 0.6667	1/3 = 0.3333	1
α_{122}	1/3 = 0.3333	2/3 = 0.6667	1
α_{1122}	2/4 = 0.5	2/4 = 0.5	1

The response function for a one degree – three blend component mixes is:

$R = (a_0 x_1^0 + a_1 x_1^1) . (b_0 x_2^0 + b_1 x_2^1). (c_0 x_3^0 + c_1 x_3^1)$. That is

$$R = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{23} x_2 x_3 + \alpha_{123} x_1 x_2 x_3 \quad (3.46)$$

The response function for a three degree – three blend component mixes is:

$R = (a_0 x_1^0 + a_1 x_1^1 + a_2 x_1^2) . (b_0 x_2^0 + b_1 x_2^1 + b_2 x_2^2). (c_0 x_3^0 + c_1 x_3^1 + c_2 x_3^2).$ That is

$$R = \alpha_1\, x_1 + \alpha_2\, x_2 + \alpha_3\, x_3 + \alpha_{12}\, x_1 x_2 + \alpha_{13}\, x_1 x_3 + \alpha_{23}\, x_2 x_3 + \alpha_{123}\, x_1 x_2 x_3 + \alpha_{11}\, x_1^2 + \alpha_{22}\, x_2^2 + \alpha_{33}\, x_3^2 + \alpha_{112}\, x_1^2 x_2 + \alpha_{113}\, x_1^2 x_3 + \alpha_{122}\, x_1 x_2^2 + \alpha_{133}\, x_1 x_3^2 + \alpha_{223}\, x_2^2 x_3 + \alpha_{233}\, x_2 x_3^2 + \alpha_{1122}\, x_1^2 x_2^2 + \alpha_{1123}\, x_1^2 x_2^1\, x_3^1 + \alpha_{1133}\, x_1^2 x_3^2 + \alpha_{1223}\, x_1^1 x_2^2\, x_3^1 + \alpha_{1233}\, x_1^1 x_2^1\, x_3^2 + \alpha_{2233}\, x_2^2 x_3^2 + \alpha_{11223}\, x_1^2 x_2^2\, x_3 + \alpha_{11233}\, x_1^2\, x_2 x_3^2 + \alpha_{12233}\, x_1\, x_2^2\, x_3^2 + \alpha_{112233} x_1^2\, x_2^2\, x_3^2 \quad (3.47)$$

Model2 was derived by using the responds function in a truncated form by omitting three terms; $\alpha_{1123}\, x_1^2 x_2^1\, x_3^1$, $\alpha_{1223}\, x_1^1 x_2^2\, x_3^1$ *and*, $\alpha_{1233}\, x_1^1 x_2^1\, x_3^2$

$$R = \alpha_1\, x_1 + \alpha_2\, x_2 + \alpha_3\, x_3 + \alpha_{12}\, x_1 x_2 + \alpha_{13}\, x_1 x_3 + \alpha_{23}\, x_2 x_3 + \alpha_{123}\, x_1 x_2 x_3 + \alpha_{11}\, x_1^2 + \alpha_{22}\, x_2^2 + \alpha_{33}\, x_3^2 + \alpha_{112}\, x_1^2 x_2 + \alpha_{113}\, x_1^2 x_3 + \alpha_{122}\, x_1 x_2^2 + \alpha_{133}\, x_1 x_3^2 + \alpha_{223}\, x_2^2 x_3 + \alpha_{233}\, x_2 x_3^2 + \alpha_{1122}\, x_1^2 x_2^2 + \alpha_{1133}\, x_1^2 x_3^2 + \alpha_{2233}\, x_2^2 x_3^2 + \alpha_{11223}\, x_1^2 x_2^2\, x_3 + \alpha_{11233}\, x_1^2\, x_2 x_3^2 + \alpha_{12233}\, x_1\, x_2^2\, x_3^2 + \alpha_{112233} x_1^2\, x_2^2\, x_3^2 \quad (3.48)$$

3.10.1Regression Model3

Model3 was formed by using the responds function as derived in its complete form omitting none of the terms.

$$R = \alpha_1\, x_1 + \alpha_2\, x_2 + \alpha_3\, x_3 + \alpha_{12}\, x_1 x_2 + \alpha_{13}\, x_1 x_3 + \alpha_{23}\, x_2 x_3 + \alpha_{123}\, x_1 x_2 x_3 + \alpha_{11}\, x_1^2 + \alpha_{22}\, x_2^2 + \alpha_{33}\, x_3^2 + \alpha_{112}\, x_1^2 x_2 + \alpha_{113}\, x_1^2 x_3 + \alpha_{122}\, x_1 x_2^2 + \alpha_{133}\, x_1 x_3^2 + \alpha_{223}\, x_2^2 x_3 + \alpha_{233}\, x_2 x_3^2 + \alpha_{1122}\, x_1^2 x_2^2 + \alpha_{1123}\, x_1^2 x_2^1\, x_3^1 + \alpha_{1133}\, x_1^2 x_3^2 + \alpha_{1123}\, x_1^1 x_2^2\, x_3^1 + \alpha_{1123}\, x_1^1 x_2^1\, x_3^2 + \alpha_{2233}\, x_2^2 x_3^2 + \alpha_{11223}\, x_1^2 x_2^2\, x_3 + \alpha_{11233}\, x_1^2\, x_2 x_3^2 + \alpha_{12233}\, x_1\, x_2^2\, x_3^2 + \alpha_{112233} x_1^2\, x_2^2\, x_3^2 \quad (3.48a)$$

3.11 COEFFICIENTS OF THE REGRESSION FUNCTION

The response matrix equation is as presented in equation (3.49). This equation is taken from equation (3.35a) of the first model with a fixed degree of accuracy. However, it differs from it in a manner that while the first model has a fixed degree of accuracy, this present mode will have as many degrees as the number of its concrete mix components..

Example is given for a one degree – three blend component mixes as:

$$
\begin{vmatrix} R_1 \\ R_2 \\ R_3 \\ R_{12} \\ R_{13} \\ R_{23} \\ R_{123} \end{vmatrix} = \begin{vmatrix}
Z_11 & Z_12 & Z_13 & Z_11 . Z_12 & Z_11 . Z_13 & Z_12 . Z_13 & Z_11 . Z_12 . Z_13 \\
Z_21 & Z_22 & Z_23 & Z_21 . Z_22 & Z_21 . Z_23 & Z_22 . Z_23 & Z_21 . Z_22 . Z_23 \\
Z_31 & Z_32 & Z_33 & Z_31 . Z_32 & Z_31 . Z_33 & Z_32 . Z_33 & Z_31 . Z_32 . Z_33 \\
Z_41 & Z_42 & Z_43 & Z_41 . Z_42 & Z_41 . Z_43 & Z_42 . Z_43 & Z_41 . Z_42 . Z_43 \\
Z_51 & Z_52 & Z_53 & Z_51 . Z_52 & Z_51 . Z_53 & Z_52 . Z_53 & Z_51 . Z_52 . Z_53 \\
Z_61 & Z_62 & Z_63 & Z_61 . Z_62 & Z_61 . Z_63 & Z_62 . Z_63 & Z_61 . Z_62 . Z_63 \\
Z_71 & Z_72 & Z_73 & Z_71 . Z_72 & Z_71 . Z_73 & Z_72 . Z_73 & Z_71 . Z_72 . Z_73
\end{vmatrix} \begin{vmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_{12} \\ \alpha_{13} \\ \alpha_{23} \\ \alpha_{123} \end{vmatrix} \quad (3.49)
$$

$$
\begin{vmatrix} RZ1 \\ RZ2 \\ RZ3 \\ RZ4 \\ RZ5 \\ RZ6 \\ RZ7 \end{vmatrix} = \begin{vmatrix}
C11 & C12 & C13 & C14 & C15 & C16 & C17 \\
C21 & C22 & C23 & C24 & C25 & C26 & C27 \\
C31 & C32 & C33 & C34 & C35 & C36 & C37 \\
C41 & C42 & C43 & C44 & C45 & C46 & C47 \\
C51 & C52 & C53 & C54 & C55 & C56 & C57 \\
C61 & C62 & C63 & C64 & C65 & C66 & C67 \\
C71 & C71 & C73 & C74 & C75 & C76 & C77
\end{vmatrix} \begin{vmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_{12} \\ \alpha_{13} \\ \alpha_{23} \\ \alpha_{123} \end{vmatrix} \quad (3.50)
$$

Where,

$C11 = \sum Zi1 . Zi1$

$C12 = \sum Zi1 . Zi2$

$C13 = \sum Zi1 . Zi3$

$C14 = \sum Zi1. (Zi1 . Zi2)$

$C15 = \sum Zi1 . (Zi1 . Zi3)$

$C16 = \sum Zi1 . (Zi2 . Zi3)$

$C17 = \sum Zi1 . (Zi1 . Zi2 . Zi3)$

$C22 = \sum Zi2 . Zi2$

$C23 = \sum Zi2 . Zi3$

$C24 = \sum Zi2. (Zi1 . Zi2)$

$C25 = \sum Zi2 . (Zi1 . Zi3)$

$C26 = \sum Zi2 . (Zi2 . Zi3)$

$C27 = \sum Zi2. (Zi1 . Zi2 . Zi3)$

$C34 = \sum Zi3 . (Zi1 . Zi2)$

$C35 = \sum Zi3 . (Zi1 . Zi3)$

$C36 = \sum Zi3 . (Zi2 . Zi3)$

$C37 = \sum Zi3 . (Zi1 . Zi2 . Zi3)$

$C44 = \sum (Zi1 . Zi2) . (Zi1 . Zi2)$

$C45 = \sum (Zi1 . Zi2) . (Zi1 . Zi3)$

$C46 = \sum (Zi1 . Zi2) . (Zi2 . Zi3)$

$C47 = \sum (Zi1 . Zi2) . (Zi1 . Zi2 . Zi3)$

$C55 = \sum (Zi1 . Zi3) . (Zi1 . Zi3)$

$C56 = \sum (Zi1 . Zi3) . (Zi2 . Zi3)$

$C57 = \sum (Zi1 . Zi3) . (Zi1 . Zi2 . Zi3)$

$C66 = \sum (Zi2 . Zi3) . (Zi2 . Zi3)$

$C67 = \sum (Zi2 . Zi3) . (Zi1 . Zi2 . Zi3)$

$C77 = \sum (Zi1 . Zi2 . Zi3) . (Zi1 . Zi2 . Zi3)$

C12 = C21; C13 = 31; C14 = C41;

C23; C32; C24; C25 = C52; C26 = C62;

C27 = C72

C34 = C43; C35 = C53; C36 = C63; C37 = C73

C45 = C54; C46 = C64; C47 = C74

C56 = C65; C57 = C75

$RZ1 = \sum Zi1 . Ri$

$RZ2 = \sum Zi2 . Ri$

$RZ3 = \sum Zi3 . Ri$

$RZ4 = \sum (Zi1 . Zi2) . Ri$

$RZ5 = \sum (Zi1 . Zi3) . Ri$

$RZ6 = \sum (Zi2 \,.\, Zi3) \,.\, Ri$

$RZ7 = \sum (Zi1 \,.\, Zi2 \,.\, Zi3) \,.\, Ri$

That is $[RZi] = \Sigma_r \Sigma \, RZ_i$

Four materials were used, but the components of the mix are three. They are water/cement ratio (S1), sand/cement ratio (S2) and granite/cement ratio (S3). Note: S = S1 + S2 + S3 and Zi = Si / S.

This has enabled the model to reduce the size of CC matrix . It will be observed that the actual number of elements in the concrete mix used herein is four (4), but this regression is keeping cement constant, thereby reducing the components for use in the regression to three (3).

Examples of the response matrix equation for a truncated and complete three degree-three blend component mixes of the model are as shown below in equation (3.51) and (3.52), with its components derived in a similar pattern to that of the two degree-three blend components responds matrix in equation 3.49. Mix ratio for compressive strength is same as those used earlier for the formulation of the fore model.

.

Response matrix equation for model2 is as follows.

RZ1		C11	C12	C13	C14	C15	C16	C17	C18	C19	C110	C111	C112	C113	C114	C115	C116	C117	C118	C119	C120	C121	C122	C123	α_{1}	
RZ2		C21	C22	C23	C24	C25	C26	C27	C28	C29	C210	C211	C212	C213	C214	C215	C216	C217	C218	C219	C220	C221	C222	C223	α_{2}	
RZ3		C31	C32	C33	C34	C35	C36	C37	C38	C39	C310	C311	C312	C313	C314	C315	C316	C317	C318	C319	C320	C321	C322	C323	α_{3}	
RZ4		C41	C42	C43	C44	C45	C46	C47	C48	C49	C410	C411	C412	C413	C414	C415	C416	C417	C418	C419	C420	C421	C422	C423	α_{12}	
RZ5		C51	C52	C53	C54	C55	C56	C57	C58	C59	C510	C511	C512	C513	C514	C515	C516	C517	C518	C519	C520	C521	C522	C523	α_{13}	
RZ6		C61	C62	C63	C64	C65	C66	C67	C68	C69	C610	C611	C612	C613	C614	C615	C616	C617	C618	C619	C620	C621	C622	C623	α_{23}	
RZ7		C71	C72	C73	C74	C75	C76	C77	C78	C79	C710	C711	C712	C713	C714	C715	C716	C717	C718	C719	C720	C721	C722	C723	α_{123}	
RZ8		C81	C82	C83	C84	C85	C86	C87	C88	C89	C810	C811	C812	C813	C814	C815	C816	C817	C818	C819	C820	C821	C822	C823	α_{11}	(3.51)
RZ9		C91	C92	C93	C94	C95	C96	C97	C98	C99	C910	C911	C912	C913	C914	C915	C916	C917	C918	C919	C920	C921	C922	C923	α_{22}	
RZ10		C101	C102	C103	C104	C105	C106	C107	C108	C109	C1010	C1011	C1012	C1013	C1014	C1015	C1016	C1017	C1018	C1019	C1020	C1021	C1022	C1023	α_{33}	
RZ11		C111	C112	C113	C114	C115	C116	C117	C118	C119	C1110	C1111	C1112	C1113	C1114	C1115	C1116	C1117	C1118	C1119	C1120	C1121	C1122	C1123	α_{112}	
RZ12	=	C121	C122	C123	C124	C125	C126	C127	C128	C129	C1210	C1211	C1212	C1213	C1214	C1215	C1216	C1217	C1218	C1219	C1220	C1221	C1222	C1223	α_{113}	
RZ13		C131	C132	C133	C134	C135	C136	C137	C138	C139	C1310	C1311	C1312	C1313	C1314	C1315	C1316	C1317	C1318	C1319	C1320	C1321	C1322	C1323	α_{122}	
RZ14		C141	C142	C143	C144	C145	C146	C147	C148	C149	C1410	C1411	C1412	C1413	C1414	C1415	C1416	C1417	C1418	C1419	C1420	C1421	C1422	C1423	α_{133}	
RZ15		C151	C152	C153	C154	C155	C156	C157	C158	C159	C1510	C1511	C1512	C1513	C1514	C1515	C1516	C1517	C1518	C1519	C1520	C1521	C1522	C1523	α_{223}	
RZ16		C161	C162	C163	C164	C165	C166	C167	C168	C169	C1610	C1611	C1612	C1613	C1614	C1615	C1616	C1617	C1618	C1619	C1620	C1621	C1622	C1623	α_{233}	
RZ17		C171	C172	C173	C174	C175	C176	C177	C178	C179	C1710	C1711	C1712	C1713	C1714	C1715	C1716	C1717	C1718	C1719	C1720	C1721	C1722	C1723	α_{1122}	
RZ18		C181	C182	C183	C184	C185	C186	C187	C188	C189	C1810	C1811	C1812	C1813	C1814	C1815	C1816	C1817	C1818	C1819	C1820	C1821	C1822	C1823	α_{1133}	
RZ19		C191	C192	C193	C194	C195	C196	C197	C198	C199	C1910	C1911	C1912	C1913	C1914	C1915	C1916	C1917	C1918	C1919	C1920	C1921	C1922	C1923	α_{2233}	
RZ20		C201	C202	C203	C204	C205	C206	C207	C208	C209	C2010	C2011	C2012	C2013	C2014	C2015	C2016	C2017	C2018	C2019	C2020	C2021	C2022	C2023	α_{11223}	
RZ21		C211	C212	C213	C214	C215	C216	C217	C218	C219	C2110	C2111	C2112	C2113	C2114	C2115	C2116	C2117	C2118	C2119	C2120	C2121	C2122	C2123	α_{11233}	
RZ22		C221	C222	C223	C224	C225	C226	C227	C228	C229	C2210	C2211	C2212	C2213	C2214	C2215	C2216	C2217	C2218	C2219	C2220	C2221	C2222	C2223	α_{12233}	
RZ23		C231	C232	C233	C234	C235	C236	C237	C238	C239	C2310	C2311	C2312	C2313	C2314	C2315	C2316	C2317	C2318	C2319	C2320	C2321	C2322	C2323	α_{112233}	
RZ23		C231	C232	C233	C234	C235	C236	C237	C238	C239	C2310	C2311	C2312	C2313	C2314	C2315	C2316	C2317	C2318	C2319	C2320	C2321	C2322	C2323	α_{112233}	

Response matrix equation for model3 is as follows. With Values of Z_i matrix determined from S_i for model3

RZ1		C11	C12	C13	C14	C15	C16	C17	C18	C19	C110	C111	C112	C113	C114	C115	C116	C117	C118	C119	C120	C121	C122	C123	C124	C125	C126	α_{1}	
RZ2		C21	C22	C23	C24	C25	C26	C27	C28	C29	C210	C211	C212	C213	C214	C215	C216	C217	C218	C219	C220	C221	C222	C223	C224	C225	C226	α_{2}	
RZ3		C31	C32	C33	C34	C35	C36	C37	C38	C39	C310	C311	C312	C313	C314	C315	C316	C317	C318	C319	C320	C321	C322	C323	C324	C325	C326	α_{3}	
RZ4		C41	C42	C43	C44	C45	C46	C47	C48	C49	C410	C411	C412	C413	C414	C415	C416	C417	C418	C419	C420	C421	C422	C423	C424	C425	C426	α_{12}	
RZ5		C51	C52	C53	C54	C55	C56	C57	C58	C59	C510	C511	C512	C513	C514	C515	C516	C517	C518	C519	C520	C521	C522	C523	C524	C525	C526	α_{13}	
RZ6		C61	C62	C63	C64	C65	C66	C67	C68	C69	C610	C611	C612	C613	C614	C615	C616	C617	C618	C619	C620	C621	C622	C623	C624	C625	C626	α_{23}	
RZ7		C71	C72	C73	C74	C75	C76	C77	C78	C79	C710	C711	C712	C713	C714	C715	C716	C717	C718	C719	C720	C721	C722	C723	C724	C725	C726	α_{123}	(3.52)
RZ8		C81	C82	C83	C84	C85	C86	C87	C88	C89	C810	C811	C812	C813	C814	C815	C816	C817	C818	C819	C820	C821	C822	C823	C824	C825	C826	α_{11}	
RZ9		C91	C92	C93	C94	C95	C96	C97	C98	C99	C910	C911	C912	C913	C914	C915	C916	C917	C918	C919	C920	C921	C922	C923	C924	C925	C926	α_{22}	
RZ10		C101	C102	C103	C104	C105	C106	C107	C108	C109	C1010	C1011	C1012	C1013	C1014	C1015	C1016	C1017	C1018	C1019	C1020	C1021	C1022	C1023	C1024	C1025	C1026	α_{33}	
RZ11		C111	C112	C113	C114	C115	C116	C117	C118	C119	C1110	C1111	C1112	C1113	C1114	C1115	C1116	C1117	C1118	C1119	C1120	C1121	C1122	C1123	C1124	C1125	C1126	α_{112}	
RZ12	=	C121	C122	C123	C124	C125	C126	C127	C128	C129	C1210	C1211	C1212	C1213	C1214	C1215	C1216	C1217	C1218	C1219	C1220	C1221	C1222	C1223	C1224	C1225	C1226	α_{113}	
RZ13		C131	C132	C133	C134	C135	C136	C137	C138	C139	C1310	C1311	C1312	C1313	C1314	C1315	C1316	C1317	C1318	C1319	C1320	C1321	C1322	C1323	C1324	C1325	C1326	α_{122}	
RZ14		C141	C142	C143	C144	C145	C146	C147	C148	C149	C1410	C1411	C1412	C1413	C1414	C1415	C1416	C1417	C1418	C1419	C1420	C1421	C1422	C1423	C1424	C1425	C1426	α_{133}	
RZ15		C151	C152	C153	C154	C155	C156	C157	C158	C159	C1510	C1511	C1512	C1513	C1514	C1515	C1516	C1517	C1518	C1519	C1520	C1521	C1522	C1523	C1524	C1525	C1526	α_{223}	
RZ16		C161	C162	C163	C164	C165	C166	C167	C168	C169	C1610	C1611	C1612	C1613	C1614	C1615	C1616	C1617	C1618	C1619	C1620	C1621	C1622	C1623	C1624	C1625	C1626	α_{233}	
RZ17		C171	C172	C173	C174	C175	C176	C177	C178	C179	C1710	C1711	C1712	C1713	C1714	C1715	C1716	C1717	C1718	C1719	C1720	C1721	C1722	C1723	C1724	C1725	C1726	α_{1122}	
RZ18		C181	C182	C183	C184	C185	C186	C187	C188	C189	C1810	C1811	C1812	C1813	C1814	C1815	C1816	C1817	C1818	C1819	C1820	C1821	C1822	C1823	C1824	C1825	C1826	α_{1123}	
RZ19		C191	C192	C193	C194	C195	C196	C197	C198	C199	C1910	C1911	C1912	C1913	C1914	C1915	C1916	C1917	C1918	C1919	C1920	C1921	C1922	C1923	C1924	C1925	C1926	α_{1133}	
RZ20		C201	C202	C203	C204	C205	C206	C207	C208	C209	C2010	C2011	C2012	C2013	C2014	C2015	C2016	C2017	C2018	C2019	C2020	C2021	C2022	C2023	C2024	C2025	C2026	α_{1223}	
RZ21		C211	C212	C213	C214	C215	C216	C217	C218	C219	C2110	C2111	C2112	C2113	C2114	C2115	C2116	C2117	C2118	C2119	C2120	C2121	C2122	C2123	C2124	C2125	C2126	α_{1233}	
RZ22		C221	C222	C223	C224	C225	C226	C227	C228	C229	C2210	C2211	C2212	C2213	C2214	C2215	C2216	C2217	C2218	C2219	C2220	C2221	C2222	C2223	C2224	C2225	C2226	α_{2233}	
RZ23		C231	C232	C233	C234	C235	C236	C237	C238	C239	C2310	C2311	C2312	C2313	C2314	C2315	C2316	C2317	C2318	C2319	C2320	C2321	C2322	C2323	C2324	C2325	C2326	α_{11223}	
RZ24		C241	C242	C243	C244	C245	C246	C247	C248	C249	C2410	C2411	C2412	C2413	C2414	C2415	C2416	C2417	C2418	C2419	C2420	C2421	C2422	C2423	C2424	C2425	C2426	α_{11233}	
RZ25		C251	C252	C253	C254	C255	C256	C257	C258	C259	C2510	C2511	C2512	C2513	C2514	C2515	C2516	C2517	C2518	C2519	C2520	C2521	C2522	C2523	C2524	C2525	C2526	α_{12233}	
RZ26		C261	C262	C263	C264	C265	C266	C267	C268	C269	C2610	C2611	C2612	C2613	C2614	C2615	C2616	C2617	C2618	C2619	C2620	C2621	C2622	C2623	C2624	C2625	C2626	α_{112233}	

The concrete mixes for model2 were divided into five groups for the formation of the models: TEST A, TEST B, TEST C, TEST D, TEST E. This was done to help reduce the calculation involved in the model formation. By expanding and using equation(3.51)and (3.52),the elements constituting the tables for Z matrix ,CC matrix, and CC matrix inverse values were determined. This was done for concrete mix proportions of different observation points within a given designated test (from TEST A to TEST E) for model2 and presented in appendix 1.

For model3 which is the complete response function for the three degree – three blend component mixes regression model, the concrete mixes were also divided into five groups: TEST A, to TEST E, so doing the z matrix, cc matrix and the cc matrix inverse for the different groups were also calculated and presented in appendix 1.

With values of RZ_i and CC matrix it becomes easy to determine the values of the constant coefficients α_i from equation 3.51 and 3.52, by making the constant coefficients α_i the subject of the equation.

$$\alpha_i = RZ_i * CC^{-1} \qquad (3.53a)$$

The expansion of the equation can be seen expressed below in equation 3.53b-c.

Expanding and using equation (3.51) (3.53b) and equation (3.52) (3.53c) the elements constituting the inverse of cc matrix was calculated as can be seen in appendix 1for model2 and model3. Substituting the values into the response matrix equation of the three degree-three blend component mixes for the 23x23 matrix and 26x26 matrix of the model. The only thing remaining for the solution of the equation to be got is substituting the values of Z_i and laboratory compressive strength into the equation, this was done in chapter five after the practical test was done.

The expansion of the equation (3.53a) for model 2

$$\begin{bmatrix} \alpha_{1} \\ \alpha_{2} \\ \alpha_{3} \\ \alpha_{12} \\ \alpha_{13} \\ \alpha_{23} \\ \alpha_{123} \\ \alpha_{11} \\ \alpha_{22} \\ \alpha_{33} \\ \alpha_{112} \\ \alpha_{113} \\ \alpha_{122} \\ \alpha_{133} \\ \alpha_{223} \\ \alpha_{233} \\ \alpha_{1122} \\ \alpha_{1133} \\ \alpha_{2233} \\ \alpha_{11223} \\ \alpha_{11233} \\ \alpha_{12233} \\ \alpha_{112233} \end{bmatrix} = \begin{bmatrix} RZ1 \\ RZ2 \\ RZ3 \\ RZ4 \\ RZ5 \\ RZ6 \\ RZ7 \\ RZ8 \\ RZ9 \\ RZ10 \\ RZ11 \\ RZ12 \\ RZ13 \\ RZ14 \\ RZ15 \\ RZ16 \\ RZ17 \\ RZ18 \\ RZ19 \\ RZ20 \\ RZ21 \\ RZ22 \\ RZ23 \end{bmatrix} \begin{bmatrix}
C11 & C12 & C13 & C14 & C15 & C16 & C17 & C18 & C19 & C110 & C111 & C112 & C113 & C114 & C115 & C116 & C117 & C118 & C119 & C120 & C121 & C122 & C123 \\
C21 & C22 & C23 & C24 & C25 & C26 & C27 & C28 & C29 & C210 & C211 & C212 & C213 & C214 & C215 & C216 & C217 & C218 & C219 & C220 & C221 & C222 & C223 \\
C31 & C32 & C33 & C34 & C35 & C36 & C37 & C38 & C39 & C310 & C311 & C312 & C313 & C314 & C315 & C316 & C317 & C318 & C319 & C320 & C321 & C322 & C323 \\
C41 & C42 & C43 & C44 & C45 & C46 & C47 & C48 & C49 & C410 & C411 & C412 & C413 & C414 & C415 & C416 & C417 & C418 & C419 & C420 & C421 & C422 & C423 \\
C51 & C52 & C53 & C54 & C55 & C56 & C57 & C58 & C59 & C510 & C511 & C512 & C513 & C514 & C515 & C516 & C517 & C518 & C519 & C520 & C521 & C522 & C523 \\
C61 & C62 & C63 & C64 & C65 & C66 & C67 & C68 & C69 & C610 & C611 & C612 & C613 & C614 & C615 & C616 & C617 & C618 & C619 & C620 & C621 & C622 & C623 \\
C71 & C72 & C73 & C74 & C75 & C76 & C77 & C78 & C79 & C710 & C711 & C712 & C713 & C714 & C715 & C716 & C717 & C718 & C719 & C720 & C721 & C722 & C723 \\
C81 & C82 & C83 & C84 & C85 & C86 & C87 & C88 & C89 & C810 & C811 & C812 & C813 & C814 & C815 & C816 & C817 & C818 & C819 & C820 & C821 & C822 & C823 \\
C91 & C92 & C93 & C94 & C95 & C96 & C97 & C98 & C99 & C910 & C911 & C912 & C913 & C914 & C915 & C916 & C917 & C918 & C919 & C920 & C921 & C922 & C923 \\
C101 & C102 & C103 & C104 & C105 & C106 & C107 & C108 & C109 & C1010 & C1011 & C1012 & C1013 & C1014 & C1015 & C1016 & C1017 & C1018 & C1019 & C1020 & C1021 & C1022 & C1023 \\
C111 & C112 & C113 & C114 & C115 & C116 & C117 & C118 & C119 & C1110 & C1111 & C1112 & C1113 & C1114 & C1115 & C1116 & C1117 & C1118 & C1119 & C1120 & C1121 & C1122 & C1123 \\
C121 & C122 & C123 & C124 & C125 & C126 & C127 & C128 & C129 & C1210 & C1211 & C1212 & C1213 & C1214 & C1215 & C1216 & C1217 & C1218 & C1219 & C1220 & C1221 & C1222 & C1223 \\
C131 & C132 & C133 & C134 & C135 & C136 & C137 & C138 & C139 & C1310 & C1311 & C1312 & C1313 & C1314 & C1315 & C1316 & C1317 & C1318 & C1319 & C1320 & C1321 & C1322 & C1323 \\
C141 & C142 & C143 & C144 & C145 & C146 & C147 & C148 & C149 & C1410 & C1411 & C1412 & C1413 & C1414 & C1415 & C1416 & C1417 & C1418 & C1419 & C1420 & C1421 & C1422 & C1423 \\
C151 & C152 & C153 & C154 & C155 & C156 & C157 & C158 & C159 & C1510 & C1511 & C1512 & C1513 & C1514 & C1515 & C1516 & C1517 & C1518 & C1519 & C1520 & C1521 & C1522 & C1523 \\
C161 & C162 & C163 & C164 & C165 & C166 & C167 & C168 & C169 & C1610 & C1611 & C1612 & C1613 & C1614 & C1615 & C1616 & C1617 & C1618 & C1619 & C1620 & C1621 & C1622 & C1623 \\
C171 & C172 & C173 & C174 & C175 & C176 & C177 & C178 & C179 & C1710 & C1711 & C1712 & C1713 & C1714 & C1715 & C1716 & C1717 & C1718 & C1719 & C1720 & C1721 & C1722 & C1723 \\
C181 & C182 & C183 & C184 & C185 & C186 & C187 & C188 & C189 & C1810 & C1811 & C1812 & C1813 & C1814 & C1815 & C1816 & C1817 & C1818 & C1819 & C1820 & C1821 & C1822 & C1823 \\
C191 & C192 & C193 & C194 & C195 & C196 & C197 & C198 & C199 & C1910 & C1911 & C1912 & C1913 & C1914 & C1915 & C1916 & C1917 & C1918 & C1919 & C1920 & C1921 & C1922 & C1923 \\
C201 & C202 & C203 & C204 & C205 & C206 & C207 & C208 & C209 & C2010 & C2011 & C2012 & C2013 & C2014 & C2015 & C2016 & C2017 & C2018 & C2019 & C2020 & C2021 & C2022 & C2023 \\
C211 & C212 & C213 & C214 & C215 & C216 & C217 & C218 & C219 & C2110 & C2111 & C2112 & C2113 & C2114 & C2115 & C2116 & C2117 & C2118 & C2119 & C2120 & C2121 & C2122 & C2123 \\
C221 & C222 & C223 & C224 & C225 & C226 & C227 & C228 & C229 & C2210 & C2211 & C2212 & C2213 & C2214 & C2215 & C2216 & C2217 & C2218 & C2219 & C2220 & C2221 & C2222 & C2223 \\
C231 & C232 & C233 & C234 & C235 & C236 & C237 & C238 & C239 & C2310 & C2311 & C2312 & C2313 & C2314 & C2315 & C2316 & C2317 & C2318 & C2319 & C2320 & C2321 & C2322 & C2323
\end{bmatrix}^{-1} \qquad (3.53b)$$

The expansion of the equation (3.53a) for model 3

α_{1}		RZ1	C11	C12	C13	C14	C15	C16	C17	C18	C19	C110	C111	C112	C113	C114	C115	C116	C117	C118	C119	C120	C121	C122	C123	C124	C125	C126
α_{2}		RZ2	C21	C22	C23	C24	C25	C26	C27	C28	C29	C210	C211	C212	C213	C214	C215	C216	C217	C218	C219	C220	C221	C222	C223	C224	C225	C226
α_{3}		RZ3	C31	C32	C33	C34	C35	C36	C37	C38	C39	C310	C311	C312	C313	C314	C315	C316	C317	C318	C319	C320	C321	C322	C323	C324	C325	C326
α_{12}		RZ4	C41	C42	C43	C44	C45	C46	C47	C48	C49	C410	C411	C412	C413	C414	C415	C416	C417	C418	C419	C420	C421	C422	C423	C424	C425	C426
α_{13}		RZ5	C51	C52	C53	C54	C55	C56	C57	C58	C59	C510	C511	C512	C513	C514	C515	C516	C517	C518	C519	C520	C521	C522	C523	C524	C525	C526
α_{23}		RZ6	C61	C62	C63	C64	C65	C66	C67	C68	C69	C610	C611	C612	C613	C614	C615	C616	C617	C618	C619	C620	C621	C622	C623	C624	C625	C626
α_{123}		RZ7	C71	C72	C73	C74	C75	C76	C77	C78	C79	C710	C711	C712	C713	C714	C715	C716	C717	C718	C719	C720	C721	C722	C723	C724	C725	C726
α_{11}		RZ8	C81	C82	C83	C84	C85	C86	C87	C88	C89	C810	C811	C812	C813	C814	C815	C816	C817	C818	C819	C820	C821	C822	C823	C824	C825	C826
α_{22}		RZ9	C91	C92	C93	C94	C95	C96	C97	C98	C99	C910	C911	C912	C913	C914	C915	C916	C917	C918	C919	C920	C921	C922	C923	C924	C925	C926
α_{33}		RZ10	C101	C102	C103	C104	C105	C106	C107	C108	C109	C1010	C1011	C1012	C1013	C1014	C1015	C1016	C1017	C1018	C1019	C1020	C1021	C1022	C1023	C1024	C1025	C1026
α_{112}		RZ11	C111	C112	C113	C114	C115	C116	C117	C118	C119	C1110	C1111	C1112	C1113	C1114	C1115	C1116	C1117	C1118	C1119	C1120	C1121	C1122	C1123	C1124	C1125	C1126
α_{113}	=	RZ12	C121	C122	C123	C124	C125	C126	C127	C128	C129	C1210	C1211	C1212	C1213	C1214	C1215	C1216	C1217	C1218	C1219	C1220	C1221	C1222	C1223	C1224	C1225	C1226
α_{122}		RZ13	C131	C132	C133	C134	C135	C136	C137	C138	C139	C1310	C1311	C1312	C1313	C1314	C1315	C1316	C1317	C1318	C1319	C1320	C1321	C1322	C1323	C1324	C1325	C1326
α_{133}		RZ14	C141	C142	C143	C144	C145	C146	C147	C148	C149	C1410	C1411	C1412	C1413	C1414	C1415	C1416	C1417	C1418	C1419	C1420	C1421	C1422	C1423	C1424	C1425	C1426
α_{223}		RZ15	C151	C152	C153	C154	C155	C156	C157	C158	C159	C1510	C1511	C1512	C1513	C1514	C1515	C1516	C1517	C1518	C1519	C1520	C1521	C1522	C1523	C1524	C1525	C1526
α_{233}		RZ16	C161	C162	C163	C164	C165	C166	C167	C168	C169	C1610	C1611	C1612	C1613	C1614	C1615	C1616	C1617	C1618	C1619	C1620	C1621	C1622	C1623	C1624	C1625	C1626
α_{1122}		RZ17	C171	C172	C173	C174	C175	C176	C177	C178	C179	C1710	C1711	C1712	C1713	C1714	C1715	C1716	C1717	C1718	C1719	C1720	C1721	C1722	C1723	C1724	C1725	C1726
α_{1123}		RZ18	C181	C182	C183	C184	C185	C186	C187	C188	C189	C1810	C1811	C1812	C1813	C1814	C1815	C1816	C1817	C1818	C1819	C1820	C1821	C1822	C1823	C1824	C1825	C1826
α_{1133}		RZ19	C191	C192	C193	C194	C195	C196	C197	C198	C199	C1910	C1911	C1912	C1913	C1914	C1915	C1916	C1917	C1918	C1919	C1920	C1921	C1922	C1923	C1924	C1925	C1926
α_{1223}		RZ20	C201	C202	C203	C204	C205	C206	C207	C208	C209	C2010	C2011	C2012	C2013	C2014	C2015	C2016	C2017	C2018	C2019	C2020	C2021	C2022	C2023	C2024	C2025	C2026
α_{1233}		RZ21	C211	C212	C213	C214	C215	C216	C217	C218	C219	C2110	C2111	C2112	C2113	C2114	C2115	C2116	C2117	C2118	C2119	C2120	C2121	C2122	C2123	C2124	C2125	C2126
α_{2233}		RZ22	C221	C222	C223	C224	C225	C226	C227	C228	C229	C2210	C2211	C2212	C2213	C2214	C2215	C2216	C2217	C2218	C2219	C2220	C2221	C2222	C2223	C2224	C2225	C2226
α_{11223}		RZ23	C231	C232	C233	C234	C235	C236	C237	C238	C239	C2310	C2311	C2312	C2313	C2314	C2315	C2316	C2317	C2318	C2319	C2320	C2321	C2322	C2323	C2324	C2325	C2326
α_{11233}		RZ24	C241	C242	C243	C244	C245	C246	C247	C248	C249	C2410	C2411	C2412	C2413	C2414	C2415	C2416	C2417	C2418	C2419	C2420	C2421	C2422	C2423	C2424	C2425	C2426
α_{12233}		RZ25	C251	C252	C253	C254	C255	C256	C257	C258	C259	C2510	C2511	C2512	C2513	C2514	C2515	C2516	C2517	C2518	C2519	C2520	C2521	C2522	C2523	C2524	C2525	C2526
α_{112233}		RZ26	C261	C262	C263	C264	C265	C266	C267	C268	C269	C2610	C2611	C2612	C2613	C2614	C2615	C2616	C2617	C2618	C2619	C2620	C2621	C2622	C2623	C2624	C2625	C2626

-1

(3.53c)

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3.12 TESTS FOR GOODNESS OF FIT OF THE MODELS

It is expected that the results of the Models will be accepted with about 95% risk of being correct or 5% risk of being incorrect. The result being correct means that there is no difference between model results and experimental test results. At this point it will be wise to state the statistical hypothesis for accepting or otherwise the adequacy of the Models' results as follows:

i. Null Hypothesis (H_0): There is no significant difference between the Models' results and experimental test results.

ii. Alternative Hypothesis (H_1): There is a significant difference between the Models' results and the experimental test results

iii. The risk involved is that 5% or below of the Models' results will be incorrect.

Several methods of testing the adequacy of Models' results exit. Some of the known methods are Least Square method, Chi-Square method, Z – test method, Student t-test method, Fisher test method and the like. For the purpose of this work the use of the Fisher method will be employed. Before treating the tests for adequacy of the Models, the error inherent in the experimental test results will be discussed. This error is called the Replication error.

3.13 ERROR OF THE REPLICATES

During the experimental test several errors were introduced. Some occurred due to human inconsistency, variation in test tools and equipment. Other occurred due to conditional variation like humidity, temperature, pressure and the like. This error was described as random error in paragraph 3.4 above.

At any arbitrary point of observation, replicate values are obtained and used to get the mean value of response at that point.

The mean value is used because the replicate values vary from each other due to the inconsistencies mentioned above. The variance of the replicates at the arbitrary point of observation is designated as S_i^2. Cramer (1946) gave the equation of variance as:

$$S_y^2 = 1/ (n-1) * [\sum_{1 \le i \le n} (y_I – ý)^2] \qquad (3.54)$$

Where n is the number of observation, y_i is the value at any arbitrary point of observation and ý is the mean value of the y_i values.

$$\text{That is } ý = \sum_{1 \le i \le n} y_i / n \qquad (3.55)$$

When equation 3.84 is expanded it becomes approximately equal to

$$S_y^2 = 1/(n-1) * [\sum_{1 \le i \le n} y_i^2 – 1/n * (\sum y_i)^2] \qquad (3.56)$$

Thus, the equation of variance of the replicates at any arbitrary point of observation will be given as:

$$S_i^2 = 1/(n_i-1) * [\sum_{1 \le i \le n_i} y_i^2 – 1/n_i * (\sum y_i)^2] \qquad (3.57)$$

Hence, the variance of the replicates at all the points of observation will be the summation of the individual variances divided by number of points of observation. That is to say

$$S_y^2 = 1/V * \sum_{1 \le i \le N} S_i^2 \qquad (3.58)$$

Where V is the degree of freedom, which is equal to N – 1. Therefore, the random error or standard deviation becomes

$$S_y = \sqrt{(S_y^2)} \qquad (3.59)$$

3.14 FISHER TEST

In the formulation of a model for predicting mix ratios where desired response is known and vice versa, two things are involved. One of them is the generation of a mathematical equation with unknown coefficients. The second is the carrying out experimental test to generate the unknown coefficients. This means that response can be got by the experimental test that uses replicates and as well be got from the model when the coefficients are known. It is very vital that the variance S_T^2 from the model should be compared with the variance S_E^2 from the experimental test to see if they are similar or different. Akhnazorova (1958) and Brookes (1979) devised means of establishing the fact to prove whether or not S_E^2 and S_T^2 are similar through the use Fisher test. S_1^2 and S_2^2 were used in this test. S_1^2 is the greater of S_E^2 and S_T^2.

S^2 is as given in equation 3.83. The equation for the Fisher-test is given as

$$F = S_1^2 / S_2^2 \qquad (3.60)$$

The range of S_1^2 / S_2^2 to accept the fact that S_E^2 and S_T^2 are similar is shown as

$$1 / f_\alpha (v_1,v_2) < S_1^2 / S_2^2 < f_\alpha (v_1,v_2) \qquad (3.61)$$

α is significant level, v is the degree of freedom = N – 1.

CHAPTER FOUR

RESULTS, DISCUSSIONS AND ANALYSIS

4.1 SPECIFIC GRAVITY OF AGGREGATES

The result of the specific gravity test is shown in Appendix 2 Tables1and 2. The specific gravity for fine aggregates is 2.62. Specific Gravity for coarse aggregate is 2.7. The specific gravity of most natural (normal weight) aggregates ranges between 2.4 – 2.7 (see Road Research (1950)). 2.62for fine aggregates and2.7coarse aggregate is within the range for most natural aggregates for it is more than 2.4. This means that both the fine and coarse aggregate can be classified as normal weight aggregates.

4.2 BULK DENSITY OF AGGREGATES

The bulk density of the bone-dry fine and coarse aggregate is shown inAppendix2Tables3 and 4. Table 3 shows then on- compacted bulk density while Table 4 shows the compacted bulk density. The mean compacted bulk density of both fine and coarse aggregates are1665.09 kg/m^3 and1294.32 kg/m^3. This value is above the maximum bulk density specified by BS 3681 (1963). This standard defines normal weight aggregates as one having a bulk density exceeding 1200 kg / m^3 for fine aggregates and 960 kg / m^3 for coarse aggregate.

4.3 WATER ABSORPTION

The result of the water absorption test is shown in Appendix 2Table 7. The mean value of the water absorption of the coarse aggregate is 4.33%. This value is within the range of values determined for different aggregates of different sizes by Newman (1959). However, the value is on the high side, which means that the coarse aggregate will require more water to become saturated. Thus, when using the coarse aggregate for concrete, the water absorption will be put into consideration. The total water required during concrete batching would be water absorption plus free water content.

4.4 VOID RATIO

Void ratio will be calculated from the mean values of the bulk density and specific gravity of the coarse aggregate.

Void ratio = 1– 1665.09/ (2.7 * 1000)

= 0.3833

This means that void occupies less volume than the solid matter. Hence, less volume of filler (a mixture of cement paste and sand otherwise called mortar) will be required in a concrete mix using this material as coarse aggregate. .

4.5 SIEVE ANALYSIS

The result of the sieve analysis is as can be seen in Figures4.1and 4.2 and Tables8 and9 in Appendix 2. These show that the grading of fine aggregate for sieve 600µm (No.25) is 40 which is between 35-59 as specified for zone 2 of the grading curve with minimal content of particles finer than 600µm (No.25) which helps in the workability of the mix and the grading of coarse aggregate fell more in the range of 13.2mm – 37.5mm and zone 1 of the grading curve.

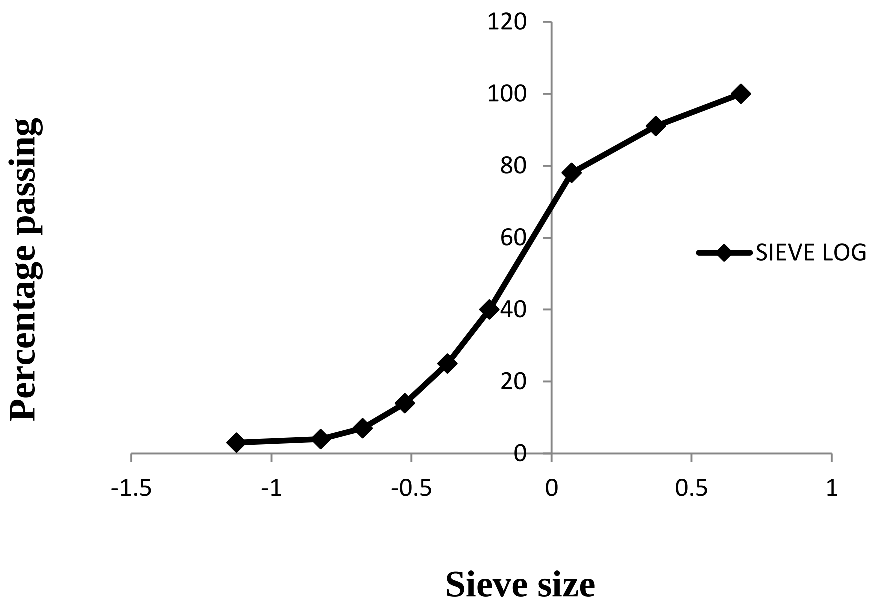

Figure4.1: Sieve analysis fine agg.

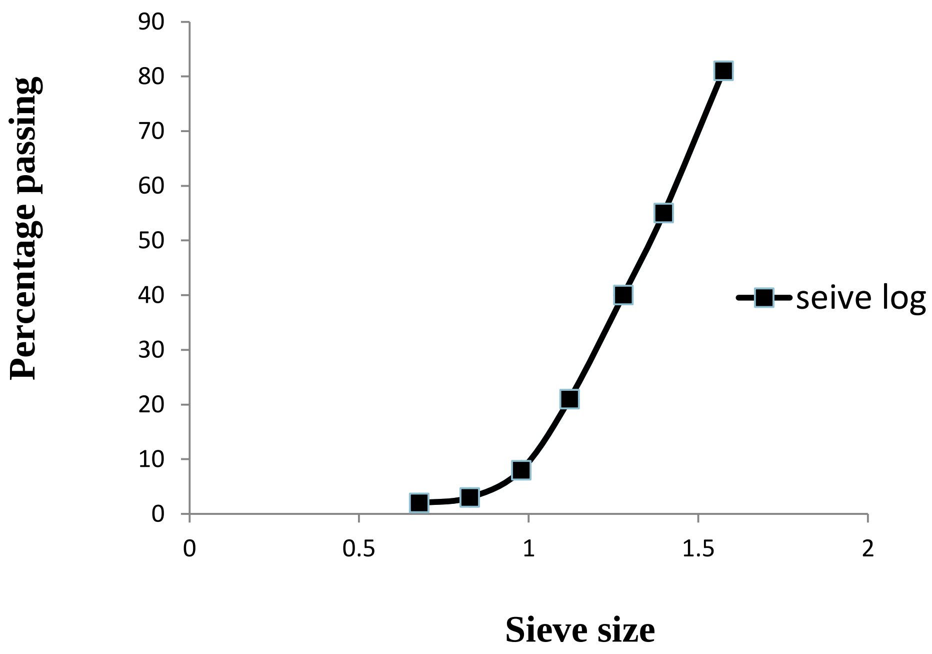

Figure 4.2: Sieve Analysis of coarse agg.

4.6 CONCRETE CUBE STRENGTH

The 28th days' cubes Strengths of the concrete are shown in Appendix 3Table 1. Table 2 in Appendix 3shows the 28th day concrete SSD density. The regression models were used to determine the optimum mixture proportion and predict cubes strengths of mixtures respectively.

4.7 Coefficients of Regression Models

Using the values of Zi matrix from chapter three in the response matrix equation of the four blend component mixes with the laboratory compressive cube strength of Table 1in Appendix 3 $[F(z).Z] = \Sigma_r z_q z_s . z_t F(z)$ was obtained for model 1 as can be seen below, as this was used in the determination of the Coefficients of Regression Models

[TEST A – MODEL 1]

Σ(z1 .F(Z)) = 36.57406
Σ(z2 .F(Z)) =70.71399
Σ(z3 .F(Z)) = 108.3629
Σ(z4.F(Z)) = 103.779
Σ(z1z2.F(Z)) = 8.087149
Σ(z1z3.F(Z))= 12.40383
Σ(z1z4.F(Z)) = 11.85761
Σ(z2z3.F(Z)) = 23.98977
Σ(z2z4.F(Z)) = 22.98036
Σ(z3z4.F(Z)) = 29.42223
Σ(z1z2z3.F(Z)) = 2.742774
Σ(z1z2z4.F(Z)) = 2.622662
Σ(z1z3z4.F(Z)) = 3.361211
Σ(z2z3z4.F(Z)) = 6.515254
Σ(z1z2z3z4.F(Z)) = 0.74344

[TEST B – MODEL 1]

Σ(z1.F(Z)) = 22.80224
Σ(z2.F(Z)) = 43.38868
Σ(z3.F(Z)) = 91.45301
Σ(z4.F(Z)) = 103.7961
Σ(z1z2.F(Z)) = 3.780867
Σ(z1z3.F(Z)) = 7.999026
Σ(z1z4.F(Z)) = 9.014874
Σ(z2z3.F(Z)) = 15.17345
Σ(z2z4.F(Z)) = 17.23294
Σ(z3z4.F(Z)) = 30.67852
Σ(z1z2z3.F(Z)) = 1.325981
Σ(z1z2z4.F(Z)) = 1.495354
Σ(z1z3z4.F(Z)) = 2.670578
Σ(z2z3z4.F(Z)) = 5.092353
Σ(z1z2z3z4.F(Z)) = 0.442893

Values of the [F(z).Z] as determined for model1 contd. Test C , D and E

[TEST C – MODEL 1]

$\Sigma(z1.F(Z)) = 11.04609$
$\Sigma(z2.F(Z)) = 20.71627$
$\Sigma(z3.F(Z)) = 52.97265$
$\Sigma(z4.F(Z)) = 71.32499$
$\Sigma(z1z2.F(Z)) = 1.465262$
$\Sigma(z1z3.F(Z)) = 3.751214$
$\Sigma(z1z4.F(Z)) = 5.040356$
$\Sigma(z2z3.F(Z)) = 7.031633$
$\Sigma(z2z4.F(Z)) = 9.469233$
$\Sigma(z3z4.F(Z)) = 20.76537$
$\Sigma(z1z2z3.F(Z)) = 0.497582$
$\Sigma(z1z2z4.F(Z)) = 0.66868$
$\Sigma(z1z3z4.F(Z)) = 1.468188$
$\Sigma(z2z3z4.F(Z)) = 2.756741$
$\Sigma(z1z2z3z4.F(Z)) = 0.194772$

[TEST D – MODEL 1]

$\Sigma(z1.F(Z)) = 5.391801$
$\Sigma(z2.F(Z)) = 9.979788$
$\Sigma(z3.F(Z)) = 33.64553$
$\Sigma(z4.F(Z)) = 41.20288$
$\Sigma(z1z2.F(Z)) = 0.596095$
$\Sigma(z1z3.F(Z)) = 2.011398$
$\Sigma(z1z4.F(Z)) = 2.459318$
$\Sigma(z2z3.F(Z)) = 3.721663$
$\Sigma(z2z4.F(Z)) = 4.558066$
$\Sigma(z3z4.F(Z)) = 13.13257$
$\Sigma(z1z2z3.F(Z)) = 0.22237$
$\Sigma(z1z2z4.F(Z)) = 0.27191$
$\Sigma(z1z3z4.F(Z)) = 0.785034$
$\Sigma(z2z3z4.F(Z)) = 1.452651$
$\Sigma(z1z2z3z4.F(Z)) = 0.086788$

[TEST E – MODEL 1]

$\Sigma(z1.F(Z)) = 2.10494$
$\Sigma(z2.F(Z)) = 3.92351$
$\Sigma(z3.F(Z)) = 14.7613$
$\Sigma(z4.F(Z)) = 20.5503$
$\Sigma(z1z2.F(Z)) = 0.19967$
$\Sigma(z1z3.F(Z)) = 0.75009$
$\Sigma(z1z4.F(Z)) = 1.0469$
$\Sigma z2z3.F(Z)) = 1.40112$
$\Sigma(z2z4.F(Z)) = 1.95034$
$\Sigma(z3z4.F(Z)) = 6.46754$
$\Sigma(z1z2z3.F(Z)) = 0.07116$
$\Sigma(z1z2z4.F(Z)) = 0.0993$
$\Sigma(z1z3z4.F(Z)) = 0.3284$
$\Sigma(z2z3z4.F(Z)) = 0.61391$
$\Sigma(z1z2z3z4.F(Z)) = 0.03115$

For the truncated response function of the three degree-three blend component mixes, Using the values of Zi matrix from chapter three in the response matrix equation of the three degree-three blend component mixes with the laboratory compressive cube strength of Table 1in Appendix 3, [RZi] = $\Sigma_r\Sigma$ R $Z_i$was obtained for model 2 as below, this was also used in the determination of the Coefficients of Regression Models.

[TEST A – MODEL 2]	[TEST B – MODEL 2]
Σ(z1.R) = 139.175	Σ(z1.R) = 27.3347
Σ(z2.R) = 139.175	Σ(z2.R) = 109.645
Σ(z3.R) = 133.297	Σ(z3.R) = 124.46
Σ(z12.R) = 20.4472	Σ(z12.R) = 11.4939
Σ(z13.R) = 19.5496	Σ(z13.R) = 12.957
Σ(z23.R) = 48.5408	Σ(z23.R) = 44.1056
Σ(z123.R) = 7.11574	Σ(z123.R) = 4.60117
Σ(z1z1.R) = 6.9608	Σ(z1z1.R) = 2.88386
Σ(z2z2.R) = 70.1874	Σ(z2z2.R) = 54.0453
Σ(z3z3.R) = 65.2065	Σ(z3z3.R) = 67.3973
Σ(z112.R) = 3.02942	Σ(z112.R) = 1.21565
Σ(z113.R) = 2.89101	Σ(z113.R) = 1.36128
Σ(z122.R) = 10.3021	Σ(z122.R) = 5.67708
Σ(z133.R) = 9.54288	Σ(z133.R) = 6.99451
Σ(z223.R) = 21.1083	Σ(z223.R) = 18.6241
Σ(z233.R) = 20.3168	Σ(z233.R) = 20.8806
Σ(z1122.R) = 1.52499	Σ(z1122.R) = 0.6016
Σ(z1133.R) = 1.40812	Σ(z1133.R) = 0.73262
Σ(z2233.R) = 7.5318	Σ(z2233.R) = 7.59741
Σ(z11223.R) = 0.45679	Σ(z11223.R) = 0.20541
Σ(z11233.R) = 0.43828	Σ(z11233.R) = 0.22751
Σ(z12233.R) = 1.10104	Σ(z12233.R) = 0.7908
Σ(z112233.R) = 0.1623	Σ(z112233.R) = 0.08306

Values of the [F(z).Z] as determined for model2 contd. Test C and D

[TEST C – MODEL 2]	[TEST D – MODEL 2]
Σ(z1.F(Z)) = 12.6884	Σ(z1.F(Z)) = 6.01389
Σ(z2.F(Z)) = 60.6959	Σ(z2.F(Z)) = 37.5952
Σ(z3.F(Z)) = 82.1157	Σ(z3.F(Z)) = 45.8309
Σ(z12.F(Z)) = 4.95402	Σ(z12.F(Z)) = 2.52828
Σ(z13.F(Z)) = 6.68946	Σ(z13.F(Z)) = 3.07783
Σ(z23.F(Z)) = 27.5214	Σ(z23.F(Z)) = 16.4736
Σ(z123.F(Z)) = 2.24279	Σ(z123.F(Z)) = 1.10771
Σ(z1z1.F(Z)) = 1.04497	Σ(z1z1.F(Z)) = 0.40778
Σ(z2z2.F(Z)) = 28.2204	Σ(z2z2.F(Z)) = 18.5933
Σ(z3z3.F(Z)) = 47.9048	Σ(z3z3.F(Z)) = 26.2794
Σ(z112.F(Z)) = 0.40809	Σ(z112.F(Z)) = 0.17142
Σ(z113.F(Z)) = 0.55005	Σ(z113.F(Z)) = 0.20849
Σ(z122.F(Z)) = 2.30313	Σ(z122.F(Z)) = 1.24914
Σ(z133.F(Z)) = 3.89661	Σ(z133.F(Z)) = 1.76163
Σ(z223.F(Z)) = 10.9433	Σ(z223.F(Z)) = 7.01042
Σ(z233.F(Z)) = 14.3354	Σ(z233.F(Z)) = 8.35547
Σ(z1122.F(Z)) = 0.18972	Σ(z1122.F(Z)) = 0.08459
Σ(z1133.F(Z)) = 0.31996	Σ(z1133.F(Z)) = 0.11913
Σ(z2233.F(Z)) = 4.97095	Σ(z2233.F(Z)) = 3.09637
Σ(z11223.F(Z)) = 0.07338	Σ(z11223.F(Z)) = 0.03198
Σ(z11233.F(Z)) = 0.09578	Σ(z11233.F(Z)) = 0.03801
Σ(z12233.F(Z)) = 0.40459	Σ(z12233.F(Z)) = 0.20821
Σ(z112233.F(Z)) = 0.03323	Σ(z112233.F(Z)) = 0.01412

Values of the [F(z).Z] as determined for model2 contd. Test E

[TEST E – MODEL 2]

Σ(z1.F(Z)) = 2.32553

Σ(z2.F(Z)) = 16.3093

Σ(z3.F(Z)) = 22.7051

Σ(z12.F(Z)) = 0.91557

Σ(z13.F(Z)) = 1.27782

Σ(z23.F(Z)) = 7.89529

Σ(z123.F(Z)) = 0.44286

Σ(z1z1.F(Z)) = 0.13215

Σ(z2z2.F(Z)) = 7.49849

Σ(z3z3.F(Z)) = 13.532

Σ(z112.F(Z)) = 0.05193

Σ(z113.F(Z)) = 0.07263

Σ(z122.F(Z)) = 0.42077

Σ(z133.F(Z)) = 0.76232

Σ(z223.F(Z)) = 3.19259

Σ(z233.F(Z)) = 4.25984

Σ(z1122.F(Z)) = 0.02386

Σ(z1133.F(Z)) = 0.04337

Σ(z2233.F(Z)) = 1.54013

Σ(z11223.F(Z)) = 0.01011

Σ(z11233.F(Z)) = 0.01355

Σ(z12233.F(Z)) = 0.08614

Σ(z112233.F(Z)) = 0.00487

Values of the [F(z).Z] as determined formodel3 Test A and B

[TEST A – MODEL 3]	[TEST B – MODEL 3]
Σ(z1.F(Z)) = 46.958	Σ(z1.F(Z)) = 27.3347
Σ(z2.F(Z)) = 139.18	Σ(z2.F(Z)) = 109.645
Σ(z3.F(Z)) = 133.3	Σ(z3.F(Z)) = 124.46
Σ(z11.F(Z)) = 6.9608	Σ(z11.F(Z)) = 2.88386
Σ(z12.F(Z)) = 20.447	Σ(z12.F(Z)) = 11.4939
Σ(z13.F(Z)) = 19.55	Σ(z13.F(Z)) = 12.957
Σ(z22.F(Z)) = 70.187	Σ(z22.F(Z)) = 54.0453
Σ(z23.F(Z)) = 48.541	Σ(z23.F(Z)) = 44.1059
Σ(z33.F(Z)) = 65.207	Σ(z33.F(Z)) = 67.3973
Σ(z112.F(Z)) = 3.0294	Σ(z112.F(Z)) = 1.21565
Σ(z113.F(Z)) = 2.891	Σ(z113.F(Z)) = 1.36128
Σ(z122.F(Z)) = 10.302	Σ(z122.F(Z)) = 5.67708
Σ(z123.F(Z)) = 7.1157	Σ(z123.F(Z)) = 4.60117
Σ(z133.F(Z)) = 9.5429	Σ(z133.F(Z)) = 6.99451
Σ(z223.F(Z)) = 21.108	Σ(z223.F(Z)) = 18.6241
Σ(z233.F(Z)) = 20.317	Σ(z233.F(Z)) = 20.8806
Σ(z1122.F(Z)) = 1.525	Σ(z1122.F(Z)) = 0.6016
Σ(z1123.F(Z)) = 1.0519	Σ(z1123.F(Z)) = 0.48436
Σ(z1133.F(Z)) = 1.4081	Σ(z1133.F(Z)) = 0.73262
Σ(z1223.F(Z)) = 3.0922	Σ(z1223.F(Z)) = 1.94718
Σ(z1233.F(Z)) = 2.9717	Σ(z1233.F(Z)) = 2.16963
Σ(z2233.F(Z)) = 7.5318	Σ(z2233.F(Z)) = 7.59741
Σ(z11223.F(Z)) = 0.4568	Σ(z11223.F(Z)) = 0.20541
Σ(z11233.F(Z)) = 0.4383	Σ(z11233.F(Z)) = 0.22751
Σ(z12233.F(Z)) = 1.101	Σ(z12233.F(Z)) = 0.7908
Σ(z112233.F(Z)) = 0.1623	Σ(z112233.F(Z)) = 0.08306

Values of the [F(z).Z] as determined for model3 contd. Test C and D

[TEST C – MODEL 3]	[TEST D – MODEL 3]
Σ(z1.F(Z)) = 12.6884	Σ(z1.F(Z)) = 6.01389
Σ(z2.F(Z)) = 60.6959	Σ(z2.F(Z)) = 37.5952
Σ(z3.F(Z)) = 82.1157	Σ(z3.F(Z)) = 45.8309
Σ(z11.F(Z)) = 4.954	Σ(z11.F(Z)) = 2.52828
Σ(z12.F(Z)) = 6.6895	Σ(z12.F(Z)) = 3.07783
Σ(z13.F(Z)) = 27.5214	Σ(z13.F(Z)) = 16.4736
Σ(z22.F(Z)) = 2.2428	Σ(z22.F(Z)) = 1.10772
Σ(z23.F(Z)) = 1.045	Σ(z23.F(Z)) = 0.40778
Σ(z33.F(Z)) = 28.2204	Σ(z33.F(Z)) = 18.5933
Σ(z112.F(Z)) = 47.9048	Σ(z112.F(Z)) = 26.2794
Σ(z113.F(Z)) = 0.4081	Σ(z113.F(Z)) = 0.17142
Σ(z122.F(Z)) = 0.5501	Σ(z122.F(Z)) = 0.20849
Σ(z123.F(Z)) = 2.3031	Σ(z123.F(Z)) = 1.24914
Σ(z133.F(Z)) = 3.8966	Σ(z133.F(Z)) = 1.76163
Σ(z223.F(Z)) = 10.9433	Σ(z223.F(Z)) = 7.01042
Σ(z233.F(Z)) = 14.3354	Σ(z233.F(Z)) = 8.35547
Σ(z1122.F(Z)) = 0.1897	Σ(z1122.F(Z)) = 0.08459
Σ(z1123.F(Z)) = 0.1845	Σ(z1123.F(Z)) = 0.07512
Σ(z1133.F(Z)) = 0.32	Σ(z1133.F(Z)) = 0.11913
Σ(z1223.F(Z)) = 0.892	Σ(z1223.F(Z)) = 0.47149
Σ(z1233.F(Z)) = 1.1663	Σ(z1233.F(Z)) = 0.5611
Σ(z2233.F(Z)) = 4.971	Σ(z2233.F(Z)) = 3.09637
Σ(z11223.F(Z)) = 0.0734	Σ(z11223.F(Z)) = 0.03198
Σ(z11233.F(Z)) = 0.0958	Σ(z11233.F(Z)) = 0.03801
Σ(z12233.F(Z)) = 0.4046	Σ(z12233.F(Z)) = 0.20821
Σ(z112233.F(Z)) = 0.0332	Σ(z112233.F(Z)) = 0.01412

Values of the [F(z).Z] as determined for model3 contd. Test E

[TEST E – MODEL 3]

$\Sigma(z1.F(Z)) = 2.32553$

$\Sigma(z2.F(Z)) = 16.3093$

$\Sigma(z3.F(Z)) = 22.7051$

$\Sigma(z11.F(Z)) = 0.91557$

$\Sigma(z12.F(Z)) = 1.27782$

$\Sigma(z13.F(Z)) = 7.89529$

$\Sigma(z22.F(Z)) = 0.44286$

$\Sigma(z23.F(Z)) = 0.13215$

$\Sigma(z33.F(Z)) = 7.49849$

$\Sigma(z112.F(Z)) = 13.532$

$\Sigma(z113.F(Z)) = 0.05193$

$\Sigma(z122.F(Z)) = 0.07263$

$\Sigma(z123.F(Z)) = 0.42077$

$\Sigma(z133.F(Z)) = 0.76232$

$\Sigma(z223.F(Z)) = 3.19259$

$\Sigma(z233.F(Z)) = 4.25984$

$\Sigma(z1122.F(Z)) = 0.02386$

$\Sigma(z1123.F(Z)) = 0.0251$

$\Sigma(z1133.F(Z)) = 0.04337$

$\Sigma(z1223.F(Z)) = 0.17869$

$\Sigma(z1233.F(Z)) = 0.23907$

$\Sigma(z2233.F(Z)) = 1.54013$

$\Sigma(z11223.F(Z)) = 0.01011$

$\Sigma(z11233.F(Z)) = 0.01356$

$\Sigma(z12233.F(Z)) = 0.08614$

$\Sigma(z112233.F(Z)) = 0.00487$

For the response matrix equation of the four blend component mixes(model1) ,Substituting the value F(z)(cubes strengths from experimental test results of Table 1in Appendix 3) and Z_i values forming [F(z).Z]and also inverse of CC matrix into equation 3.35c of chapter three will give the coefficients, [$\propto$] of the Regression model equation used in writing the model program as:

[TEST A – MODEL 1]		[TEST B – MODEL 1]		[TEST C – MODEL 1]	
α_1 =	21.83472	α_1=	-12.9763	α_1=	7512.862
α_2=	2267.427	α_2=	15.67677	α_2=	27.94118
α_3=	68252.05	α_3=	5.263604	α_3=	3906.93
α_4=	49279.36	α_4=	428.4744	α_4=	-6988.23
α_{12}=	395205.1	α_{12}=	-4592.21	α_{12}=	-12344.2
α_{13}=	-193947	α_{13}=	426.8312	α_{13}=	-21392.6
α_{14}=	-180777	α_{14}=	463.7088	α_{14}=	9715.488
α_{23}=	-275419	α_{23}=	-564.072	α_{23}=	-27244.4
α_{24}=	-199801	α_{24}=	-2006.7	α_{24}=	49808.77
α_{34}=	81853	α_{34}=	-1125.31	α_{34}=	241.2594
α_{123}=	-34620.5	α_{123}=	9840.188	α_{123}=	73760.37
α_{124}=	-6391.64	α_{124}=	-1592.49	α_{124}=	-86621.9
α_{134}=	-52863.6	α_{134}=	-540.674	α_{134}=	1969.56
α_{234}=	-324223	α_{234}=	7098.251	α_{234}=	-3128.62
α_{1234}=	-157617	α_{1234}=	5925.682	α_{1234}=	7665.748

Values of the coefficients as determined for model1 contd. Test D and E

[TEST D – MODEL 1]		[TEST E – MODEL 1]	
α_1=	-31.8503	α_1=	6665.586
α_2=	-42571.9	α_2=	9.417578
α_3=	4992.444	α_3=	3181.488
α_4=	5798.872	α_4=	-175.78
α_{12}=	10547.54	α_{12}=	2078.453
α_{13}=	-3422.44	α_{13}=	-8568.78
α_{14}=	-3860.64	α_{14}=	-9611.89
α_{23}=	6316.858	α_{23}=	-31802.7
α_{24}=	-636.265	α_{24}=	1490.386
α_{34}=	-3225.5	α_{34}=	-2263.2
α_{123}=	15516.7	α_{123}=	-29515.9
α_{124}=	15590.53	α_{124}=	24110.93
α_{134}=	8572.021	α_{134}=	-913.613
α_{234}=	23563.91	α_{234}=	24160.75
α_{1234}=	24332.28	α_{1234}=	9675.522

For the response matrix equation of the three degree-three blend component Mixes (model2 and model3)Substituting the valueRi(cubes strengths from experimental test results ofTable 1in Appendix 3) and $Z_i$values forming [R.Z_i]and also inverse of CC matrix into equation 3.53b-c of chapter three gave the coefficients, [$\propto$] of the Regression model equations used in writing the model program as follows:

Values of the coefficients as determined for model2 Test A,B and C

[TEST A – MODEL 2]		[TEST B – MODEL 2]		[TEST C – MODEL 2]	
α_{1}=	-6761.7	α_{1}=	20646.23	α_{1}=	-5566.533
α_{2}=	901.522	α_{2}=	-28330.47	α_{2}=	3349.2487
α_{3}=	37.3544	α_{3}=	7449.0299	α_{3}=	-3748.143
α_{12}=	-17157	α_{12}=	-65999.64	α_{12}=	-7386.329
α_{13}=	-4627.2	α_{13}=	-77137.09	α_{13}=	-2567.737
α_{23}=	-135.11	α_{23}=	128328.68	α_{23}=	-9304.884
α_{123}=	35468.6	α_{123}=	-22110.37	α_{123}=	-947.4341
α_{11}=	-28194	α_{11}=	77061.888	α_{11}=	15870.289
α_{22}=	-5008.7	α_{22}=	19593.048	α_{22}=	-3729.642
α_{33}=	3025.77	α_{33}=	-6422.537	α_{33}=	5858.9167
α_{112}=	19740.1	α_{112}=	-47687.68	α_{112}=	-3584.177
α_{113}=	6248.4	α_{113}=	-96108.16	α_{113}=	44123.491
α_{122}=	13868.8	α_{122}=	102545.7	α_{122}=	11702.177
α_{133}=	-865.68	α_{133}=	60968.315	α_{133}=	10661.503
α_{223}=	25712	α_{223}=	-58304.74	α_{223}=	10927.874
α_{233}=	-13525	α_{233}=	-108003.2	α_{233}=	-1999.097
α_{1122}=	-25310	α_{1122}=	-75985.92	α_{1122}=	-549.675
α_{1133}=	21209.6	α_{1133}=	-30378.86	α_{1133}=	-25670.01
α_{2233}=	-18746	α_{2233}=	-65091.83	α_{2233}=	13611.462
α_{11223}=	1319742	α_{11223}=	163398.93	α_{11223}=	84320.204
α_{11233}=	911186	α_{11233}=	250757.94	α_{11233}=	-28507.8
α_{12233}=	17565.3	α_{12233}=	-56382.95	α_{12233}=	148480.82
α_{112233}=	-4E+06	α_{112233}=	119190.17	α_{112233}=	-230435.7

Values of the coefficients as determined for model2 contd. Test D and E

[TEST D – MODEL 2]		[TEST E – MODEL 2]	
α_{1}=	-45274	α_{1}=	10345.5617
α_{2}=	-55329.3	α_{2}=	2143.89795
α_{3}=	-13112.3	α_{3}=	-12594.393
α_{12}=	3348.472	α_{12}=	-33646.08
α_{13}=	3113.871	α_{13}=	19718.1159
α_{23}=	18572.95	α_{23}=	2594.03336
α_{123}=	64878.02	α_{123}=	3227.17922
α_{11}=	57391.5	α_{11}=	-10869.045
α_{22}=	62304.68	α_{22}=	-314.87125
α_{33}=	18655.57	α_{33}=	12681.6767
α_{112}=	-56094.7	α_{112}=	2097.98015
α_{113}=	24922.86	α_{113}=	-4.0035824
α_{122}=	98282.08	α_{122}=	22410.8851
α_{133}=	49138.65	α_{133}=	-23068.576
α_{223}=	3005.445	α_{223}=	-4055.7336
α_{233}=	12277.13	α_{233}=	6510.44366
α_{1122}=	248121.4	α_{1122}=	3278.58736
α_{1133}=	188849.8	α_{1133}=	38011.2967
α_{2233}=	116629.5	α_{2233}=	19826.6662
α_{11223}=	96562.02	α_{11223}=	28199.636
α_{11233}=	60318.95	α_{11233}=	83066.1257
α_{12233}=	692430.9	α_{12233}=	28763.1952
α_{112233}=	240102.9	α_{112233}=	23504.1278

Values of the coefficients as determined for model3 Test A,B and C

[TEST A – MODEL 3]		[TESTB – MODEL 3]		[TEST C – MODEL 3]	
α_{1}=	2453.236	α_{1}=	16721.848	α_{1}=	-346.64355
α_{2}=	-757.188	α_{2}=	-46891.49	α_{2}=	-392.12891
α_{3}=	-14.1872	α_{3}=	1570.2444	α_{3}=	-501.11432
α_{12}=	-9295.07	α_{12}=	-10724.03	α_{12}=	1069.2782
α_{13}=	-898.157	α_{13}=	20637.352	α_{13}=	1470.7179
α_{23}=	-654.062	α_{23}=	1419.7978	α_{23}=	386.93136
α_{123}=	1132.477	α_{123}=	42878.303	α_{123}=	994.41103
α_{11}=	-466.295	α_{11}=	21612.051	α_{11}=	1476.355
α_{22}=	-55.4475	α_{22}=	7507.7505	α_{22}=	375.30511
α_{33}=	-31066.7	α_{33}=	10192.586	α_{33}=	499.42009
α_{112}=	-43320.4	α_{112}=	-36029.14	α_{112}=	361.1003
α_{113}=	-5490.72	α_{113}=	10432.94	α_{113}=	282.6218
α_{122}=	-13095.5	α_{122}=	33763.32	α_{122}=	-846.1227
α_{133}=	-3897.18	α_{133}=	-29546.55	α_{133}=	-903.98885
α_{223}=	-33.2621	α_{223}=	38891.884	α_{223}=	762.33668
α_{233}=	478.1587	α_{233}=	-28658.56	α_{233}=	690.60386
α_{1122}=	27370.92	α_{1122}=	-12523.47	α_{1122}=	-1145.5714
α_{1123}=	143333.5	α_{1123}=	-12423.8	α_{1123}=	209.17806
α_{1133}=	33578.86	α_{1133}=	18654.829	α_{1133}=	-728.05823
α_{1223}=	14627.09	α_{1223}=	21361.154	α_{1223}=	76.082309
α_{1233}=	26436.52	α_{1233}=	-26644.53	α_{1233}=	243.37636
α_{2233}=	10140.73	α_{2233}=	53942.822	α_{2233}=	-860.791
α_{11223}=	313712.3	α_{11223}=	-42775.97	α_{11223}=	181.41411
α_{11233}=	270748.1	α_{11233}=	11458.349	α_{11233}=	-327.05779
α_{12233}=	-96159.8	α_{12233}=	12137.533	α_{12233}=	-2658.4237
α_{112233}=	-957506	α_{112233}=	-9424.41	α_{112233}=	-687.76228

Values of the coefficients as determined for model3 contd. Test D and E

[TEST D – MODEL 3]		[TEST E – MODEL 3]	
α_1=	1671.151	α_1=	203.61272
α_2=	-838.664	α_2=	107.968068
α_3=	-580.378	α_3=	-205.1111
α_{12}=	-2507.24	α_{12}=	-1440.9269
α_{13}=	3190.485	α_{13}=	-1162.8802
α_{23}=	835.1221	α_{23}=	-166.21953
α_{123}=	9533.099	α_{123}=	-2164.6886
α_{11}=	-9763.79	α_{11}=	6250.16794
α_{22}=	513.3696	α_{22}=	-27.060141
α_{33}=	781.406	α_{33}=	270.971072
α_{112}=	-8756.38	α_{112}=	2184.71852
α_{113}=	9124.251	α_{113}=	1445.96808
α_{122}=	1491.643	α_{122}=	1788.6728
α_{133}=	-5729.17	α_{133}=	2523.22673
α_{223}=	2253.959	α_{223}=	-323.81447
α_{233}=	-4.65814	α_{233}=	-354.06729
α_{1122}=	7352.361	α_{1122}=	-11885.066
α_{1123}=	-9826.46	α_{1123}=	20514.5986
α_{1133}=	11318.3	α_{1133}=	-13012.544
α_{1223}=	687.3558	α_{1223}=	-3105.3531
α_{1233}=	-11267.8	α_{1233}=	-3549.7053
α_{2233}=	-2601.45	α_{2233}=	2486.78644
α_{11223}=	22081.63	α_{11223}=	19807.6311
α_{11233}=	-15232.4	α_{11233}=	19433.883
α_{12233}=	1062.108	α_{12233}=	4313.71141
α_{112233}=	-35196.3	α_{112233}=	22530.6027

4.8 REGRESSION MODEL 1

Substituting the value F(z)(cubes strengths from experimental test results ofTable 1in Appendix 3) into equation 3.35c of chapter three gave the coefficients of the regression model equation used in writing the model as can be seen above, Substituting these coefficients into equation 3.31 gave the final Regression equation as

[TEST A – MODEL 1]

$y_1=21.83472z_1.+2267.427z_2.+68252.05z_3.+49279.36z_4.+395205.1z_1z_2-193947\, z_1z_3-180777\, z_1z_4-275419\, z_2z_3$
$-199801z_2z_4+81853z_3z_4-34620.5z_1z_2z_3-6391.64z_1z_2z_4-52863.6z_1z_3z_4-324223z_2z_3z_4-157617z_1z_2z_3z_4$

[TEST B – MODEL 1]

$y_2=-12.9763z_1.+15.67677z_2.+5.263604z_3.+428.4744z_4-4592.21z_1z_2.+426.8312z_1z_3.+463.7088z_1z_4-564.072z_2z_3$
$-2006.7\, z_2z_4-1125.31z_3z_4.+9840.188z_1z_2z_3-1592.49z_1z_2z_4-540.674z_1z_3z_4.+7098.25z_2z_3z_4.+5925.68z_1\, z_2z_3z_4$

[TEST C – MODEL 1]

$y_3=7512.862z_1+27.94118z_2+3906.93z_3-6988.23z_4-12344.2z_1z_2-21392.6z_1z_3+9715.488z_1z_4-27244.4z_2z_3$
$+49808.77\, z_2z_4+241.2594z_3z_4+73760.37z_1z_2z_3-86621.9z_1z_2z_4+1969.56z_1z_3z_4-3128.6z_2z_3z_4+7665.75z_1z_2z_3z_4$

[TEST D – MODEL 1]

$y_4=-31.8503z_1-42571.9z_2.+4992.444z_3.+5798.872z_4.+10547.54z_1z_2-3422.44z_1z_3-3860.64z_1z_4.+6316.858z_2z_3$
$-636.265z_2\, z_4-3225.5z_3z_4.+15516.7z_1z_2z_3+15590.5z_1z_2z_4+8572.02\, z_1z_3z_4.+23563.91z_2z_3z_4.+24332.28z_1z_2z_3z_4$

[TEST E – MODEL 1]

$y_5=6665.586z_1+9.417578z_2.+3181.488z_3-175.78z_4.+2078.453z_1z_2-8568.78z_1z_3-9611.89z_1z_4+31802.7z_2z_3$
$+1490.39z_2z_4-2263.2z_3z_4-29516z_1z_2z_3.+24110.9z_1z_2z_4-913.613z_1z_3z_4+24160.75z_2z_3z_4.+9675.522z_1z_2z_3z_4$

4.8.1 TEST FOR GOODNESS OF FIT OF REGRESSION MODEL

As mentioned above a test will be conducted here to test for the adequacy of this model. It is expected that the results of the model is about 95% accurate. If it is not it will not be accepted as being adequate.

Statement of statistical hypothesis is as follows:

1. Null Hypothesis (H_{0}): There is no significant difference between the Model results and the experimental results.

2. Alternative Hypothesis (H_1): There is a significant difference between the Model results and experimental results.

The risk is that 5% or below of the Model's results is incorrect.

4.8.2 STANDARD RESPONSE ERROR OF THE REPLICATES

Table 1in Appendix 4 Regression Model's result versus Experimental Test results

For the test the parameter $\tilde{Y}$, is evaluated using the following equation

$$\tilde{Y} = \sum Y_i / n$$

Where Y_i is the response and n the number of responses.

Using $S_I^2 = 1/(n_I-1) * [\sum y_I^2 - 1/n_I *(\sum y_I)^2]$, $\tilde{Y} = \sum Y_i / n$ for $1<i<n$

$n_I = 4$

From Table 1 in Appendix 4

$\sum S_i^2 = 241.562$

Total Variance of the Replicate is given by

$S_y^2 = \sum S_i^2 / (N - 1) = 241.562/(60 - 1) = 4.094271$

Therefore, the Standard Error of the Replicates is the square root of the above Variance.

$S_y = \sqrt{S_y^2} = \sqrt{4.094271} = 2.02343$

4.8.3 FISHER TEST TO ANALYSE REGRESSION MODEL 1

Table 2 in Appendix 4 was generated in accordance to Fisher Test discussed in chapter three above.

For this test the parameter Y ,is evaluated using the following equation

Using $\ddot{y}_P = \sum Y_P / N$, $\ddot{y}_M = \sum Y_M / N$, $N = 60$

Where Y_i is the response and n the number of responses.

Therefore from Table 2 in Appendix 4

$S_p^2 = \sum(Y_p \ddot{y}_p) / (N - 1) = 5462.98933 / (60 - 1) = 92.59304$

$S_M^2 = \sum(Y_M \ddot{y}_M) / (N - 1) = 5336.0483 / (60 - 1) = 90.4415$

Therefore, $S_1^2 = 92.59304$ and $S_2^2 = 90.4415$.

$F_{calculated} = S_1^2 / S_2^2 = 92.59304 / 90.4415 = 1.024$

f – value from the tables is as discussed in chapter three above.

That is to say f from table is given as $t_{\propto} (V_1, V_2)$

This is equal to $t_{0.05} (59, 59)$

From Appendix 5, $F_{.0.05} (59,59) = 1.464$ (by interpolation)

$1/F = 0.683$

Thus, the condition $1/F \angle S_1^2 / S_2^2 \angle F$ has been satisfied. Null Hypothesis will be accepted.

4.9 REGRESSION MODEL 2

Substituting the value R(cubes strengths from experimental test results of Table 1in Appendix 3) into equation 3.53b-c of chapter three for the second model gave the coefficients of the regression model equation used in writing the model as can be seen above: Substituting these coefficients into equation 3.47and 3.48 will give the final Regression equation as follows:

For model2(Truncated response function)

[TEST A – MODEL 2]

$$Y_1=-6761.7x_1+901.522x_2+37.3544x_3-17157x_{12}-4627.2x_{13}-135.11x_{23}+35468.6x_{123}-28194x_{11}$$
$$-5008.7x_{22}+3025.77x_{33}+19740.1x_{112}+6248.4x_{113}+13868.8x_{122}-865.68x_{133}+25712x_{223}-13525x_{233}$$
$$-25310x_{1122}+21209.6x_{1133}-18746x_{2233}+1319742x_{11223}+911186x_{11233}+17565.3x_{12233}-4.00E+06x_{112233}$$

[TEST B – MODEL 2]

$$Y_2=20646.23x_1-28330.47x_2+7449.0299\alpha 3x_3-65999.64x_{12}-77137.09x_{13}+128328.68x_{23}-22110.37x_{123}$$
$$+77061.888x_{11}+19593.048x_{22}-6422.537x_{33}-47687.68x_{112}-96108.16x_{113}+102545.7x_{122}+60968.315x_{133}$$
$$-58304.74x_{223}-108003.2x_{233}-75985.92x_{1122}-30378.86x_{1133}-65091.83x_{2233}+163398.93x_{11223}+250757.94x_{11233}$$
$$-56382.95x_{12233}+119190.17x_{112233}$$

[TEST C – MODEL 2]

$$Y_3=-5566.533x_1+3349.2487x_2-3748.143x_3-7386.329x_{12}-2567.737x_{13}-9304.884x_{23}-947.4341x_{123}+15870.289x_{11}$$
$$-3729.642x_{22}+5858.916x_{33}-3584.177x_{112}+44123.491x_{113}+11702.177x_{122}+10661.503x_{133}+10927.87x_{223}$$
$$-1999.097x_{233}-549.675x_{1122}-25670.01x_{1133}+13611.462x_{2233}+84320.204x_{11223}-28507.8x_{11233}+148480.82x_{12233}$$
$$-230435.7x_{112233}$$

[TEST D – MODEL 2]

$$Y_4=-45274x_1-55329.3x_2-13112.3x_3+3348.472x_{12}+3113.871x_{13}+18572.95x_{23}+64878.02x_{123}+57391.5x_{11}$$
$$+62304.68x_{22}+18655.57x_{33}-56094.7x_{112}+24922.86x_{113}+11702.12x_{122}+49138.65x_{133}+3005.445x_{223}+$$
$$+12277.13x_{233}+248121.4x_{1122}+188849.8x_{1133}+116629.5x_{2233}+96562.02x_{11223}+60318.95x_{11233}$$
$$+692430.9x_{12233}+240102.9x_{112233}$$

[TEST E – MODEL 2]

$$Y_5=+10345.561x_1+2143.897x_2-12594.393x_3-33646.08x_{12}+19718.115x_{13}+2594.033x_{23}+3227.179x_{123}$$
$$-10869.045x_{11}-314.871x_{22}+12681.67x_{33}+2097.980x_{112}-4.0035x_{113}+22410.885x_{122}-23068.576x_{133}$$
$$-4055.734x_{223}+6510.444x_{233}+3278.587x_{1122}+38011.296x_{1133}+19826.666x_{2233}+28199.636x_{11223}+$$
$$+83066.125x_{11233}+28763.195x_{12233}+23504.127x_{112233}$$

4.9.1 REGRESSION MODEL 3

Model3 (complete response function)

[TEST A – MODEL 3]

$Y_1=2453.24X_1 -757.19X_2-14.187X_3-9295.1X_{12}-898.16X_{13}-654.06X_{23}+1132.48X_{123}-466.3X_{11}-55.448X_{22}-31067X_{33}$
$-43320X_{112}-5490.7X_{113}-13096X_{122}-3897.2X_{133}-33.262X_{223}+478.159X_{233}+27370.9X_{1122}+143334X_{1123}$
$+33578.9X_{1133}+14627.1X_{1223}+26436.5X_{1233}+10140.7X_{2233}+313712X_{11223}+270748X_{11233}-96160X_{12233}$
$-957506X_{112233}$

[TEST B – MODEL 3]

$Y_2=16722X_1-46891X_2+1570X_3-10724X_{12}+20637X_{13}+1420X_{23}+42878X_{123}+21612X_{11}+7508X_{22}+10193X_{33}$
$-36029X_{112}+10433X_{113}+33763X_{122}-29547X_{133}+38892X_{223}-28659X_{233}-12523X_{1122}-12424X_{1123}+18655X_{1133}$
$+21361X_{1223}-26645X_{1233}+53943X_{2233}-42776X_{11223}+11458X_{11233}+12138X_{12233}-9424X_{112233}$

[TEST C – MODEL 3]

$Y_3=-346.644X_1-392.129X_2-501.114X_3+1069.28X_{12}+1470.72X_{13}+386.931X_{23}+994.411X_{123}+1476.36X_{11}$
$+375.305X_{22}+499.42X_{33}+361.1X_{112}+282.622X_{113}-846.123X_{122}-903.989X_{133}+762.337X_{223}+690.604X_{233}$
$-1145.57X_{1122}+209.178X_{1123}-728.058X_{1133}+76.0823X_{1223}+243.376X_{1233}-860.791X_{2233}+181.414X_{11223}$
$-327.058X_{11233}-2658.42X_{12233}-687.762X_{112233}$

[TEST D – MODEL 3]

$Y_4=+1671.151X_1-838.664X_2-580.378X_3-2507.24X_{12}+3190.485X_{13}+835.1221X_{23}+9533.099X_{123}-9763.79X_{11}$
$+513.369X_{22}+781.406X_{33}-8756.38X_{112}+9124.251X_{113}+1491.643X_{122}-5729.17X_{133}+2253.959X_{223}-4.658X_{233}$
$+7352.361X_{1122}-9826.46X_{1123}+11318.3X_{1133} +687.355X_{1223}-11267.8X_{1233}-2601.45X_{2233}+22081.63X_{11223}$
$-15232.4X_{11233}+1062.108X_{12233}-35196.3X_{112233}$

[TEST E – MODEL 3]

$Y_5=+203.61272X_1+107.968068X_2-205.1111X_3-1440.9269X_{12}-1162.8802X_{13}-166.21953X_{23}-2164.6886X_{123}$
$+6250.16794X_{11}-27.060141X_{22}+270.971072X_{33}+2184.71852X_{112}+1445.96808X_{113}+1788.6728X_{122}+2523.22673X_{133}$
$-323.81447X_{223}-354.06729X_{233}-11885.066X_{1122}+20514.5986X_{1123}-13012.544X_{1133}-3105.3531X_{1223}-3549.7053X_{1233}$
$+2486.78644X_{2233}+19807.6311X_{11223}+19433.883X_{11233}+4313.71141X_{12233}+22530.6027X_{112233}$

4.9.2TEST FOR GOODNESS OF FIT FOR REGRESSION MODEL

The same process followed in paragraph 4.8.1 was observed here for testing of "goodness of fit" of the Regression model.

Statement of statistical hypothesis is as follows:

1 Null Hypothesis ($H_{0)}$): There is no significant difference between the Model results and the experimental results.

2 Alternative Hypothesis (H_1): There is a significant difference between the Model results and experimental results.

The risk is that 5% or below of the Model's results is incorrect.

4.9.3 FISHER TEST TO ANALYSE REGRESSION MODEL 2

Table 3 in Appendix 4; fisher test analysing regression model 2 was generated in accordance to Fisher Test discussed in chapter three above. For this test the parameter Y ,is evaluated using the following equation

Using $\ddot{y}_P = \sum Y_P / N$, $\ddot{y}_M = \sum Y_M / N$, $N = 60$
Where Y_i isthe response and n the number of responses.
Therefore from Table 3 in Appendix 4

$S_p^2 = \sum(Y_p \ddot{y}_p) / (N - 1) = 5462.98933 / (60 - 1) = 92.59304$

$S_M^2 = \sum(Y_M \ddot{y}_M) / (N - 1) = 5375.32757 / (60 - 1) = 91.10725$

Therefore, $S_1^2 = 92.59304$ and $S_2^2 = 91.10725$.
$F_{calculated} = S_1^2 / S_2^2 = 92.59304 / 91.10725 = 1.016$

f from table is given as $t_\infty (V_1, V_2)$

This is equal to $t_{0.05} (59, 59)$

From Appendix 5, $F_{.0.05} (59,59) = 1.464$ (by interpolation)

$1/F = 0.683$

Thus, the condition $1/F \angle S_1^2 / S_2^2 \angle F$ has been satisfied. Null Hypothesis is accepted.

4.9.4 FISHER TEST TO ANALYSE REGRESSION MODEL 3

Table 4 in Appendix 4 was generated in accordance to Fisher Test discussed in chapter three above For this test the parameter Y ,is evaluated using the following equation

Using $\ddot{y}_P = \sum Y_P / N$, $\ddot{y}_M = \sum Y_M / N$, $N = 60$

Where Y_i isthe response and n the number of responses.

Therefore from Table 4 in Appendix 4

$S_p^2 = \sum(Y_p \ddot{y}_p) / (N - 1) = 5462.98933 / (60 - 1) = 92.59304$

$S_M^2 = \sum(Y_M \ddot{y}_M) / (N - 1) = 5354.6461 / (60 - 1) = 90.75671$

Therefore, $S_1^2 = 92.59304$ and $S_2^2 = 90.75671$

$F_{calculated} = S_1^2 / S_2^2 = 92.59304 / 90.75671 = 1.020$

ffrom table is given as $t_\infty (V_1, V_2)$

This is equal to $t_{0.05} (59, 59)$

From Appendix5, $F_{.0.05} (59, 59) = 1.464$ (by interpolation)

$1/F = 0.683$

Thus, the condition $1/F \angle S_1^2 / S_2^2 \angle F$ has been satisfied. Null Hypothesis is accepted.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

The regression models developed herein have been shown to be adequate enough for compressive cube strength prediction.The Fisher F-test revealed that the compressive cube strengths predicted by the regressions are very close to those from the experiment. For model 1the calculated F (F = 1.024) is less than the allowable F or F from statistic table (f = 1.464) at 95% confidence level, for model 2 the calculated F (F = 1.016) is less than the allowable F or F from statistic table (f = 1.464) at 95% confidence level and for model 3 the calculated f (f = 1.020) is less than the allowable F or F from statistic table (F= 1.464) at 95% confidence level. Laboratory conditions and some human errors during the conduct of the laboratory experiment might be attributed to the difference between laboratory compressive cube strength and compressive strength predicted by the models.The experimental data are in very good agreement with the data from the models.The models'parameters as estimated are therefore acceptable.Thus, within 95% confidence level, one can predict the compressive cube strength of concrete made with water, cement (OPC), river sand and sandstone by using these models. Model1, which is for a two degree polynomial, has a result that is in good agreement with the experimental data; however, the data from model 2, which is for the truncated three degree polynomial are closer to the experimental data than data from model1. It is important to note that there exist no significant difference between the data from model2 andmodel3.Model3 is more cumbersome to handle than model2.

This implies that the extra effort put in model3 did not pay off in accuracy over model2.This is to say that the new regression models can be employed, like Scheffe's simplex,Osadebe's alternative regression models and Ibearugbulem et al (2013) model, in the optimization and prediction of concrete mixes. Based on the result of this project it will be concluded that the new Regression models are working well and can be used to predict compressive cube strength when the concrete mix ratios are known and vice versa at 95% confidence level.

5.2 CONTRIBUTIONS TO KNOWLEDGE

i. This work obtained a new mathematical model for predicting the compressive strength of sandstone aggregate concrete.

ii. This work also obtained another model (with improved accuracy) mathematical model based on Ibearugbulem's principle for predicting the compressive strength of sandstone aggregate concrete, a polynomial function with a higher degree.

5.3 RECOMMENDATION

Based on the results of this research work, it is important to make the following recommendations:

i For different concrete made with water, cement, sand, and coarse aggregates, the model can be used in 95% confidence level to predict concrete mixes.

ii The new regression models can be used to predict future 28th day compressive strength of sandstone concrete when the mix proportions of the concrete mix is known.

iii Future research work should develop a regression Model for predicting concrete responses other than compressive strength at curing age of 28 days using sandstone.

iv Future research work should investigate the use of the regression model for higher degree of accuracy and higher number of components than the ones used herein.

v Future research work should investigate the formulation of suitably truncated model2 with less number of coefficient to reduce amount of work involved without jeopardizing the accuracy.

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APPENDCES

Appendix 1 z matrix cc matrix and cc matrix inverse values for the models

Table1:Z matrix values [for concrete mix proportions from observation point 1-12 (TEST A – MODEL 1)]

z1	z2	z3	z4	z1z2	z1z3	z1z4	z2z3	z2z4	z3z4	z1z2z3	z1z2z4	z1z3z4	z2z3z4	z1z2z3z4
0.101124	0.224719	0.168539	0.505618	0.022724	0.017043	0.05113	0.037874	0.113622	0.085217	0.00383	0.01149	0.008617	0.01915	0.001936
0.101124	0.224719	0.337079	0.337079	0.022724	0.034087	0.034087	0.075748	0.075748	0.113622	0.00766	0.00766	0.01149	0.025533	0.002582
0.101124	0.224719	0.505618	0.168539	0.022724	0.05113	0.017043	0.113622	0.037874	0.085217	0.01149	0.00383	0.008617	0.01915	0.001936
0.111111	0.222222	0.166667	0.5	0.024691	0.018519	0.055556	0.037037	0.111111	0.083333	0.004115	0.012346	0.009259	0.018519	0.002058
0.111111	0.222222	0.333333	0.333333	0.024691	0.037037	0.037037	0.074074	0.074074	0.111111	0.00823	0.00823	0.012346	0.024691	0.002743
0.111111	0.222222	0.5	0.166667	0.024691	0.055556	0.018519	0.111111	0.037037	0.083333	0.012346	0.004115	0.009259	0.018519	0.002058
0.120879	0.21978	0.164835	0.494505	0.026567	0.019925	0.059775	0.036228	0.108683	0.081512	0.004379	0.013137	0.009853	0.017915	0.002166
0.120879	0.21978	0.32967	0.32967	0.026567	0.03985	0.03985	0.072455	0.072455	0.108683	0.008758	0.008758	0.013137	0.023886	0.002887
0.120879	0.21978	0.494505	0.164835	0.026567	0.059775	0.019925	0.108683	0.036228	0.081512	0.013137	0.004379	0.009853	0.017915	0.002166
0.130435	0.217391	0.163043	0.48913	0.028355	0.021267	0.0638	0.035444	0.106333	0.07975	0.004623	0.013869	0.010402	0.017337	0.002261
0.130435	0.217391	0.326087	0.326087	0.028355	0.042533	0.042533	0.070888	0.070888	0.106333	0.009246	0.009246	0.013869	0.023116	0.003015
0.130435	0.217391	0.48913	0.163043	0.028355	0.0638	0.021267	0.106333	0.035444	0.07975	0.013869	0.004623	0.010402	0.017337	0.002261

[for concrete mix proportions from observation point 13-24 [TEST B – MODEL 1]]

z1	z2	z3	z4	z1z2	z1z3	z1z4	z2z3	z2z4	z3z4	z1z2z3	z1z2z4	z1z3z4	z2z3z4	z1z2z3z4
0.07563	0.168067	0.189076	0.567227	0.012711	0.0143	0.0429	0.031777	0.095332	0.107249	0.002403	0.00721	0.008111	0.018025	0.001363
0.07563	0.168067	0.378151	0.378151	0.012711	0.0286	0.0286	0.063555	0.063555	0.142998	0.004807	0.004807	0.010815	0.024033	0.001818
0.07563	0.168067	0.567227	0.189076	0.012711	0.0429	0.0143	0.095332	0.031777	0.107249	0.00721	0.002403	0.008111	0.018025	0.001363
0.083333	0.166667	0.1875	0.5625	0.013889	0.015625	0.046875	0.03125	0.09375	0.105469	0.002604	0.007813	0.008789	0.017578	0.001465
0.083333	0.166667	0.375	0.375	0.013889	0.03125	0.03125	0.0625	0.0625	0.140625	0.005208	0.005208	0.011719	0.023438	0.001953
0.083333	0.166667	0.5625	0.1875	0.013889	0.046875	0.015625	0.09375	0.03125	0.105469	0.007813	0.002604	0.008789	0.017578	0.001465
0.090909	0.165289	0.18595	0.557851	0.015026	0.016905	0.050714	0.030736	0.092207	0.103733	0.002794	0.008382	0.00943	0.017146	0.001559
0.090909	0.165289	0.371901	0.371901	0.015026	0.033809	0.033809	0.061471	0.061471	0.13831	0.005588	0.005588	0.012574	0.022861	0.002078
0.090909	0.165289	0.557851	0.18595	0.015026	0.050714	0.016905	0.092207	0.030736	0.103733	0.008382	0.002794	0.00943	0.017146	0.001559
0.098361	0.163934	0.184426	0.553279	0.016125	0.01814	0.054421	0.030234	0.090701	0.102039	0.002974	0.008921	0.010037	0.016728	0.001645
0.098361	0.163934	0.368852	0.368852	0.016125	0.036281	0.036281	0.060468	0.060468	0.136052	0.005948	0.005948	0.013382	0.022304	0.002194
0.098361	0.163934	0.553279	0.184426	0.016125	0.054421	0.01814	0.090701	0.030234	0.102039	0.008921	0.002974	0.010037	0.016728	0.001645

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Table2:Z matrix values [for concrete mix proportions from observation point 25-36 [TEST C – MODEL 1]]

z1	z2	z3	z4	z1z2	z1z3	z1z4	z2z3	z2z4	z3z4	z1z2z3	z1z2z4	z1z3z4	z2z3z4	z1z2z3z4
0.060403	0.134228	0.201342	0.604027	0.008108	0.012162	0.036485	0.027026	0.081077	0.121616	0.001632	0.004897	0.007346	0.016324	0.000986
0.060403	0.134228	0.402685	0.402685	0.008108	0.024323	0.024323	0.054052	0.054052	0.162155	0.003265	0.003265	0.009795	0.021766	0.001315
0.060403	0.134228	0.604027	0.201342	0.008108	0.036485	0.012162	0.081077	0.027026	0.121616	0.004897	0.001632	0.007346	0.016324	0.000986
0.066667	0.133333	0.2	0.6	0.008889	0.013333	0.04	0.026667	0.08	0.12	0.001778	0.005333	0.008	0.016	0.001067
0.066667	0.133333	0.4	0.4	0.008889	0.026667	0.026667	0.053333	0.053333	0.16	0.003556	0.003556	0.010667	0.021333	0.001422
0.066667	0.133333	0.6	0.2	0.008889	0.04	0.013333	0.08	0.026667	0.12	0.005333	0.001778	0.008	0.016	0.001067
0.072848	0.13245	0.198675	0.596026	0.009649	0.014473	0.043419	0.026315	0.078944	0.118416	0.001917	0.005751	0.008626	0.015684	0.001143
0.072848	0.13245	0.397351	0.397351	0.009649	0.028946	0.028946	0.052629	0.052629	0.157888	0.003834	0.003834	0.011502	0.020912	0.001523
0.072848	0.13245	0.596026	0.198675	0.009649	0.043419	0.014473	0.078944	0.026315	0.118416	0.005751	0.001917	0.008626	0.015684	0.001143
0.078947	0.131579	0.197368	0.592105	0.010388	0.015582	0.046745	0.02597	0.077909	0.116863	0.00205	0.006151	0.009226	0.015377	0.001214
0.078947	0.131579	0.394737	0.394737	0.010388	0.031163	0.031163	0.051939	0.051939	0.155817	0.0041	0.0041	0.012301	0.020502	0.001619
0.078947	0.131579	0.592105	0.197368	0.010388	0.046745	0.015582	0.077909	0.02597	0.116863	0.006151	0.00205	0.009226	0.015377	0.001214

[for concrete mix proportions from observation point 37-48] [TEST D – MODEL 1]

z1	z2	z3	z4	z1z2	z1z3	z1z4	z2z3	z2z4	z3z4	z1z2z3	z1z2z4	z1z3z4	z2z3z4	z1z2z3z4
0.043062	0.095694	0.215311	0.645933	0.004121	0.009272	0.027815	0.020604	0.061812	0.139076	0.000887	0.002662	0.005989	0.013309	0.000573
0.043062	0.095694	0.430622	0.430622	0.004121	0.018544	0.018544	0.041208	0.041208	0.185435	0.001775	0.001775	0.007985	0.017745	0.000764
0.043062	0.095694	0.645933	0.215311	0.004121	0.027815	0.009272	0.061812	0.020604	0.139076	0.002662	0.000887	0.005989	0.013309	0.000573
0.047619	0.095238	0.214286	0.642857	0.004535	0.010204	0.030612	0.020408	0.061224	0.137755	0.000972	0.002915	0.00656	0.01312	0.000625
0.047619	0.095238	0.428571	0.428571	0.004535	0.020408	0.020408	0.040816	0.040816	0.183673	0.001944	0.001944	0.008746	0.017493	0.000833
0.047619	0.095238	0.642857	0.214286	0.004535	0.030612	0.010204	0.061224	0.020408	0.137755	0.002915	0.000972	0.00656	0.01312	0.000625
0.052133	0.094787	0.21327	0.63981	0.004941	0.011118	0.033355	0.020215	0.060646	0.136452	0.001054	0.003162	0.007114	0.012934	0.000674
0.052133	0.094787	0.42654	0.42654	0.004941	0.022237	0.022237	0.04043	0.04043	0.181937	0.002108	0.002108	0.009485	0.017245	0.000899
0.052133	0.094787	0.63981	0.21327	0.004941	0.033355	0.011118	0.060646	0.020215	0.136452	0.003162	0.001054	0.007114	0.012934	0.000674
0.056604	0.09434	0.212264	0.636792	0.00534	0.012015	0.036045	0.020025	0.060075	0.135168	0.001133	0.0034	0.007651	0.012752	0.000722
0.056604	0.09434	0.424528	0.424528	0.00534	0.02403	0.02403	0.04005	0.04005	0.180224	0.002267	0.002267	0.010201	0.017002	0.000962
0.056604	0.09434	0.636792	0.212264	0.00534	0.036045	0.012015	0.060075	0.020025	0.135168	0.0034	0.001133	0.007651	0.012752	0.000722

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Table3:Z matrix values [for concrete mix proportions from observation point 49-60 TEST E MODEL1]

1z	z2	z3	z4	z1z2	z1z3	z1z4	z2z3	z2z4	z3z4	z1z2z3	z1z2z4	z1z3z4	z2z3z4	z1z2z3z4
0.043062	0.095694	0.215311	0.645933	0.004121	0.009272	0.027815	0.020604	0.061812	0.139076	0.000887	0.002662	0.005989	0.013309	0.000573
0.043062	0.095694	0.430622	0.430622	0.004121	0.018544	0.018544	0.041208	0.041208	0.185435	0.001775	0.001775	0.007985	0.017745	0.000764
0.043062	0.095694	0.645933	0.215311	0.004121	0.027815	0.009272	0.061812	0.020604	0.139076	0.002662	0.000887	0.005989	0.013309	0.000573
0.047619	0.095238	0.214286	0.642857	0.004535	0.010204	0.030612	0.020408	0.061224	0.137755	0.000972	0.002915	0.00656	0.01312	0.000625
0.047619	0.095238	0.428571	0.428571	0.004535	0.020408	0.020408	0.040816	0.040816	0.183673	0.001944	0.001944	0.008746	0.017493	0.000833
0.047619	0.095238	0.642857	0.214286	0.004535	0.030612	0.010204	0.061224	0.020408	0.137755	0.002915	0.000972	0.00656	0.01312	0.000625
0.052133	0.094787	0.21327	0.63981	0.004941	0.011118	0.033355	0.020215	0.060646	0.136452	0.001054	0.003162	0.007114	0.012934	0.000674
0.052133	0.094787	0.42654	0.42654	0.004941	0.022237	0.022237	0.04043	0.04043	0.181937	0.002108	0.002108	0.009485	0.017245	0.000899
0.052133	0.094787	0.63981	0.21327	0.004941	0.033355	0.011118	0.060646	0.020215	0.136452	0.003162	0.001054	0.007114	0.012934	0.000674
0.056604	0.09434	0.212264	0.636792	0.00534	0.012015	0.036045	0.020025	0.060075	0.135168	0.001133	0.0034	0.007651	0.012752	0.000722
0.056604	0.09434	0.424528	0.424528	0.00534	0.02403	0.02403	0.04005	0.04005	0.180224	0.002267	0.002267	0.010201	0.017002	0.000962
0.056604	0.09434	0.636792	0.212264	0.00534	0.036045	0.012015	0.060075	0.020025	0.135168	0.0034	0.001133	0.007651	0.012752	0.000722

Table 4:CC matrix values [for concrete mix proportions from observation point 1-12 [TEST A – MODEL 1]]

0.16259	0.307014	0.460521	0.460521	0.0358541	0.0537811	0.0537811	0.101685	0.101685	0.127106	0.011862	0.011862	0.014827	0.02807	0.003271
0.307014	0.586331	0.8794967	0.8794967	0.06779	0.101685	0.101685	0.1944529	0.194453	0.243066	0.022456	0.022456	0.02807	0.053749	0.0062
0.460521	0.879497	1.5391193	1.0993709	0.101685	0.1779487	0.1271062	0.3402926	0.243066	0.364599	0.039298	0.02807	0.042105	0.080624	0.0093
0.460521	0.879497	1.0993709	1.5391193	0.101685	0.1271062	0.1779487	0.2430662	0.340293	0.364599	0.02807	0.039298	0.042105	0.080624	0.0093
0.035854	0.06779	0.101685	0.101685	0.0079077	0.0118615	0.0118615	0.0224559	0.022456	0.02807	0.002617	0.002617	0.003271	0.0062	0.000722
0.053781	0.101685	0.1779487	0.1271062	0.0118615	0.0207576	0.0148269	0.0392978	0.02807	0.042105	0.004579	0.003271	0.004906	0.0093	0.001082
0.053781	0.101685	0.1271062	0.1779487	0.0118615	0.0148269	0.0207576	0.0280698	0.039298	0.042105	0.003271	0.004579	0.004906	0.0093	0.001082
0.101685	0.194453	0.3402926	0.2430662	0.0224559	0.0392978	0.0280698	0.0752487	0.053749	0.080624	0.00868	0.0062	0.0093	0.017831	0.002054
0.101685	0.194453	0.2430662	0.3402926	0.0224559	0.0280698	0.0392978	0.0537491	0.075249	0.080624	0.0062	0.00868	0.0093	0.017831	0.002054
0.127106	0.243066	0.3645993	0.3645993	0.0280698	0.0421047	0.0421047	0.0806236	0.080624	0.102795	0.0093	0.0093	0.011857	0.022735	0.002619
0.011861	0.022456	0.0392978	0.0280698	0.0026165	0.0045788	0.0032706	0.0086797	0.0062	0.0093	0.00101	0.000722	0.001082	0.002054	0.000239
0.011861	0.022456	0.0280698	0.0392978	0.0026165	0.0032706	0.0045788	0.0061998	0.00868	0.0093	0.000722	0.00101	0.001082	0.002054	0.000239
0.014827	0.02807	0.0421047	0.0421047	0.0032706	0.0049059	0.0049059	0.0092997	0.0093	0.011857	0.001082	0.001082	0.00138	0.002619	0.000305
0.02807	0.053749	0.0806236	0.0806236	0.0061998	0.0092997	0.0092997	0.017831	0.017831	0.022735	0.002054	0.002054	0.002619	0.005029	0.000579
0.003271	0.0062	0.0092997	0.0092997	0.0007215	0.0010823	0.0010823	0.0020544	0.002054	0.002619	0.000239	0.000239	0.000305	0.000579	6.72E-05

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Table5:CC matrix values [for concrete mix proportions from observation point 13-24 [TEST B – MODEL 1]]

0.091811	0.173253	0.389818	0.3898182	0.0152124	0.0342279	0.0342279	0.0646528	0.064653	0.121224	0.005672	0.005672	0.010635	0.020107	0.001762
0.173253	0.330658	0.743981	0.743981	0.0287346	0.0646528	0.0646528	0.1235142	0.123514	0.231589	0.010724	0.010724	0.020107	0.038451	0.003335
0.389818	0.743981	1.95295	1.3949643	0.0646528	0.1697136	0.121224	0.3242248	0.231589	0.521076	0.02815	0.020107	0.045241	0.086515	0.007505
0.389818	0.743981	1.394964	1.9529501	0.0646528	0.121224	0.1697136	0.2315892	0.324225	0.521076	0.020107	0.02815	0.045241	0.086515	0.007505
0.015212	0.028735	0.064653	0.0646528	0.0025208	0.0056718	0.0056718	0.0107238	0.010724	0.020107	0.00094	0.00094	0.001762	0.003335	0.000292
0.034228	0.064653	0.169714	0.121224	0.0056718	0.0148885	0.0106346	0.02815	0.020107	0.045241	0.002467	0.001762	0.003965	0.007505	0.000657
0.034228	0.064653	0.121224	0.1697136	0.0056718	0.0106346	0.0148885	0.0201072	0.02815	0.045241	0.001762	0.002467	0.003965	0.007505	0.000657
0.064653	0.123514	0.324225	0.2315892	0.0107238	0.02815	0.0201072	0.0538318	0.038451	0.086515	0.00467	0.003335	0.007505	0.014366	0.001245
0.064653	0.123514	0.231589	0.3242248	0.0107238	0.0201072	0.02815	0.0384513	0.053832	0.086515	0.003335	0.00467	0.007505	0.014366	0.001245
0.121224	0.231589	0.521076	0.5210756	0.0201072	0.0452411	0.0452411	0.0865154	0.086515	0.165461	0.007505	0.007505	0.014353	0.027474	0.002381
0.005672	0.010724	0.02815	0.0201072	0.0009399	0.0024673	0.0017624	0.0046696	0.003335	0.007505	0.000409	0.000292	0.000657	0.001245	0.000109
0.005672	0.010724	0.020107	0.02815	0.0009399	0.0017624	0.0024673	0.0033354	0.00467	0.007505	0.000292	0.000409	0.000657	0.001245	0.000109
0.010635	0.020107	0.045241	0.0452411	0.0017624	0.0039653	0.0039653	0.0075047	0.007505	0.014353	0.000657	0.000657	0.001257	0.002381	0.000208
0.020107	0.038451	0.086515	0.0865154	0.0033354	0.0075047	0.0075047	0.0143656	0.014366	0.027474	0.001245	0.001245	0.002381	0.004562	0.000395
0.001762	0.003335	0.007505	0.0075047	0.0002921	0.0006572	0.0006572	0.001245	0.001245	0.002381	0.000109	0.000109	0.000208	0.000395	3.45E-05

[for concrete mix proportions from observation point 25-36 [TEST C – MODEL 1]]

0.0588972	0.111099	0.3332983	0.3332983	0.0078159	0.0234477	0.0234477	0.0442644	0.044264	0.110661	0.003112	0.003112	0.007779	0.014697	0.001033
0.1110994	0.211953	0.6358598	0.6358598	0.0147548	0.0442644	0.0442644	0.0845136	0.084514	0.211284	0.005879	0.005879	0.014697	0.028084	0.001952
0.3332983	0.63586	2.2255095	1.5896496	0.0442644	0.1549253	0.1106609	0.2957977	0.211284	0.633852	0.020576	0.014697	0.044092	0.084252	0.005856
0.3332983	0.63586	1.5896496	2.2255095	0.0442644	0.1106609	0.1549253	0.2112841	0.295798	0.633852	0.014697	0.020576	0.044092	0.084252	0.005856
0.0078159	0.014755	0.0442644	0.0442644	0.0010373	0.0031118	0.0031118	0.0058789	0.005879	0.014697	0.000413	0.000413	0.001033	0.001952	0.000137
0.0234477	0.044264	0.1549253	0.1106609	0.0031118	0.0108912	0.0077794	0.0205763	0.014697	0.044092	0.001446	0.001033	0.003097	0.005856	0.000411
0.0234477	0.044264	0.1106609	0.1549253	0.0031118	0.0077794	0.0108912	0.0146974	0.020576	0.044092	0.001033	0.001446	0.003097	0.005856	0.000411
0.0442644	0.084514	0.2957977	0.2112841	0.0058789	0.0205763	0.0146974	0.0393173	0.028084	0.084252	0.002733	0.001952	0.005856	0.011199	0.000778
0.0442644	0.084514	0.2112841	0.2957977	0.0058789	0.0146974	0.0205763	0.0280838	0.039317	0.084252	0.001952	0.002733	0.005856	0.011199	0.000778
0.1106609	0.211284	0.6338523	0.6338523	0.0146974	0.0440921	0.0440921	0.0842515	0.084252	0.214841	0.005856	0.005856	0.014934	0.028558	0.001984
0.0031118	0.005879	0.0205763	0.0146974	0.000413	0.0014455	0.0010325	0.002733	0.001952	0.005856	0.000192	0.000137	0.000411	0.000778	5.46E-05
0.0031118	0.005879	0.0146974	0.0205763	0.000413	0.0010325	0.0014455	0.0019521	0.002733	0.005856	0.000137	0.000192	0.000411	0.000778	5.46E-05
0.0077794	0.014697	0.0440921	0.0440921	0.0010325	0.0030974	0.0030974	0.0058564	0.005856	0.014934	0.000411	0.000411	0.001048	0.001984	0.000139
0.0146974	0.028084	0.0842515	0.0842515	0.0019521	0.0058564	0.0058564	0.0111993	0.011199	0.028558	0.000778	0.000778	0.001984	0.003796	0.000264
0.0010325	0.001952	0.0058564	0.0058564	0.000137	0.0004111	0.0004111	0.0007779	0.000778	0.001984	5.46E-05	5.46E-05	0.000139	0.000264	1.85E-05

Table6:CC matrix values [for concrete mix proportions from observation point 37-48 [TEST D – MODEL 1]]

0.0409654	0.077254	0.2897038	0.2897038	0.0045337	0.0170014	0.0170014	0.0320826	0.032083	0.100258	0.001882	0.001882	0.00588	0.011103	0.000651
0.0772543	0.147346	0.5525455	0.5525455	0.0085554	0.0320826	0.0320826	0.0612309	0.061231	0.191347	0.003553	0.003553	0.011103	0.021205	0.00123
0.2897038	0.552546	2.4173868	1.7267048	0.0320826	0.1403615	0.1002582	0.2678853	0.191347	0.71755	0.015545	0.011103	0.041637	0.079519	0.004611
0.2897038	0.552546	1.7267048	2.4173868	0.0320826	0.1002582	0.1403615	0.1913467	0.267885	0.71755	0.011103	0.015545	0.041637	0.079519	0.004611
0.0045337	0.008555	0.0320826	0.0320826	0.0005018	0.0018816	0.0018816	0.0035531	0.003553	0.011103	0.000208	0.000208	0.000651	0.00123	7.20E-05
0.0170014	0.032083	0.1403615	0.1002582	0.0018816	0.0082321	0.0058801	0.0155446	0.011103	0.041637	0.000911	0.000651	0.002441	0.004611	0.00027
0.0170014	0.032083	0.1002582	0.1403615	0.0018816	0.0058801	0.0082321	0.0111033	0.015545	0.041637	0.000651	0.000911	0.002441	0.004611	0.00027
0.0320826	0.061231	0.2678853	0.1913467	0.0035531	0.0155446	0.0111033	0.0296871	0.021205	0.079519	0.001722	0.00123	0.004611	0.008813	0.000511
0.0320826	0.061231	0.1913467	0.2678853	0.0035531	0.0111033	0.0155446	0.0212051	0.029687	0.079519	0.00123	0.001722	0.004611	0.008813	0.000511
0.1002582	0.191347	0.71755	0.71755	0.0111033	0.0416374	0.0416374	0.0795191	0.079519	0.253467	0.004611	0.004611	0.014699	0.02809	0.001628
0.0018816	0.003553	0.0155446	0.0111033	0.0002083	0.0009111	0.0006508	0.0017216	0.00123	0.004611	0.000101	7.20E-05	0.00027	0.000511	2.99E-05
0.0018816	0.003553	0.0111033	0.0155446	0.0002083	0.0006508	0.0009111	0.0012297	0.001722	0.004611	7.20E-05	0.000101	0.00027	0.000511	2.99E-05
0.0058801	0.011103	0.0416374	0.0416374	0.0006508	0.0024405	0.0024405	0.0046114	0.004611	0.014699	0.00027	0.00027	0.000861	0.001628	9.53E-05
0.0111033	0.021205	0.0795191	0.0795191	0.0012297	0.0046114	0.0046114	0.0088127	0.008813	0.02809	0.000511	0.000511	0.001628	0.003113	0.00018
0.0006508	0.00123	0.0046114	0.0046114	7.20E-05	0.0002701	0.0002701	0.0005107	0.000511	0.001628	2.99E-05	2.99E-05	9.53E-05	0.00018	1.05E-05

[for concrete mix proportions from observation point 49-60 [TEST E – MODEL 1]]

0.0301312	0.056812	0.2556549	0.2556549	0.0028599	0.0128694	0.0128694	0.0242786	0.024279	0.091045	0.001222	0.001222	0.004581	0.008646	0.000435
0.0568122	0.108336	0.4875131	0.4875131	0.0053952	0.0242786	0.0242786	0.0463235	0.046324	0.173713	0.002306	0.002306	0.008646	0.016507	0.000821
0.2556549	0.487513	2.5594439	1.8281742	0.0242786	0.1274624	0.0910446	0.2431981	0.173713	0.781708	0.012105	0.008646	0.038909	0.07428	0.003695
0.2556549	0.487513	1.8281742	2.5594439	0.0242786	0.0910446	0.1274624	0.173713	0.243198	0.781708	0.0086464	0.012105	0.038909	0.07428	0.003695
0.0028599	0.005395	0.0242786	0.0242786	0.0002714	0.0012215	0.0012215	0.0023057	0.002306	0.008646	0.000116	0.000116	0.000435	0.000821	4.13E-05
0.0128694	0.024279	0.1274624	0.0910446	0.0012215	0.0064129	0.0045807	0.0121049	0.008646	0.038909	0.000609	0.000435	0.001957	0.003695	0.000186
0.0128694	0.024279	0.0910446	0.1274624	0.0012215	0.0045807	0.0064129	0.0086464	0.012105	0.038909	0.000435	0.000609	0.001957	0.003695	0.000186
0.0242786	0.046324	0.2431982	0.173713	0.0023057	0.0121049	0.0086464	0.0231093	0.016507	0.07428	0.00115	0.000821	0.003695	0.007059	0.000351
0.0242786	0.046324	0.173713	0.2431981	0.0023057	0.0086464	0.0121049	0.0165067	0.023109	0.07428	0.000821	0.00115	0.003695	0.007059	0.000351
0.0910446	0.173713	0.7817083	0.7817083	0.0086464	0.0389088	0.0389088	0.07428	0.07428	0.284121	0.003695	0.003695	0.014134	0.026999	0.001342
0.0012215	0.002306	0.012105	0.0086464	0.0001159	0.0006087	0.0004348	0.0011496	0.000821	0.003695	5.78E-05	4.13E-05	0.000186	0.000351	1.76E-05
0.0012215	0.002306	0.0086464	0.0121049	0.0001159	0.0004348	0.0006087	0.0008212	0.00115	0.003695	4.13E-05	5.78E-05	0.000186	0.000351	1.76E-05
0.0045807	0.008646	0.0389088	0.0389088	0.0004348	0.0019566	0.0019566	0.0036952	0.003695	0.014134	0.000186	0.000186	0.00071	0.001342	6.74E-05
0.0086464	0.016507	0.07428	0.07428	0.0008212	0.0036952	0.0036952	0.0070585	0.007059	0.026999	0.000351	0.000351	0.001342	0.002566	0.000128
0.0004348	0.000821	0.0036952	0.0036952	4.13E-05	0.0001857	0.0001857	0.000351	0.000351	0.001342	1.76E-05	1.76E-05	6.74E-05	0.000128	6.40E-06

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Table7:CC matrix inverse values [for concrete mix proportions from observation point 1-12[TEST A – MODEL 1]]

-75093.6	-1408964	650598.58	650598.57	1380913.1	-267308.7	-267308.7	-713725.6	-713725.6	-269676	-1266969	-1266969	481015.4	1092631	-1077555
566431.3	-1.20E+08	62097133	62097133	-44686397	3702545.6	3702545.9	-83762920	-83762919	-1.40E+07	-56284668	-56284668	48260023	58544516	-1.71E+08
3140805	-3.20E+09	1.611E+09	1.68E+09	-825870375	72614281	-76063259	-2.10E+09	-2.40E+09	-3.90E+08	-1.72E+09	-1.33E+09	1.31E+09	1.62E+09	-4.63E+09
3140805	-3.20E+09	1.684E+09	1.61E+09	-825870377	-76063268	72614289	-2.40E+09	-2.10E+09	-3.90E+08	-1.33E+09	-1.72E+09	1.31E+09	1.62E+09	-4.63E+09
1.64E+08	-2.00E+10	1.03E+10	1.03E+10	-1.02E+10	1.349E+09	1.35E+09	-1.43E+10	-1.43E+10	-2.30E+09	-9.44E+09	-9.44E+09	8.09E+09	9.71E+09	-2.87E+10
-4.80E+07	9.87E+09	-4.97E+09	-5.12E+09	4.114E+09	-534882180	-3.32E+08	6.66E+09	7.25E+09	1.17E+09	4.77E+09	4.50E+09	-3.98E+09	-4.82E+09	1.41E+10
-4.80E+07	9.87E+09	-5.12E+09	-4.97E+09	4.114E+09	-332434662	-5.35E+08	7.25E+09	6.66E+09	1.17E+09	4.50E+09	4.77E+09	-3.98E+09	-4.82E+09	1.41E+10
-1.30E+07	1.31E+10	-6.53E+09	-6.82E+09	3.359E+09	-296722726	301645097	8.50E+09	9.71E+09	1.59E+09	6.95E+09	5.40E+09	-5.32E+09	-6.56E+09	1.88E+10
-1.30E+07	1.31E+10	-6.82E+09	-6.53E+09	3.359E+09	301645134	-2.97E+08	9.71E+09	8.50E+09	1.59E+09	5.40E+09	6.95E+09	-5.32E+09	-6.56E+09	1.88E+10
1198676	-4.50E+09	2.262E+09	2.26E+09	-1.308E+09	92834134	92834147	-3.00E+09	-3.00E+09	-5.00E+08	-2.15E+09	-2.15E+09	1.77E+09	2.06E+09	-6.39E+09
-5.20E+07	5.47E+08	-457299624	-69052251	589577959	64527502	-2.11E+08	1.09E+09	-4.58E+08	61169139	5.20E+08	-58307686	-2.23E+08	-2.52E+08	7.93E+08
-5.20E+07	5.47E+08	-69052225	-4.57E+08	589577948	-210627355	64527499	-4.58E+08	1.09E+09	61169133	-58307714	5.20E+08	-2.23E+08	-2.52E+08	7.93E+08
-1.40E+07	2.82E+09	-1.38E+09	-1.37E+09	1.163E+09	-185071862	-1.85E+08	1.72E+09	1.72E+09	3.39E+08	1.32E+09	1.32E+09	-1.14E+09	-1.40E+09	4.03E+09
-5290673	1.78E+10	-8.95E+09	-8.95E+09	5.188E+09	-373954047	-3.74E+08	1.19E+10	1.19E+10	1.96E+09	8.52E+09	8.52E+09	-7.00E+09	-8.14E+09	2.53E+10
62819562	9.35E+09	-4.89E+09	-4.89E+09	1.019E+09	440263043	440263015	7.05E+09	7.05E+09	8.90E+08	4.59E+09	4.59E+09	-3.49E+09	-3.72E+09	1.31E+10

[for concrete mix proportions from observation point 13-24 [TEST B – MODEL 1]]

194307.85	62368.38	-265635	98002.799	-742736.57	130216.42	-391034	1396905.9	-610911.6	58992.82	18470.37	1058682	20797	-324263	-483281.1
-132310.1	-1485204	-10204.5	193873.75	1483689	54315.598	-238217.2	1855024.2	728209.7	-8095.91	993208.3	1576989	91434.8	55186.33	-625381.5
-186083.4	-775145	-420889	75324.528	1500656.6	490705.5	-220584.9	3247731.2	507894	-22045.5	277964.2	1697421	-106798	123724.8	748043.5
-19002776	-7.90E+07	13482117	-48771085	153246537	-30825646	58410268	19896564	3.64E+08	-2251278	1.90E+08	11822876	-10906176	12634738	76389942
45767822	6.40E+08	2.53E+08	-76327863	-1.182E+09	-78075167	394208660	-2.17E+09	-3.46E+08	1.91E+08	-8.11E+08	-1.75E+09	-1.08E+08	-1.05E+09	-4.86E+08
1570920.2	-2.00E+08	-5.70E+07	10251590	313900741	2679215.9	-1.15E+08	552685129	1.79E+08	-4.10E+07	1.75E+08	5.06E+08	15254487	2.24E+08	1.47E+08
30397861	-7.60E+07	-7.30E+07	79519085	81427927	21685372	-1.76E+08	495427721	-3.46E+08	-3.70E+07	38679914	3.37E+08	31799001	2.05E+08	31449062
1724186.8	3307570	2210420	-1025337	-6955101.9	-3573992.3	37507.955	-16041967	1767116	182859	-2636080	-5045120	376709.6	-1194006	-1220350
105712517	4.36E+08	-7.40E+07	268641962	-845561584	168068668	-3.23E+08	-1.10E+08	-2.00E+09	12502461	-1.04E+09	-68641399	60058255	-70334707	-4.19E+08
-6044272	61665052	-5.50E+07	-7833970	216075075	10077696	-56836851	224430852	-33318950	-3.10E+07	-54973979	78561257	37265602	1.72E+08	-46883016
-77267244	3.60E+08	12216861	43259486	-350232080	93682762	187579136	-5.12E+08	-6.76E+08	-1.30E+07	27709586	-7.97E+08	53642393	70176238	-2.61E+08
-1.43E+08	84557056	24295891	-91513504	182581013	174778916	202390192	-2.44E+08	3.89E+08	-2.00E+07	-3.25E+08	2.57E+08	15723405	1.14E+08	4318746
8395804	1.43E+08	85615677	-40017953	-290775045	-74200085	105887550	-6.45E+08	48835779	56571938	55297478	-3.04E+08	-60474818	-3.15E+08	63119994
33710273	-3.30E+08	3.01E+08	41109299	-1.196E+09	-57821471	315336529	-1.26E+09	1.81E+08	1.73E+08	3.00E+08	-4.44E+08	-2.08E+08	-9.55E+08	2.57E+08
-19557296	-1.40E+09	-2.10E+08	311257512	535462635	414139845	-3.27E+08	2.79E+09	-68824300	-1.70E+08	23022344	1.50E+09	1.78E+08	9.46E+08	-91018747

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Table8:CC matrix inverse values [for concrete mix proportions from observation point 25-36 [TEST C – MODEL 1]

35427676	83923709	-17376994	-17376996	-117478633	-17131834	-17131831	25680217	25680225	-7641928	-60883978	-60883988	-1898919.2	52772675	82206107
-740136.6	9816001.2	-1294729.1	-1294729.2	-12276619	3881503.4	3881503.6	-2375240.5	-2375239.9	-269457.36	-9591699.6	-9591700.5	-1324700.5	1816891.3	12999588
-4980259.3	-17602023	147029890	-148598832	-53674253	-298653319	325860047	-1.016E+09	1.067E+09	11141755	1.377E+09	-1.283E+09	6687283.4	-77201618	-145613875
-4980259.4	-17602023	-148598833	147029890	-53674254	325860049	-298653320	1.067E+09	-1.016E+09	11141755	-1.283E+09	1.377E+09	6687283.5	-77201619	-145613878
-9411518.6	-41191733	-70255468	-70255462	2.197E+09	-376080610	-376080622	535362480	535362440	192724517	809160144	809160202	144513978	-1.335E+09	-2.743E+09
-39958608	-1.37E+08	-273572165	350941203	-187970418	856103018	-683563100	2.092E+09	-2.315E+09	-22867809	-3.838E+09	3.564E+09	-41981045	158128571	516240697
-39958608	-1.37E+08	350941202	-273572164	-187970415	-683563099	856103016	-2.315E+09	2.092E+09	-22867810	3.564E+09	-3.838E+09	-41981045	158128574	516240704
37418641	113647414	-1.035E+09	1.047E+09	383259143	2.104E+09	-2.304E+09	7.159E+09	-7.506E+09	-77607562	-9.722E+09	9.083E+09	-45528642	537563356	1.009E+09
37418642	113647417	1.047E+09	-1.035E+09	383259152	-2.304E+09	2.104E+09	-7.506E+09	7.159E+09	-77607564	9.083E+09	-9.722E+09	-45528643	537563367	1.009E+09
3968214.1	-1.23E+08	26938295	26938295	345958139	-75444542	-75444542	-44621932	-44621933	-7461727.7	49179138	49179139	35856600	53291104	-228994767
-7999147.5	386217140	1.309E+09	-1.352E+09	285877904	-3.819E+09	3.582E+09	-9.705E+09	9.1E+09	-82027442	1.949E+10	-1.886E+10	107773283	575349876	-210500049
-7999148.7	386217137	-1.352E+09	1.309E+09	285877893	3.582E+09	-3.819E+09	9.1E+09	-9.705E+09	-82027440	-1.886E+10	1.949E+10	107773285	575349861	-210500077
1783457.5	101369888	-9058837.9	-9058839.6	12174324	-20437073	-20437070	-54720686	-54720674	16417327	60840990	60840974	-21752994	-117349003	75121495
-27872903	863539017	-187844245	-187844245	-2.407E+09	525023439	525023440	307571782	307571786	52431562	-339943601	-339943605	-252649376	-373212518	1.597E+09
-41928111	172303271	-145029838	-145029824	-2.904E+09	766314424	766314396	816745085	816744992	-70269758	-890343676	-890343552	-82378184	484786865	1.251E+09

[for concrete mix proportions from observation point 37-48 [TEST D – MODEL 1]]

2830279	-33506262	4522132.9	4522132.9	1698808	-3856287.5	-3856287.5	-350329.26	-350329.29	-2492933.7	-452802.84	-452802.86	571215.1	21068203	19452012
5943381.9	7.33E+09	-987215336	-987215337	-2.821E+09	787672782	787672782	96113960	96113964	370816373	-3.897E+09	-3.897E+09	-7788793.6	-3.133E+09	-3.613E+09
-46493934	-446292997	69802327	72722413	278217214	-23340156	-45839878	-90327292	-115777442	-925471.26	336639770	524282543	1792353.1	7880640.5	-8065519.8
-46493934	-446292997	72722413	69802327	278217214	-45839878	-23340156	-115777442	-90327292	-925471.28	524282542	336639770	1792353.1	7880640.6	-8065519.6
64780266	-3.591E+09	409628008	409628008	2.874E+09	-508630974	-508630974	587665960	587665958	-251207398	1.065E+09	1.065E+09	102956687	2.127E+09	1.474E+09
83273864	-190067049	46363754	23864032	-370383959	-91584166	-50692446	-176039918	15816828	-21109396	132213572	-44355508	-35386173	177166418	549164720
83273863	-190067048	23864032	46363754	-370383959	-50692445	-91584166	15816828	-176039919	-21109396	-44355507	132213572	-35386173	177166417	549164719
390285416	-4.524E+09	527503790	502053640	829943958	-697500691	-505643944	653319293	874983821	-413014040	1.559E+09	-35242748	-6526544.6	3.488E+09	4.175E+09
390285416	-4.524E+09	502053639	527503790	829943959	-505643945	-697500691	874983823	653319290	-413014040	-35242741	1.559E+09	-6526544.6	3.488E+09	4.175E+09
-40321777	853400758	-106302619	-106302619	-218350584	107177809	107177809	-64256352	-64256352	60039959	-323059851	-323059851	-31786268	-507864012	-297802142
-4.79E+08	1.78E+09	-436828002	-249185230	787780921	798774288	622205209	1.681E+09	86541438	92781255	-886223012	-992862016	184592252	-775624881	-2.729E+09
-4.79E+08	1.78E+09	-249185230	-436828002	787780918	622205208	798774288	86541439	1.681E+09	92781254	-992862016	-886223021	184592252	-775624874	-2.729E+09
42578276	-513051294	79206158	79206158	115439152	-110206134	-110206134	-90565376	-90565376	-61151717	274541683	274541682	48552338	515705013	184256944
342074402	-7.226E+09	900530998	900530998	1.851E+09	-908792929	-908792929	540606907	540606903	-509016339	2.739E+09	2.739E+09	267796685	4.307E+09	2.514E+09
-8983544	-3.547E+09	297125496	297125496	1.023E+09	-10921774	-10921774	1.494E+09	1.494E+09	-12764844	567491556	567491557	-110189184	96449869	1.318E+09

Table 9:CC matrix inverse values [for concrete mix proportions from observation point 49-60]

78266127	-2.03E+08	-1211285.7	36533105	237498072	-20193676	-177431975	241992808	-138694703	9101385.4	-874033722	449377763	-17804401	-92376199	118994036
1167862.9	-6100094	679242	904187.02	-3911341.3	-226553.39	-1163645.6	47133.012	-2221648.1	-527634.88	-8680620.3	-793492.7	-586350.35	5216358	12935836
24073817	-75811029	5419516.9	3431513	19901260	-33457969	-25176199	30683159	50734040	7141280	51131141	-18573183	-4619127.7	-71586288	-23083253
-3053997.3	9617364.9	384621.83	-1507460.9	-2524668	-221930.6	7660243.9	-14705994	4377431.8	-905940.69	31105399	-35235692	585981.18	9081415.6	2928334.7
67045579	182721529	87812574	41505469	-1.296E+09	-124677693	68231779	-1.081E+09	-614213064	-96430391	867323929	-756317452	79645006	963929065	184446525
-53886124	152825320	-76583174	16432268	-159011680	147096421	692260.28	594223657	-337355175	17984792	-35169651	555619778	-3302499.9	-178006153	-191628175
-189886060	581103695	43184349	-153337277	-271439637	-49283836	528313846	-1.089E+09	886227423	-22358359	2.278E+09	-1.942E+09	22792285	226405444	-61224221
-237624291	754916905	-56742121	-32393474	-187070949	336093469	241229096	-277545883	-522960669	-69825588	-554400234	226853441	46281447	699680579	219336082
29228275	-85430423	-3279051.3	12255030	33529807	-670673.01	-71952642	129411856	-27428010	9333811.9	-291891378	325241846	-4920491.2	-93836498	-36536315
-12067227	41012053	-1398368.5	922812.11	73325463	7784807.2	-1884934.3	-31889480	-55300760	-3204335.6	-46245474	35140848	-12638714	31924367	169238673
-818754930	1.68E+09	696736742	-767654403	-92529459	-827022696	2.603E+09	-8.886E+09	5.811E+09	-283378602	1.065E+10	-1.111E+10	221535584	2.841E+09	506143939
987857093	-4.01E+09	-573937564	1.167E+09	1.401E+09	979324477	-3.604E+09	1.026E+10	-7.227E+09	252536515	-1.474E+10	1.673E+10	-125105403	-2.531E+09	-1.226E+09
39570192	-1.65E+08	1007720.2	30085968	74576193	-3978911.9	-125115169	176579813	-116701534	-13382486	-405915270	613639856	34125206	130855813	-158705160
121177383	-4.15E+08	14255445	-8042069.4	-730373775	-76910010	15978584	321381961	546273273	31407176	451366674	-330439236	123901004	-311091549	-1.695E+09
-299741523	1.41E+09	-1360542.6	-350358865	-1.615E+09	-58937077	1.395E+09	-1.573E+09	1.946E+09	187477708	4.984E+09	-7.253E+09	-176226237	-1.878E+09	-55612818

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Table10:Z matrix values [for concrete mix proportions from observation point 1-12] [TEST A – MODEL 2]

z1	z2	z3	z12	z13	z23	z123	z1z1	z2z2	z3z3	z112	z113	z122	z133	z223	z233	z1122	z1133	z2233	z11223	z11233	z12233	z112233
0.130435	0.217391	0.652174	0.028355	0.085066	0.141777	0.018493	0.017013	0.047259	0.425331	0.003699	0.011096	0.006164	0.055478	0.030821	0.092463	0.000804	0.007236	0.020101	0.00052437	0.001573	0.002622	0.000342
0.130435	0.434783	0.434783	0.056711	0.056711	0.189036	0.024657	0.017013	0.189036	0.189036	0.007397	0.007397	0.024657	0.024657	0.08219	0.08219	0.0032161	0.003216	0.035735	0.00139831	0.001398	0.004661	0.000608
0.130435	0.652174	0.217391	0.085066	0.028355	0.141777	0.018493	0.017013	0.425331	0.047259	0.011096	0.003699	0.055478	0.006164	0.092463	0.030821	0.0072363	0.000804	0.020101	0.0015731	0.000524	0.002622	0.000342
0.142857	0.214286	0.642857	0.030612	0.091837	0.137755	0.019679	0.020408	0.045918	0.413265	0.004373	0.01312	0.00656	0.059038	0.029519	0.088557	0.0009371	0.008434	0.018976	0.00060243	0.001807	0.002711	0.000387
0.142857	0.428571	0.428571	0.061224	0.061224	0.183673	0.026239	0.020408	0.183673	0.183673	0.008746	0.008746	0.026239	0.026239	0.078717	0.078717	0.0037484	0.003748	0.033736	0.00160647	0.001606	0.004819	0.000688
0.142857	0.642857	0.214286	0.091837	0.030612	0.137755	0.019679	0.020408	0.413265	0.045918	0.01312	0.004373	0.059038	0.00656	0.088557	0.029519	0.008434	0.000937	0.018976	0.00180728	0.000602	0.002711	0.000387
0.15493	0.211268	0.633803	0.032732	0.098195	0.133902	0.020745	0.024003	0.044634	0.401706	0.005071	0.015213	0.006915	0.062236	0.028289	0.084867	0.0010714	0.009642	0.01793	0.00067903	0.002037	0.002778	0.00043
0.15493	0.422535	0.422535	0.065463	0.065463	0.178536	0.027661	0.024003	0.178536	0.178536	0.010142	0.010142	0.027661	0.027661	0.075438	0.075438	0.0042854	0.004285	0.031875	0.00181075	0.001811	0.004938	0.000765
0.15493	0.633803	0.211268	0.098195	0.032732	0.133902	0.020745	0.024003	0.401706	0.044634	0.015213	0.005071	0.062236	0.006915	0.084867	0.028289	0.0096422	0.001071	0.01793	0.00203709	0.000679	0.002778	0.00043
0.166667	0.208333	0.625	0.034722	0.104167	0.130208	0.021701	0.027778	0.043403	0.390625	0.005787	0.017361	0.007234	0.065104	0.027127	0.08138	0.0012056	0.010851	0.016954	0.00075352	0.002261	0.002826	0.000471
0.166667	0.416667	0.416667	0.069444	0.069444	0.173611	0.028935	0.027778	0.173611	0.173611	0.011574	0.011574	0.028935	0.028935	0.072338	0.072338	0.0048225	0.004823	0.030141	0.00200939	0.002009	0.005023	0.000837
0.166667	0.625	0.208333	0.104167	0.034722	0.130208	0.021701	0.027778	0.390625	0.043403	0.017361	0.005787	0.065104	0.007234	0.08138	0.027127	0.0108507	0.001206	0.016954	0.00226056	0.000754	0.002826	0.000471

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[for concrete mix proportions from observation point 12-24] [TEST B – MODEL 2]

z1	z2	z3	z12	z13	z23	z123	z1z1	z2z2	z3z3	z112	z113	z122	z133	z223	z233	z1122	z1133	z2233	z11223	z11233	z12233	z112233
0.090909	0.227273	0.681818	0.020661	0.061983	0.154959	0.014087	0.008264	0.051653	0.464876	0.001878	0.005635	0.004696	0.042261	0.035218	0.105654	0.0004269	0.003842	0.024012	0.00029106	0.000873	0.002183	0.000198
0.090909	0.454545	0.454545	0.041322	0.041322	0.206612	0.018783	0.008264	0.206612	0.206612	0.003757	0.003757	0.018783	0.018783	0.093914	0.093914	0.0017075	0.001708	0.042688	0.00077615	0.000776	0.003881	0.000353
0.090909	0.681818	0.227273	0.061983	0.020661	0.154959	0.014087	0.008264	0.464876	0.051653	0.005635	0.001878	0.042261	0.004696	0.105654	0.035218	0.003842	0.000427	0.024012	0.00087317	0.000291	0.002183	0.000198
0.1	0.225	0.675	0.0225	0.0675	0.151875	0.015188	0.01	0.050625	0.455625	0.00225	0.00675	0.005063	0.045563	0.034172	0.102516	0.0005063	0.004556	0.023066	0.00034172	0.001025	0.002307	0.000231
0.1	0.45	0.45	0.045	0.045	0.2025	0.02025	0.01	0.2025	0.2025	0.0045	0.0045	0.02025	0.02025	0.091125	0.091125	0.002025	0.002025	0.041006	0.00091125	0.000911	0.004101	0.00041
0.1	0.675	0.225	0.0675	0.0225	0.151875	0.015188	0.01	0.455625	0.050625	0.00675	0.00225	0.045563	0.005063	0.102516	0.034172	0.0045563	0.000506	0.023066	0.00102516	0.000342	0.002307	0.000231
0.108911	0.222772	0.668317	0.024262	0.072787	0.148882	0.016215	0.011862	0.049627	0.446647	0.002642	0.007927	0.005405	0.048645	0.033167	0.099501	0.0005887	0.005298	0.022166	0.00039341	0.00118	0.002414	0.000263
0.108911	0.445545	0.445545	0.048525	0.048525	0.19851	0.02162	0.011862	0.19851	0.19851	0.005285	0.005285	0.02162	0.02162	0.088445	0.088445	0.0023546	0.002355	0.039406	0.0010491	0.001049	0.004292	0.000467
0.108911	0.668317	0.222772	0.072787	0.024262	0.148882	0.016215	0.011862	0.446647	0.049627	0.007927	0.002642	0.048645	0.005405	0.099501	0.033167	0.0052979	0.000589	0.022166	0.00118024	0.000393	0.002414	0.000263
0.117647	0.220588	0.661765	0.025952	0.077855	0.145978	0.017174	0.013841	0.048659	0.437933	0.003053	0.009159	0.005725	0.051521	0.032201	0.096603	0.0006735	0.006061	0.021309	0.00044569	0.001337	0.002507	0.000295
0.117647	0.441176	0.441176	0.051903	0.051903	0.194637	0.022898	0.013841	0.194637	0.194637	0.006106	0.006106	0.022898	0.022898	0.085869	0.085869	0.0026939	0.002694	0.037883	0.0011885	0.001188	0.004457	0.000524
0.117647	0.661765	0.220588	0.077855	0.025952	0.145978	0.017174	0.013841	0.437933	0.048659	0.009159	0.003053	0.051521	0.005725	0.096603	0.032201	0.0060613	0.000673	0.021309	0.00133706	0.000446	0.002507	0.000295

Table11:Z matrix values

[for concrete mix proportions from observation point 25-36] [TEST C – MODEL 2]

z1	z2	z3	z12	z13	z23	z123	z1z1	z2z2	z3z3	z112	z113	z122	z133	z223	z233	z1122	z1133	z2233	z11223	z11233	z12233	z112233
0.069767	0.232558	0.697674	0.016225	0.048675	0.16225	0.01132	0.004867	0.054083	0.48675	0.001132	0.003396	0.003773	0.033959	0.037733	0.113198	0.000263	0.002369	0.026325	0.0001837	0.000551	0.001837	0.00012814
0.069767	0.465116	0.465116	0.03245	0.03245	0.216333	0.015093	0.004867	0.216333	0.216333	0.002264	0.002264	0.015093	0.015093	0.10062	0.10062	0.001053	0.001053	0.0468	0.0004898	0.00049	0.003265	0.0002278
0.069767	0.697674	0.232558	0.048675	0.016225	0.16225	0.01132	0.004867	0.48675	0.054083	0.003396	0.001132	0.033959	0.003773	0.113198	0.037733	0.002369	0.000263	0.026325	0.000551	0.000184	0.001837	0.00012814
0.076923	0.230769	0.692308	0.017751	0.053254	0.159763	0.012289	0.005917	0.053254	0.47929	0.001365	0.004096	0.004096	0.036868	0.036868	0.110605	0.000315	0.002836	0.025524	0.0002182	0.000654	0.001963	0.00015103
0.076923	0.461538	0.461538	0.035503	0.035503	0.213018	0.016386	0.005917	0.213018	0.213018	0.002731	0.002731	0.016386	0.016386	0.098316	0.098316	0.00126	0.00126	0.045377	0.0005818	0.000582	0.003491	0.0002685
0.076923	0.692308	0.230769	0.053254	0.017751	0.159763	0.012289	0.005917	0.47929	0.053254	0.004096	0.001365	0.036868	0.004096	0.110605	0.036868	0.002836	0.000315	0.025524	0.0006545	0.000218	0.001963	0.00015103
0.083969	0.229008	0.687023	0.01923	0.057689	0.157333	0.013211	0.007051	0.052444	0.472	0.001615	0.004844	0.004404	0.039634	0.036031	0.108092	0.00037	0.003328	0.024754	0.000254	0.000762	0.002079	0.00017454
0.083969	0.458015	0.458015	0.038459	0.038459	0.209778	0.017615	0.007051	0.209778	0.209778	0.003229	0.003229	0.017615	0.017615	0.096082	0.096082	0.001479	0.001479	0.044007	0.0006775	0.000677	0.003695	0.00031029
0.083969	0.687023	0.229008	0.057689	0.01923	0.157333	0.013211	0.007051	0.472	0.052444	0.004844	0.001615	0.039634	0.004404	0.108092	0.036031	0.003328	0.00037	0.024754	0.0007621	0.000254	0.002079	0.00017454
0.090909	0.227273	0.681818	0.020661	0.061983	0.154959	0.014087	0.008264	0.051653	0.464876	0.001878	0.005635	0.004696	0.042261	0.035218	0.105654	0.000427	0.003842	0.024012	0.0002911	0.000873	0.002183	0.00019845
0.090909	0.454545	0.454545	0.041322	0.041322	0.206612	0.018783	0.008264	0.206612	0.206612	0.003757	0.003757	0.018783	0.018783	0.093914	0.093914	0.001708	0.001708	0.042688	0.0007762	0.000776	0.003881	0.0003528
0.090909	0.681818	0.227273	0.061983	0.020661	0.154959	0.014087	0.008264	0.464876	0.051653	0.005635	0.001878	0.042261	0.004696	0.105654	0.035218	0.003842	0.000427	0.024012	0.0008732	0.000291	0.002183	0.00019845

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[for concrete mix proportions from observation point 37-48] [TEST D – MODEL 2]

z1	z2	z3	z12	z13	z23	z123	z1z1	z2z2	z3z3	z112	z113	z122	z133	z223	z233	z1122	z1133	z2233	z11223	z11233	z12233	z112233
0.056604	0.235849	0.707547	0.01335	0.04005	0.166874	0.009446	0.003204	0.055625	0.500623	0.000756	0.002267	0.003149	0.028337	0.039357	0.118071	0.000178	0.001604	0.027847	0.0001261	0.000378	0.001576	8.922E-05
0.056604	0.471698	0.471698	0.0267	0.0267	0.222499	0.012594	0.003204	0.222499	0.222499	0.001511	0.001511	0.012594	0.012594	0.104952	0.104952	0.000713	0.000713	0.049506	0.0003363	0.000336	0.002802	1.586E-04
0.056604	0.707547	0.235849	0.04005	0.01335	0.166874	0.009446	0.003204	0.500623	0.055625	0.002267	0.000756	0.028337	0.003149	0.118071	0.039357	0.001604	0.000178	0.027847	0.0003783	0.000126	0.001576	8.922E-05
0.0625	0.234375	0.703125	0.014648	0.043945	0.164795	0.0103	0.003906	0.054932	0.494385	0.000916	0.002747	0.003433	0.030899	0.038624	0.115871	0.000215	0.001931	0.027157	0.0001509	0.000453	0.001697	1.061E-04
0.0625	0.46875	0.46875	0.029297	0.029297	0.219727	0.013733	0.003906	0.219727	0.219727	0.001831	0.001831	0.013733	0.013733	0.102997	0.102997	0.000858	0.000858	0.04828	0.0004023	0.000402	0.003017	1.886E-04
0.0625	0.703125	0.234375	0.043945	0.014648	0.164795	0.0103	0.003906	0.494385	0.054932	0.002747	0.000916	0.030899	0.003433	0.115871	0.038624	0.001931	0.000215	0.027157	0.0004526	0.000151	0.001697	1.061E-04
0.068323	0.232919	0.698758	0.015914	0.047741	0.162754	0.01112	0.004668	0.054251	0.488262	0.001087	0.003262	0.003707	0.03336	0.037909	0.113726	0.000253	0.002279	0.026489	0.000177	0.000531	0.00181	1.237E-04
0.068323	0.465839	0.465839	0.031827	0.031827	0.217006	0.014826	0.004668	0.217006	0.217006	0.002175	0.002175	0.014826	0.014826	0.10109	0.10109	0.001013	0.001013	0.047091	0.0004719	0.000472	0.003217	2.198E-04
0.068323	0.698758	0.232919	0.047741	0.015914	0.162754	0.01112	0.004668	0.488262	0.054251	0.003262	0.001087	0.03336	0.003707	0.113726	0.037909	0.002279	0.000253	0.026489	0.0005309	0.000177	0.00181	1.237E-04
0.074074	0.231481	0.694444	0.017147	0.05144	0.160751	0.011907	0.005487	0.053584	0.482253	0.00127	0.00381	0.003969	0.035722	0.037211	0.111633	0.000294	0.002646	0.025841	0.0002042	0.000613	0.001914	1.418E-04
0.074074	0.462963	0.462963	0.034294	0.034294	0.214335	0.015877	0.005487	0.214335	0.214335	0.00254	0.00254	0.015877	0.015877	0.099229	0.099229	0.001176	0.001176	0.045939	0.0005445	0.000544	0.003403	2.521E-04
0.074074	0.694444	0.231481	0.05144	0.017147	0.160751	0.011907	0.005487	0.482253	0.053584	0.00381	0.00127	0.035722	0.003969	0.111633	0.037211	0.002646	0.000294	0.025841	0.0006125	0.000204	0.001914	1.418E-04

Table12:Z matrix values [for concrete mix proportions from observation point 49-60] [TEST E – MODEL 2]

z1	z2	z3	z12	z13	z23	z123	z1z1	z2z2	z3z3	z112	z113	z122	z133	z223	z233	z1122	z1133	z2233	z11223	z11233	z12233	z112233
0.047619	0.238095	0.714286	0.011338	0.034014	0.170068	0.008098	0.002268	0.056689	0.510204	0.00054	0.00162	0.002699	0.024295	0.040492	0.121477	0.000129	0.001157	0.028923	9.2E-05	0.000275	0.001377	6.5585E-05
0.047619	0.47619	0.47619	0.022676	0.022676	0.226757	0.010798	0.002268	0.226757	0.226757	0.00108	0.00108	0.010798	0.010798	0.10798	0.10798	0.000514	0.000514	0.051419	2.4E-04	0.000245	0.002449	0.0001166
0.047619	0.714286	0.238095	0.034014	0.011338	0.170068	0.008098	0.002268	0.510204	0.056689	0.00162	0.00054	0.024295	0.002699	0.121477	0.040492	0.001157	0.000129	0.028923	2.8E-04	9.18E-05	0.001377	6.5585E-05
0.052632	0.236842	0.710526	0.012465	0.037396	0.168283	0.008857	0.00277	0.056094	0.504848	0.000656	0.001968	0.002952	0.026571	0.039856	0.119569	0.000155	0.001398	0.028319	1.1E-04	0.000331	0.00149	7.8446E-05
0.052632	0.473684	0.473684	0.024931	0.024931	0.224377	0.011809	0.00277	0.224377	0.224377	0.001312	0.001312	0.011809	0.011809	0.106284	0.106284	0.000622	0.000622	0.050345	2.9E-04	0.000294	0.00265	0.00013946
0.052632	0.710526	0.236842	0.037396	0.012465	0.168283	0.008857	0.00277	0.504848	0.056094	0.001968	0.000656	0.026571	0.002952	0.119569	0.039856	0.001398	0.000155	0.028319	3.3E-04	0.00011	0.00149	7.8446E-05
0.057592	0.235602	0.706806	0.013569	0.040706	0.166525	0.00959	0.003317	0.055508	0.499575	0.000781	0.002344	0.003197	0.028771	0.039234	0.117701	0.000184	0.001657	0.027731	1.3E-04	0.00039	0.001597	9.1977E-05
0.057592	0.471204	0.471204	0.027137	0.027137	0.222033	0.012787	0.003317	0.222033	0.222033	0.001563	0.001563	0.012787	0.012787	0.104623	0.104623	0.000736	0.000736	0.049299	3.5E-04	0.000347	0.002839	0.00016351
0.057592	0.706806	0.235602	0.040706	0.013569	0.166525	0.00959	0.003317	0.499575	0.055508	0.002344	0.000781	0.028771	0.003197	0.117701	0.039234	0.001657	0.000184	0.027731	3.9E-04	0.00013	0.001597	9.1977E-05
0.0625	0.234375	0.703125	0.014648	0.043945	0.164795	0.0103	0.003906	0.054932	0.494385	0.000916	0.002747	0.003433	0.030899	0.038624	0.115871	0.000215	0.001931	0.027157	1.5E-04	0.000453	0.001697	0.00010608
0.0625	0.46875	0.46875	0.029297	0.029297	0.219727	0.013733	0.003906	0.219727	0.219727	0.001831	0.001831	0.013733	0.013733	0.102997	0.102997	0.000858	0.000858	0.04828	4.0E-04	0.000402	0.003017	0.00018859
0.0625	0.703125	0.234375	0.043945	0.014648	0.164795	0.0103	0.003906	0.494385	0.054932	0.002747	0.000916	0.030899	0.003433	0.115871	0.038624	0.001931	0.000215	0.027157	4.5E-04	0.000151	0.001697	0.00010608

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Table 14:CC matrix for concrete mix proportions from observation point 1-12 **[TEST A – MODEL 2]**

0.267607	0.758529	0.758529	0.113579	0.113579	0.268729	0.040181	0.040449	0.376221	0.376221	0.017144	0.017144	0.056254	0.056254	0.114274	0.114274	0.008479	0.008479	0.041315	0.002568301	0.002568301	0.00616	0.000925932
0.758529	2.536998	1.812141	0.376221	0.268729	0.771706	0.114274	0.113579	1.389071	0.771706	0.056254	0.040181	0.205693	0.114274	0.378024	0.279409	0.030712	0.017062	0.119047	0.008334044	0.006159946	0.017577	0.002617007
0.758529	1.812141	2.536998	0.268729	0.376221	0.771706	0.114274	0.113579	0.771706	1.389071	0.040181	0.056254	0.114274	0.205693	0.279409	0.378024	0.017062	0.030712	0.119047	0.006159946	0.008334044	0.017577	0.002617007
0.113579	0.376221	0.268729	0.056254	0.040181	0.114274	0.017062	0.017144	0.205693	0.114274	0.008479	0.006057	0.030712	0.017062	0.055897	0.041315	0.004622942	0.002568301	0.017577	0.001252732	0.000925932	0.002617007	0.000392824
0.113579	0.268729	0.376221	0.040181	0.056254	0.114274	0.017062	0.017144	0.114274	0.205693	0.006057	0.008479	0.017062	0.030712	0.041315	0.055897	0.002568301	0.004622942	0.017577	0.000925932	0.001252732	0.002617007	0.000392824
0.268729	0.771706	0.771706	0.114274	0.114274	0.279409	0.041315	0.040181	0.378024	0.378024	0.017062	0.017062	0.055897	0.055897	0.119047	0.119047	0.008334044	0.008334044	0.04402	0.002617007	0.002617007	0.00649021	0.000964903
0.040181	0.114274	0.114274	0.017062	0.017062	0.041315	0.00616	0.006057	0.055897	0.055897	0.002568301	0.002568301	0.008334	0.008334	0.017577	0.017577	0.001252732	0.001252732	0.00649	0.000392824	0.000392824	0.000964903	0.000144632
0.040449	0.113579	0.113579	0.017144	0.017144	0.040181	0.006057	0.006161	0.056254	0.056254	0.002607875	0.002607875	0.008479	0.008479	0.017062	0.017062	0.001288134	0.001288134	0.00616	0.000389637	0.000389637	0.000925932	0.000140284
0.376221	1.389071	0.771706	0.205693	0.114274	0.378024	0.055897	0.056254	0.805354	0.279409	0.030712123	0.017062291	0.119084	0.041315	0.20308	0.119047	0.017755137	0.006159946	0.05745	0.004464306	0.002617007	0.008470274	0.00125928
0.376221	0.771706	1.389071	0.114274	0.205693	0.378024	0.055897	0.056254	0.279409	0.805354	0.017062291	0.030712123	0.041315	0.119084	0.119047	0.20308	0.006159946	0.017755137	0.05745	0.002617007	0.004464306	0.008470274	0.00125928
0.0171439	0.0562538	0.0401813	0.0084794	0.0060567	0.0170623	0.002568301	0.002607875	0.0307121	0.0170623	0.001288134	0.000920096	0.004622942	0.002568301	0.008334	0.0061599	0.000701347	0.000389637	0.002617007	0.000189796	0.000140284	0.000392824	5.94E-05
0.0171439	0.0401813	0.0562538	0.0060567	0.0084794	0.0170623	0.002568301	0.002607875	0.0170623	0.0307121	0.000920096	0.001288134	0.002568301	0.004622942	0.0061599	0.008334	0.000389637	0.000701347	0.002617007	0.000140284	0.000189796	0.000392824	5.94E-05
0.0562538	0.205693	0.1142739	0.0307121	0.0170623	0.0558967	0.008334044	0.008479377	0.1190842	0.0413149	0.004622942	0.002568301	0.017755137	0.006159946	0.0299851	0.0175775	0.002668863	0.000925932	0.008470274	0.000670112	0.000392824	0.00125928	0.000188758
0.0562538	0.1142739	0.205693	0.0170623	0.0307121	0.0558967	0.008334044	0.008479377	0.0413149	0.1190842	0.002568301	0.004622942	0.006159946	0.017755137	0.0175775	0.0299851	0.000925932	0.002668863	0.008470274	0.000392824	0.000670112	0.00125928	0.000188758
0.1142739	0.3780235	0.2794087	0.0558967	0.0413149	0.1190469	0.017577491	0.017062291	0.20308	0.1190469	0.008334044	0.006159946	0.029985131	0.017577491	0.0574496	0.0440198	0.004464306	0.002617007	0.0187648	0.00125928	0.000964903	0.002762654	0.000410135
0.1142739	0.2794087	0.3780235	0.0413149	0.0558967	0.1190469	0.017577491	0.017062291	0.1190469	0.20308	0.006159946	0.008334044	0.017577491	0.029985131	0.0440198	0.0574496	0.002617007	0.004464306	0.0187648	0.000964903	0.00125928	0.002762654	0.000410135
0.0084794	0.0307121	0.0170623	0.004622942	0.002568301	0.008334	0.001252732	0.001288134	0.017755137	0.0061599	0.000701347	0.000389637	0.002668863	0.000925932	0.004464306	0.002617007	0.000404347	0.000140284	0.00125928	0.000101388	5.94E-05	0.000188758	2.85E-05
0.0084794	0.0170623	0.0307121	0.002568301	0.004622942	0.008334	0.001252732	0.001288134	0.006159946	0.017755137	0.000389637	0.000701347	0.000925932	0.002668863	0.002617007	0.004464306	0.000140284	0.000404347	0.00125928	5.94E-05	0.000101388	0.000188758	2.85E-05
0.0413149	0.1190469	0.1190469	0.017577491	0.017577491	0.0440198	0.00649021	0.006159946	0.057449583	0.057449583	0.002617007	0.002617007	0.008470274	0.008470274	0.0187648	0.0187648	0.00125928	0.00125928	0.007085696	0.000410135	0.000410135	0.001041687	0.000154423
0.002568301	0.008334	0.0061599	0.001252732	0.000925932	0.002617007	0.000392824	0.000389637	0.004464306	0.002617007	0.000189796	0.000140284	0.000670112	0.000392824	0.00125928	0.000964903	0.000101388	5.94E-05	0.000410135	2.85E-05	2.19E-05	6.14E-05	9.26E-06
0.002568301	0.0061599	0.008334	0.000925932	0.001252732	0.002617007	0.000392824	0.000389637	0.002617007	0.004464306	0.000140284	0.000189796	0.000392824	0.000670112	0.000964903	0.00125928	5.94E-05	0.000101388	0.000410135	2.19E-05	2.85E-05	6.14E-05	9.26E-06
0.006159946	0.0175775	0.0175775	0.002617007	0.002617007	0.00649021	0.000964903	0.000925932	0.008470274	0.008470274	0.000392824	0.000392824	0.00125928	0.00125928	0.002762654	0.002762654	0.000188758	0.000188758	0.001041687	6.14E-05	6.14E-05	0.000154423	2.31E-05
0.000925932	0.002617007	0.002617007	0.000392824	0.000392824	0.000964903	0.000144632	0.000140284	0.00125928	0.00125928	5.94E-05	5.94E-05	0.000188758	0.000188758	0.000410135	0.000410135	2.85E-05	2.85E-05	0.000154423	9.26E-06	9.26E-06	2.31E-05	3.48E-06

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Table 15: CC matrix for concrete mix proportions from observation point 13-24 **[TEST B – MODEL 2]**

0.131900626	0.560250248	0.560250248	0.058943058	0.058943058	0.208877996	0.021952772	0.01401451	0.292429194	0.292429194	0.006256404	0.006256404	0.030733881	0.030733881	0.093462612	0.093462612	0.003258884	0.003258884	0.035551298	0.001039415	0.001039415	0.003728561	0.000394554
0.560250248	2.807903695	2.005645496	0.292429194	0.208877996	0.89838375	0.093462612	0.058943058	1.61709075	0.89838375	0.030733881	0.021952772	0.168232701	0.093462612	0.462829655	0.342091484	0.017662498	0.009812499	0.153270093	0.005044523	0.003728561	0.015911369	0.001667003
0.560250248	2.005645496	2.807903695	0.208877996	0.292429194	0.89838375	0.093462612	0.058943058	0.89838375	1.61709075	0.021952772	0.030733881	0.093462612	0.168232701	0.342091484	0.462829655	0.009812499	0.017662498	0.153270093	0.003728561	0.005044523	0.015911369	0.001667003
0.058943058	0.292429194	0.208877996	0.030733881	0.021952772	0.093462612	0.009812499	0.006256404	0.168232701	0.093462612	0.003258884	0.002327775	0.017662498	0.009812499	0.048098815	0.035551298	0.001870947	0.001039415	0.015911369	0.000533809	0.000394554	0.001667003	0.000176221
0.058943058	0.208877996	0.292429194	0.021952772	0.030733881	0.093462612	0.009812499	0.006256404	0.093462612	0.168232701	0.002327775	0.003258884	0.009812499	0.017662498	0.035551298	0.048098815	0.001039415	0.001870947	0.015911369	0.000394554	0.000533809	0.001667003	0.000176221
0.208877996	0.89838375	0.89838375	0.093462612	0.093462612	0.342091484	0.035551298	0.021952772	0.462829655	0.462829655	0.009812499	0.009812499	0.048098815	0.048098815	0.153270093	0.153270093	0.005044523	0.005044523	0.059589447	0.001667003	0.001667003	0.006179541	0.000646737
0.021952772	0.093462612	0.093462612	0.009812499	0.009812499	0.035551298	0.003728561	0.002327775	0.048098815	0.048098815	0.001039415	0.001039415	0.005044523	0.005044523	0.015911369	0.015911369	0.000533809	0.000533809	0.006179541	0.000176221	0.000176221	0.000646737	6.83E-05
0.01401451	0.058943058	0.058943058	0.006256404	0.006256404	0.021952772	0.002327775	0.001501701	0.030733881	0.030733881	0.000669745	0.000669745	0.003258884	0.003258884	0.009812499	0.009812499	0.000348523	0.000348523	0.003728561	0.000111052	0.000111052	0.000394554	4.21E-05
0.292429194	1.61709075	0.89838375	0.168232701	0.093462612	0.462829655	0.048098815	0.030733881	0.986028395	0.342091484	0.017662498	0.009812499	0.102471388	0.035551298	0.261460747	0.153270093	0.010747028	0.003728561	0.077769278	0.002843711	0.001667003	0.008064825	0.000844046
0.292429194	0.89838375	1.61709075	0.093462612	0.168232701	0.462829655	0.048098815	0.030733881	0.342091484	0.986028395	0.009812499	0.017662498	0.035551298	0.102471388	0.153270093	0.261460747	0.003728561	0.010747028	0.077769278	0.001667003	0.002843711	0.008064825	0.000844046
0.006256404	0.030733881	0.021952772	0.003258884	0.002327775	0.009812499	0.001039415	0.000669745	0.017662498	0.009812499	0.000348523	0.000248945	0.001870947	0.001039415	0.005044523	0.003728561	0.000199893	0.000111052	0.001667003	5.70E-05	4.21E-05	0.000176221	1.88E-05
0.006256404	0.021952772	0.030733881	0.002327775	0.003258884	0.009812499	0.001039415	0.000669745	0.009812499	0.017662498	0.000248945	0.000348523	0.001039415	0.001870947	0.003728561	0.005044523	0.000111052	0.000199893	0.001667003	4.21E-05	5.70E-05	0.000176221	1.88E-05
0.030733881	0.168232701	0.093462612	0.017662498	0.009812499	0.048098815	0.005044523	0.003258884	0.102471388	0.035551298	0.001870947	0.001039415	0.010747028	0.003728561	0.027142923	0.015911369	0.001137245	0.000394554	0.008064825	0.000300612	0.000176221	0.000844046	8.91E-05
0.030733881	0.093462612	0.168232701	0.009812499	0.017662498	0.048098815	0.005044523	0.003258884	0.035551298	0.102471388	0.001039415	0.001870947	0.003728561	0.010747028	0.015911369	0.027142923	0.000394554	0.001137245	0.008064825	0.000176221	0.000300612	0.000844046	8.91E-05
0.093462612	0.462829655	0.342091484	0.048098815	0.035551298	0.153270093	0.015911369	0.009812499	0.261460747	0.153270093	0.005044523	0.003728561	0.027142923	0.015911369	0.077769278	0.059589447	0.002843711	0.001667003	0.026704953	0.000844046	0.000646737	0.002766402	0.00028922
0.093462612	0.342091484	0.462829655	0.035551298	0.048098815	0.153270093	0.015911369	0.009812499	0.153270093	0.261460747	0.003728561	0.005044523	0.015911369	0.027142923	0.059589447	0.077769278	0.001667003	0.002843711	0.026704953	0.000646737	0.000844046	0.002766402	0.00028922
0.003258884	0.017662498	0.009812499	0.001870947	0.001039415	0.005044523	0.000533809	0.000348523	0.010747028	0.003728561	0.000199893	0.000111052	0.001137245	0.000394554	0.002843711	0.001667003	0.000121385	4.21E-05	0.000844046	3.21E-05	1.88E-05	8.91E-05	9.49E-06
0.003258884	0.009812499	0.017662498	0.001039415	0.001870947	0.005044523	0.000533809	0.000348523	0.003728561	0.010747028	0.000111052	0.000199893	0.000394554	0.001137245	0.001667003	0.002843711	4.21E-05	0.000121385	0.000844046	1.88E-05	3.21E-05	8.91E-05	9.49E-06
0.035551298	0.153270093	0.153270093	0.015911369	0.015911369	0.059589447	0.006179541	0.003728561	0.077769278	0.077769278	0.001667003	0.001667003	0.008064825	0.008064825	0.026704953	0.026704953	0.000844046	0.000844046	0.010599909	0.00028922	0.00028922	0.001096888	0.000114555
0.001039415	0.005044523	0.003728561	0.000533809	0.000394554	0.001667003	0.000176221	0.000111052	0.002843711	0.001667003	5.70E-05	4.21E-05	0.000300612	0.000176221	0.000844046	0.000646737	3.21E-05	1.88E-05	0.00028922	9.49E-06	7.28E-06	3.05E-05	3.25E-06
0.001039415	0.003728561	0.005044523	0.000394554	0.000533809	0.001667003	0.000176221	0.000111052	0.001667003	0.002843711	4.21E-05	5.70E-05	0.000176221	0.000300612	0.000646737	0.000844046	1.88E-05	3.21E-05	0.00028922	7.28E-06	9.49E-06	3.05E-05	3.25E-06
0.003728561	0.015911369	0.015911369	0.001667003	0.001667003	0.006179541	0.000646737	0.000394554	0.008064825	0.008064825	0.000176221	0.000176221	0.000844046	0.000844046	0.002766402	0.002766402	8.91E-05	8.91E-05	0.001096888	3.05E-05	3.05E-05	0.000114555	1.21E-05
0.000394554	0.001667003	0.001667003	0.000176221	0.000176221	0.000646737	6.83E-05	4.21E-05	0.000844046	0.000844046	1.88E-05	1.88E-05	8.91E-05	8.91E-05	0.00028922	0.00028922	9.49E-06	9.49E-06	0.000114555	3.25E-06	3.25E-06	1.21E-05	1.28E-06

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Table 16:CC matrix for concrete mix proportions from observation point 25-36 [TEST C – MODEL 2]

0.078299969	0.443203628	0.443203628	0.035942787	0.035942787	0.169692017	0.01375028	0.006414395	0.237568824	0.237568824	0.002942115	0.002942115	0.019250392	0.019250392	0.077970869	0.077970869	0.001574491	0.001574491	0.03045467	0.000515912	0.000515912	0.002463686	0.000201182
0.443203628	2.960091609	2.114351149	0.237568824	0.169692017	0.972329566	0.077970869	0.035942787	1.750193219	0.972329566	0.019250392	0.01375028	0.140347564	0.077970869	0.514256251	0.380102446	0.011363079	0.006312822	0.174823888	0.003333223	0.002463686	0.013995492	0.001131252
0.443203628	2.114351149	2.960091609	0.169692017	0.237568824	0.972329566	0.077970869	0.035942787	0.972329566	1.750193219	0.01375028	0.019250392	0.077970869	0.140347564	0.380102446	0.514256251	0.006312822	0.011363079	0.174823888	0.002463686	0.003333223	0.013995492	0.001131252
0.035942787	0.237568824	0.169692017	0.019250392	0.01375028	0.077970869	0.006312822	0.002942115	0.140347564	0.077970869	0.001574491	0.001124637	0.011363079	0.006312822	0.041203377	0.03045467	0.000928642	0.000515912	0.013995492	0.000272187	0.000201182	0.001131252	9.23E-05
0.035942787	0.169692017	0.237568824	0.01375028	0.019250392	0.077970869	0.006312822	0.002942115	0.077970869	0.140347564	0.001124637	0.001574491	0.006312822	0.011363079	0.03045467	0.041203377	0.000515912	0.000928642	0.013995492	0.000201182	0.000272187	0.001131252	9.23E-05
0.169692017	0.972329566	0.972329566	0.077970869	0.077970869	0.380102446	0.03045467	0.01375028	0.514256251	0.514256251	0.006312822	0.006312822	0.041203377	0.041203377	0.174823888	0.174823888	0.003333223	0.003333223	0.069771143	0.001131252	0.001131252	0.00558081	0.000450721
0.01375028	0.077970869	0.077970869	0.006312822	0.006312822	0.03045467	0.002463686	0.001124637	0.041203377	0.041203377	0.000515912	0.000515912	0.003333223	0.003333223	0.013995492	0.013995492	0.000272187	0.000272187	0.00558081	9.23E-05	9.23E-05	0.000450721	3.67E-05
0.006414395	0.035942787	0.035942787	0.002942115	0.002942115	0.01375028	0.001124637	0.000530164	0.019250392	0.019250392	0.000242987	0.000242987	0.001574491	0.001574491	0.006312822	0.006312822	0.000129937	0.000129937	0.002463686	4.25E-05	4.25E-05	0.000201182	1.66E-05
0.237568824	1.750193219	0.972329566	0.140347564	0.077970869	0.514256251	0.041203377	0.019250392	1.095589404	0.380102446	0.011363079	0.006312822	0.087781108	0.03045467	0.298228986	0.174823888	0.007101214	0.002463686	0.091057254	0.001929783	0.001131252	0.00728343	0.000588229
0.237568824	0.972329566	1.750193219	0.077970869	0.140347564	0.514256251	0.041203377	0.019250392	0.380102446	1.095589404	0.006312822	0.011363079	0.03045467	0.087781108	0.174823888	0.298228986	0.002463686	0.007101214	0.091057254	0.001131252	0.001929783	0.00728343	0.000588229
0.002942115	0.019250392	0.01375028	0.001574491	0.001124637	0.006312822	0.000515912	0.000242987	0.011363079	0.006312822	0.000129937	9.28E-05	0.000928642	0.000515912	0.003333223	0.002463686	7.66E-05	4.25E-05	0.001131252	2.24E-05	1.66E-05	9.23E-05	7.60E-06
0.002942115	0.01375028	0.019250392	0.001124637	0.001574491	0.006312822	0.000515912	0.000242987	0.006312822	0.011363079	9.28E-05	0.000129937	0.000515912	0.000928642	0.002463686	0.003333223	4.25E-05	7.66E-05	0.001131252	1.66E-05	2.24E-05	9.23E-05	7.60E-06
0.019250392	0.140347564	0.077970869	0.011363079	0.006312822	0.041203377	0.003333223	0.001574491	0.087781108	0.03045467	0.000928642	0.000515912	0.007101214	0.002463686	0.023874662	0.013995492	0.000579877	0.000201182	0.00728343	0.000157457	9.23E-05	0.000588229	4.80E-05
0.019250392	0.077970869	0.140347564	0.006312822	0.011363079	0.041203377	0.003333223	0.001574491	0.03045467	0.087781108	0.000515912	0.000928642	0.002463686	0.007101214	0.013995492	0.023874662	0.000201182	0.000579877	0.00728343	9.23E-05	0.000157457	0.000588229	4.80E-05
0.077970869	0.514256251	0.380102446	0.041203377	0.03045467	0.174823888	0.013995492	0.006312822	0.298228986	0.174823888	0.003333223	0.002463686	0.023874662	0.013995492	0.091057254	0.069771143	0.001929783	0.001131252	0.032095166	0.000588229	0.000450721	0.002565044	0.000206987
0.077970869	0.380102446	0.514256251	0.03045467	0.041203377	0.174823888	0.013995492	0.006312822	0.174823888	0.298228986	0.002463686	0.003333223	0.013995492	0.023874662	0.069771143	0.091057254	0.001131252	0.001929783	0.032095166	0.000450721	0.000588229	0.002565044	0.000206987
0.001574491	0.011363079	0.006312822	0.000928642	0.000515912	0.003333223	0.000272187	0.000129937	0.007101214	0.002463686	7.66E-05	4.25E-05	0.000579877	0.000201182	0.001929783	0.001131252	4.78E-05	1.66E-05	0.000588229	1.30E-05	7.60E-06	4.80E-05	3.95E-06
0.001574491	0.006312822	0.011363079	0.000515912	0.000928642	0.003333223	0.000272187	0.000129937	0.002463686	0.007101214	4.25E-05	7.66E-05	0.000201182	0.000579877	0.001131252	0.001929783	1.66E-05	4.78E-05	0.000588229	7.60E-06	1.30E-05	4.80E-05	3.95E-06
0.03045467	0.174823888	0.174823888	0.013995492	0.013995492	0.069771143	0.00558081	0.002463686	0.091057254	0.091057254	0.001131252	0.001131252	0.00728343	0.00728343	0.032095166	0.032095166	0.000588229	0.000588229	0.013075838	0.000206987	0.000206987	0.00104414	8.42E-05
0.000515912	0.003333223	0.002463686	0.000272187	0.000201182	0.001131252	9.23E-05	4.25E-05	0.001929783	0.001131252	2.24E-05	1.66E-05	0.000157457	9.23E-05	0.000588229	0.000450721	1.30E-05	7.60E-06	0.000206987	3.95E-06	3.02E-06	1.69E-05	1.39E-06
0.000515912	0.002463686	0.003333223	0.000201182	0.000272187	0.001131252	9.23E-05	4.25E-05	0.001131252	0.001929783	1.66E-05	2.24E-05	9.23E-05	0.000157457	0.000450721	0.000588229	7.60E-06	1.30E-05	0.000206987	3.02E-06	3.95E-06	1.69E-05	1.39E-06
0.002463686	0.013995492	0.013995492	0.001131252	0.001131252	0.00558081	0.000450721	0.000201182	0.00728343	0.00728343	9.23E-05	9.23E-05	0.000588229	0.000588229	0.002565044	0.002565044	4.80E-05	4.80E-05	0.00104414	1.69E-05	1.69E-05	8.42E-05	6.85E-06
0.000201182	0.001131252	0.001131252	9.23E-05	9.23E-05	0.000450721	3.67E-05	1.66E-05	0.000588229	0.000588229	7.60E-06	7.60E-06	4.80E-05	4.80E-05	0.000206987	0.000206987	3.95E-06	3.95E-06	8.42E-05	1.39E-06	1.39E-06	6.85E-06	5.63E-07

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Table 17:CC matrix for concrete mix proportions from observation point 37-48 **[TEST D – MODEL 2]**

0.051795706	0.36635339	0.36635339	0.024171542	0.024171542	0.14257577	0.009400568	0.003452623	0.199606078	0.199606078	0.001610179	0.001610179	0.013160795	0.013160795	0.066587601	0.066587601	0.000876124	0.000876124	0.026435093	0.000291878	0.000291878	0.001740589	0.000115719
0.36635339	3.05748063	2.183914736	0.199606078	0.14257577	1.020669483	0.066587601	0.024171542	1.837205069	1.020669483	0.013160795	0.009400568	0.119857682	0.066587601	0.548597082	0.4054848	0.007897289	0.004387383	0.189524853	0.002354915	0.001740589	0.012347252	0.000812435
0.36635339	2.183914736	3.05748063	0.14257577	0.199606078	1.020669483	0.066587601	0.024171542	1.020669483	1.837205069	0.009400568	0.013160795	0.066587601	0.119857682	0.4054848	0.548597082	0.004387383	0.007897289	0.189524853	0.001740589	0.002354915	0.012347252	0.000812435
0.024171542	0.199606078	0.14257577	0.013160795	0.009400568	0.066587601	0.004387383	0.001610179	0.119857682	0.066587601	0.000876124	0.000625803	0.007897289	0.004387383	0.035765126	0.026435093	0.000525381	0.000291878	0.012347252	0.000156561	0.000115719	0.000812435	5.40E-05
0.024171542	0.14257577	0.199606078	0.009400568	0.013160795	0.066587601	0.004387383	0.001610179	0.066587601	0.119857682	0.000625803	0.000876124	0.004387383	0.007897289	0.026435093	0.035765126	0.000291878	0.000525381	0.012347252	0.000115719	0.000156561	0.000812435	5.40E-05
0.14257577	1.020669483	1.020669483	0.066587601	0.066587601	0.4054848	0.026435093	0.009400568	0.548597082	0.548597082	0.004387383	0.004387383	0.035765126	0.035765126	0.189524853	0.189524853	0.002354915	0.002354915	0.076863812	0.000812435	0.000812435	0.005004075	0.000329037
0.009400568	0.066587601	0.066587601	0.004387383	0.004387383	0.026435093	0.001740589	0.000625803	0.035765126	0.035765126	0.000291878	0.000291878	0.002354915	0.002354915	0.012347252	0.012347252	0.000156561	0.000156561	0.005004075	5.40E-05	5.40E-05	0.000329037	2.18E-05
0.003452623	0.024171542	0.024171542	0.001610179	0.001610179	0.009400568	0.000625803	0.000232265	0.013160795	0.013160795	0.000108252	0.000108252	0.000876124	0.000876124	0.004387383	0.004387383	5.89E-05	5.89E-05	0.001740589	1.96E-05	1.96E-05	0.000115719	7.77E-06
0.199606078	1.837205069	1.020669483	0.119857682	0.066587601	0.548597082	0.035765126	0.013160795	1.168750305	0.4054848	0.007897289	0.004387383	0.076195268	0.026435093	0.323307103	0.189524853	0.005016993	0.001740589	0.100313789	0.001385919	0.000812435	0.006530742	0.000429421
0.199606078	1.020669483	1.837205069	0.066587601	0.119857682	0.548597082	0.035765126	0.013160795	0.4054848	1.168750305	0.004387383	0.007897289	0.026435093	0.076195268	0.189524853	0.323307103	0.001740589	0.005016993	0.100313789	0.000812435	0.001385919	0.006530742	0.000429421
0.001610179	0.013160795	0.009400568	0.000876124	0.000625803	0.004387383	0.000291878	0.000108252	0.007897289	0.004387383	5.89E-05	4.20E-05	0.000525381	0.000291878	0.002354915	0.001740589	3.53E-05	1.96E-05	0.000812435	1.05E-05	7.77E-06	5.40E-05	3.62E-06
0.001610179	0.009400568	0.013160795	0.000625803	0.000876124	0.004387383	0.000291878	0.000108252	0.004387383	0.007897289	4.20E-05	5.89E-05	0.000291878	0.000525381	0.001740589	0.002354915	1.96E-05	3.53E-05	0.000812435	7.77E-06	1.05E-05	5.40E-05	3.62E-06
0.013160795	0.119857682	0.066587601	0.007897289	0.004387383	0.035765126	0.002354915	0.000876124	0.076195268	0.026435093	0.000525381	0.000291878	0.005016993	0.001740589	0.021062959	0.012347252	0.000333543	0.000115719	0.006530742	9.21E-05	5.40E-05	0.000429421	2.85E-05
0.013160795	0.066587601	0.119857682	0.004387383	0.007897289	0.035765126	0.002354915	0.000876124	0.026435093	0.076195268	0.000291878	0.000525381	0.001740589	0.005016993	0.012347252	0.021062959	0.000115719	0.000333543	0.006530742	5.40E-05	9.21E-05	0.000429421	2.85E-05
0.066587601	0.548597082	0.4054848	0.035765126	0.026435093	0.189524853	0.012347252	0.004387383	0.323307103	0.189524853	0.002354915	0.001740589	0.021062959	0.012347252	0.100313789	0.076863812	0.001385919	0.000812435	0.035929869	0.000429421	0.000329037	0.002337519	0.000153595
0.066587601	0.4054848	0.548597082	0.026435093	0.035765126	0.189524853	0.012347252	0.004387383	0.189524853	0.323307103	0.001740589	0.002354915	0.012347252	0.021062959	0.076863812	0.100313789	0.000812435	0.001385919	0.035929869	0.000329037	0.000429421	0.002337519	0.000153595
0.000876124	0.007897289	0.004387383	0.000525381	0.000291878	0.002354915	0.000156561	5.89E-05	0.005016993	0.001740589	3.53E-05	1.96E-05	0.000333543	0.000115719	0.001385919	0.000812435	2.24E-05	7.77E-06	0.000429421	6.17E-06	3.62E-06	2.85E-05	1.91E-06
0.000876124	0.004387383	0.007897289	0.000291878	0.000525381	0.002354915	0.000156561	5.89E-05	0.001740589	0.005016993	1.96E-05	3.53E-05	0.000115719	0.000333543	0.000812435	0.001385919	7.77E-06	2.24E-05	0.000429421	3.62E-06	6.17E-06	2.85E-05	1.91E-06
0.026435093	0.189524853	0.189524853	0.012347252	0.012347252	0.076863812	0.005004075	0.001740589	0.100313789	0.100313789	0.000812435	0.000812435	0.006530742	0.006530742	0.035929869	0.035929869	0.000429421	0.000429421	0.014874579	0.000153595	0.000153595	0.000967034	6.35E-05
0.000291878	0.002354915	0.001740589	0.000156561	0.000115719	0.000812435	5.40E-05	1.96E-05	0.001385919	0.000812435	1.05E-05	7.77E-06	9.21E-05	5.40E-05	0.000429421	0.000329037	6.17E-06	3.62E-06	0.000153595	1.91E-06	1.46E-06	1.02E-05	6.83E-07
0.000291878	0.001740589	0.002354915	0.000115719	0.000156561	0.000812435	5.40E-05	1.96E-05	0.000812435	0.001385919	7.77E-06	1.05E-05	5.40E-05	9.21E-05	0.000329037	0.000429421	3.62E-06	6.17E-06	0.000153595	1.46E-06	1.91E-06	1.02E-05	6.83E-07
0.001740589	0.012347252	0.012347252	0.000812435	0.000812435	0.005004075	0.000329037	0.000115719	0.006530742	0.006530742	5.40E-05	5.40E-05	0.000429421	0.000429421	0.002337519	0.002337519	2.85E-05	2.85E-05	0.000967034	1.02E-05	1.02E-05	6.35E-05	4.21E-06
0.000115719	0.000812435	0.000812435	5.40E-05	5.40E-05	0.000329037	2.18E-05	7.77E-06	0.000429421	0.000429421	3.62E-06	3.62E-06	2.85E-05	2.85E-05	0.000153595	0.000153595	1.91E-06	1.91E-06	6.35E-05	6.83E-07	6.83E-07	4.21E-06	2.82E-07

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Table 18:CC matrix for concrete mix proportions from observation point 49-60 [TEST E – MODEL 2]

0.036782106	0.312122322	0.312122322	0.017357652	0.017357652	0.122818612	0.006826193	0.002066801	0.171946057	0.171946057	0.000974788	0.000974788	0.009556671	0.009556671	0.057996209	0.057996209	0.000536392	0.000536392	0.02327924	0.000180715	0.000180715	0.001292346	7.25E-05
0.312122322	3.125129177	2.232235127	0.171946057	0.122818612	1.054708257	0.057996209	0.017357652	1.898474863	1.054708257	0.009556671	0.009556671	0.104393177	0.057996209	0.573109427	0.42360262	0.005798751	0.003221528	0.20016169	0.001748468	0.001292346	0.010993447	0.000609946
0.312122322	2.232235127	3.125129177	0.122818612	0.171946057	1.054708257	0.057996209	0.017357652	1.054708257	1.898474863	0.006826193	0.006826193	0.057996209	0.104393177	0.42360262	0.573109427	0.003221528	0.005798751	0.20016169	0.001292346	0.001748468	0.010993447	0.000609946
0.017357652	0.171946057	0.122818612	0.009556671	0.006826193	0.057996209	0.003221528	0.000974788	0.104393177	0.057996209	0.000536392	0.000536392	0.005798751	0.003221528	0.031495442	0.02327924	0.000325287	0.000180715	0.010993447	9.80E-05	7.25E-05	0.000609946	3.42E-05
0.017357652	0.122818612	0.171946057	0.006826193	0.009556671	0.057996209	0.003221528	0.000974788	0.057996209	0.104393177	0.000383137	0.000383137	0.003221528	0.005798751	0.02327924	0.031495442	0.000180715	0.000325287	0.010993447	7.25E-05	9.80E-05	0.000609946	3.42E-05
0.122818612	1.054708257	1.054708257	0.057996209	0.057996209	0.42360262	0.02327924	0.006826193	0.573109427	0.573109427	0.003221528	0.003221528	0.031495442	0.031495442	0.20016169	0.20016169	0.001748468	0.001748468	0.082065635	0.000609946	0.000609946	0.004504607	0.000249782
0.006826193	0.057996209	0.057996209	0.003221528	0.003221528	0.02327924	0.001292346	0.000383137	0.031495442	0.031495442	0.000180715	0.000180715	0.001748468	0.001748468	0.010993447	0.010993447	9.80E-05	9.80E-05	0.004504607	3.42E-05	3.42E-05	0.000249782	1.40E-05
0.002066801	0.017357652	0.017357652	0.000974788	0.000974788	0.006826193	0.000383137	0.000117226	0.009556671	0.009556671	5.53E-05	5.53E-05	0.000536392	0.000536392	0.003221528	0.003221528	3.04E-05	3.04E-05	0.001292346	1.02E-05	1.02E-05	7.25E-05	4.10E-06
0.171946057	1.898474863	1.054708257	0.104393177	0.057996209	0.573109427	0.031495442	0.009556671	1.220972258	0.42360262	0.005798751	0.005798751	0.067098985	0.02327924	0.341452295	0.20016169	0.003724996	0.001292346	0.107102608	0.001040495	0.000609946	0.005878894	0.000325987
0.171946057	1.054708257	1.898474863	0.057996209	0.104393177	0.573109427	0.031495442	0.009556671	0.42360262	1.220972258	0.003221528	0.003221528	0.02327924	0.067098985	0.20016169	0.341452295	0.001292346	0.003724996	0.107102608	0.000609946	0.001040495	0.005878894	0.000325987
0.000974788	0.009556671	0.006826193	0.000536392	0.000383137	0.003221528	0.000180715	5.53E-05	0.005798751	0.003221528	3.04E-05	3.04E-05	0.000325287	0.000180715	0.001748468	0.001292346	1.84E-05	1.02E-05	0.000609946	5.55E-06	4.10E-06	3.42E-05	1.93E-06
0.000974788	0.006826193	0.009556671	0.000383137	0.000536392	0.003221528	0.000180715	5.53E-05	0.003221528	0.005798751	2.17E-05	3.04E-05	0.000180715	0.000325287	0.001292346	0.001748468	1.02E-05	1.84E-05	0.000609946	4.10E-06	5.55E-06	3.42E-05	1.93E-06
0.009556671	0.104393177	0.057996209	0.005798751	0.003221528	0.031495442	0.001748468	0.000536392	0.067098985	0.02327924	0.000325287	0.000325287	0.003724996	0.001292346	0.018753527	0.010993447	0.00020884	7.25E-05	0.005878894	5.83E-05	3.42E-05	0.000325987	1.83E-05
0.009556671	0.057996209	0.104393177	0.003221528	0.005798751	0.031495442	0.001748468	0.000536392	0.02327924	0.067098985	0.000180715	0.000180715	0.001292346	0.003724996	0.010993447	0.018753527	7.25E-05	0.00020884	0.005878894	3.42E-05	5.83E-05	0.000325987	1.83E-05
0.057996209	0.573109427	0.42360262	0.031495442	0.02327924	0.20016169	0.010993447	0.003221528	0.341452295	0.20016169	0.001748468	0.001748468	0.018753527	0.010993447	0.107102608	0.082065635	0.001040495	0.000609946	0.038780514	0.000325987	0.000249782	0.002127413	0.000117897
0.057996209	0.42360262	0.573109427	0.02327924	0.031495442	0.20016169	0.010993447	0.003221528	0.20016169	0.341452295	0.001292346	0.001292346	0.010993447	0.018753527	0.082065635	0.107102608	0.000609946	0.001040495	0.038780514	0.000249782	0.000325987	0.002127413	0.000117897
0.000536392	0.005798751	0.003221528	0.000325287	0.000180715	0.001748468	9.80E-05	3.04E-05	0.003724996	0.001292346	1.84E-05	1.84E-05	0.00020884	7.25E-05	0.001040495	0.000609946	1.18E-05	4.10E-06	0.000325987	3.30E-06	1.93E-06	1.83E-05	1.03E-06
0.000536392	0.003221528	0.005798751	0.000180715	0.000325287	0.001748468	9.80E-05	3.04E-05	0.001292346	0.003724996	1.02E-05	1.02E-05	7.25E-05	0.00020884	0.000609946	0.001040495	4.10E-06	1.18E-05	0.000325987	1.93E-06	3.30E-06	1.83E-05	1.03E-06
0.02327924	0.20016169	0.20016169	0.010993447	0.010993447	0.082065635	0.004504607	0.001292346	0.107102608	0.107102608	0.000609946	0.000609946	0.005878894	0.005878894	0.038780514	0.038780514	0.000325987	0.000325987	0.016229869	0.000117897	0.000117897	0.000889807	4.93E-05
0.000180715	0.001748468	0.001292346	9.80E-05	7.25E-05	0.000609946	3.42E-05	1.02E-05	0.001040495	0.000609946	5.55E-06	5.55E-06	5.83E-05	3.42E-05	0.000325987	0.000249782	3.30E-06	1.93E-06	0.000117897	1.03E-06	7.91E-07	6.60E-06	3.73E-07
0.000180715	0.001292346	0.001748468	7.25E-05	9.80E-05	0.000609946	3.42E-05	1.02E-05	0.000609946	0.001040495	4.10E-06	4.10E-06	3.42E-05	5.83E-05	0.000249782	0.000325987	1.93E-06	3.30E-06	0.000117897	7.91E-07	1.03E-06	6.60E-06	3.73E-07
0.001292346	0.010993447	0.010993447	0.000609946	0.000609946	0.004504607	0.000249782	7.25E-05	0.005878894	0.005878894	3.42E-05	3.42E-05	0.000325987	0.000325987	0.002127413	0.002127413	1.83E-05	1.83E-05	0.000889807	6.60E-06	6.60E-06	4.93E-05	2.76E-06
7.25E-05	0.000609946	0.000609946	3.42E-05	3.42E-05	0.000249782	1.40E-05	4.10E-06	0.000325987	0.000325987	1.93E-06	1.93E-06	1.83E-05	1.83E-05	0.000117897	0.000117897	1.03E-06	1.03E-06	4.93E-05	3.73E-07	3.73E-07	2.76E-06	1.56E-07

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Table 19:CC matrix inverse for concrete mix proportions from observation point 1-12 **[TEST A – MODEL 2]**

- 29799.98	824579.5 042	- 870904.5	216699.2 601	- 563718.2	1055141. 062	- 1307029.	3094825. 402	- 675554.6	- 252555.7	- 9194524.	- 1968664	1584142 1.6	7637358. 929	- 9280762.	1479854. 667	- 9437600.	- 26914574	28563991 .9	- 30233503	22559429 7.3	- 27458128	1250547 925
3699.417 547	- 188830.8	203774.1 471	- 91565.87	104812.7 02	- 93002.50	161828.7 079	- 190254.6	189932.8 4	- 211098.0	2503674. 476	- 295456.1	- 1523032.	- 367697.9	920999.5 264	384661.8 874	- 3691407.	8130144. 881	- 3402188.	49254533 .55	- 55253902	21983626 .93	- 8366412
- 2473.330	59970.75 96	- 58503.19	29987.04 774	- 40211.25	- 27625.85	25221.75 817	- 35131.63	- 170688.5	161950.5 85	- 1897941.	2597587. 895	- 308190.1	- 137067.1	803015.5 907	- 400456.1	5217307. 535	- 3778514.	- 928541.1	- 12790500	6360715. 792	5165174. 825	- 1108240
- 94022.25	3685441. 372	- 3882267.	2018946. 42	- 1486167.	998890.5 31	- 3511404.	2800214. 537	- 845819.4	2059412. 417	3864158 3.25	- 6414141	3710021 1.83	- 7521852.	- 3548405	8831613. 9	- 2157800	- 48262285	62378247 .76	- 13778544	12871716 05	- 32160582	1581909 358
- 98414.18	- 579898.4	373484.1 798	27743.31 506	488336.2 75	1045406. 181	- 3608601.	2910584. 918	1238743. 795	- 16308.85	- 4421245	1763926 7.92	8994988. 294	2161182 8.58	- 1247902	- 1481597	- 1523942	- 56735327	64138253 .99	25725449 0.5	- 34824353	- 33357219	1633551 439
45075.13 255	106224.3 151	- 50397.67	23559.49 385	- 48532.33	27452.34 205	728177.2 568	125705.2 888	- 342546.6	- 303471.7	1773602. 529	804382.4 206	1084.467 192	- 756773.7	1881674. 528	2875697. 035	- 871807.4	- 2486259.	- 8755319.	- 15411758	33356226 .31	14524820 .76	- 1522102
416646.2 57	- 4843735.	5491300. 218	- 2099260.	2657872. 026	- 4608641.	1064659 3.2	- 1130383	1725269. 412	- 853173.2	2084353 4.11	8479958 7.86	- 8193744	- 3192855	6286717 7.79	- 2725515.	5752807 5.11	16406116 0.7	- 17515445	18048557 02	- 14132036	12985251 23	- 6103980
- 475913.5	3675649. 507	- 4164330.	2248197. 397	- 1360481.	2959874. 366	- 7347868.	7474507. 198	655192.7 692	2611154. 884	- 2035228	- 6886824	6159516 4.62	2365928 1.96	- 6293665	- 1317917	- 4363980	- 12445396	18218544 2	- 13548285	10863357 63	- 99364466	4866803 197
- 20511.33	1224002. 312	- 1268780.	534708.0 916	- 612699.6	217239.1 289	- 453929.2	515455.8 797	- 290309.6	331603.8 883	5206609. 289	- 1021942	8432577. 026	- 3629434.	- 9410843.	6409938. 985	7863512. 044	- 17831984	8219646. 888	- 38880878	38737856 0	- 55885794	2411807 76.2
- 7192.303	- 940260.2	924558.6 967	- 442854.3	415506.6 162	76174.93 902	- 159170.3	180744.6 955	239862.6 707	- 225382.8	- 6648878.	4891135. 76	- 3669606.	5353829. 285	5391528. 244	- 6443796.	- 1135895	7863512. 047	2882220. 636	29007713 4.9	- 29057864	- 19596363	8457008 1.87
175459.3 72	- 3285860.	3539911. 833	- 2722123.	1869017. 866	- 3421497.	3548848. 993	- 5058037.	- 159272.0	- 560582.7	1151120 9.23	3541921 9.18	- 3554620	- 6714163.	4250686 2.75	- 7544178.	634417.4 159	82282113 .36	- 81072362	10941301 36	- 92612011	51517153 8.2	- 2453301
148835.2 536	- 54672.08	250600.6 132	177219.6 824	- 1131560.	- 3139516.	2959639. 824	- 4388965.	355764.1 322	- 1022018.	1010141 8.63	3032228 2	- 2084963	- 1517616	1313727 2.02	1793017 9.12	3905923 1.42	30918025 .7	- 70403098	18316191 9.1	- 17008349	44263067 4.1	- 2140244
63115.26 467	- 3977397.	4124920. 477	- 2064598.	1809807. 947	- 995488.3	2256673. 691	- 3250085.	490187.7 83	- 447928.2	- 3923973	6204721 8.48	- 3150681	9169930. 14	3506265 8.54	- 2206915	- 3819872.	51173422 .74	- 36365579	14569398 77	- 13826262	25976289 4.2	- 1206150
42580.61 31	2126643. 554	- 2023950.	861294.5 171	- 1194164.	- 778002.2	1802228. 41	- 2734043.	65691.53 227	17909.18 679	4731078 2.35	- 2952181	2013482. 161	- 1954176	- 1103124	2102042 4.85	2581642 0.49	11557326 .34	- 28136589	- 76811043	84099219 0.9	20381357 2.4	- 9646954
31259.05 074	- 5847985.	5972646. 572	- 2420449.	2901585. 204	- 994982.6	1523243. 057	- 2650470.	1200057. 579	- 700883.4	- 4353329	6304064 9.92	- 4351097	2102993 2	4640681 1.44	- 3706771	- 1052725	56936693 .76	- 29594530	19368235 25	- 18665879	24574600 8.6	- 1116698
2489.084 917	4102749. 998	- 4040897.	2000645. 066	- 1628903.	- 690274.9	886544.8 815	- 1927472.	- 213245.5	770340.5 679	4814797 1.56	- 3567176	1550241 6.88	- 3124639	- 2750406	3263397 9.98	3099451 7.55	1432769. 803	- 18065346	- 12951325	13633620 25	16735850 5	- 7784094
- 1383627.	7591944. 647	- 7927318.	4026624. 636	- 4540052.	743393.2 837	- 2643476.	1580540. 607	501421.6 955	- 341839.6	- 4327271	2466945 6.61	2172906 2.33	4129272. 726	- 6009943	4826130 7.48	7444531 9.99	- 11090686	37315276 .41	- 11762320	11473495 00	- 26847111	1272214 932
- 1276694.	- 7321954.	7220029. 254	- 4111835.	4005008. 619	- 389161.6	- 276960.7	- 1106738.	- 571389.9	515688.3 101	4076019 1.69	- 3322965	- 6026669.	6844290. 54	5298255 4.28	- 4917576	- 7988516	95393275 .67	- 5537048.	99892818 8.3	- 10203544	22884009 .66	1484254 3.2
- 214165.6	2550115. 772	- 2931336.	514490.4 604	- 2008577.	2845075. 347	- 6170987.	6674899. 438	- 708947.0	658596.4 8	- 1226250	- 4618324	4462342 4.36	1809991 8.92	- 3539593	- 607162.6	- 3051149	- 87014067	99962588 .5	- 96180876	74497200 7.7	- 71057160	3387820 976
2344632 4.76	- 1981265	2139828 74.2	- 8919131	9387113 0.61	- 9674002	2918542 83.2	- 3253929	3546437 8.4	- 8970771	5582272 21.8	3057294 491	- 2709824	- 7967410	2463416 043	- 9088351.	1849794 869	47102696 75	- 63873107	63003467 703	- 52630245	39070970 365	- 1.89255E
2363327 2.18	- 9389662	1101611 20.6	- 4758180	5297246 2.56	- 9872001	2959915 52	- 3300909	- 1303348	- 4158622	1173632 596	2487577 616	- 2309376	- 1240966	1959881 038	5217979 39.4	1579986 122	50709345 35	- 64622274	43305423 843	- 32919165	39580332 874	- 1.91453E
1203547. 59	- 3333498.	1664899. 412	- 466635.6	1834086. 081	- 2183569.	3657774. 801	- 6134648.	1891263. 339	644235.0 758	1004927 7.84	4098074 2.16	- 4001495	- 1582884	3196183 5.97	238833.7 071	2782266 1	79345920 .23	- 84177695	86063463 0.2	- 69573544	64228754 7.6	- 2917802
- 8916886	4954129 83.4	- 5479183	2178252 04.7	- 2624117	3503174 68.8	- 1022640	1094577 643	- 5401881	2062773 42	- 2860155	- 9316577	8542883 735	3494440 019	- 7398821	- 7771788	- 5807512	- 16562125	21500991 573	- 1.80336E	1.4453E+ 11	- 1.34363E	6.49139E +11

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Table 20:CC matrix inverse for concrete mix proportions from observation point 13-24 **[TEST B – MODEL 2]**

-6340070	-2421294	-2421294	175391209	175391210.6	-1639319	-2261627	144047986.7	36694347.58	36694346.45	-4838173	-4838173	-7375605	-7375605	-4055610	-4055610	-3957182	-3957182	323545202.8	-6908432.	-6908437.	-2264935	-2192323
-2421294	-2910114	173717585.5	39010155.47	-2069746	-4092865	-8254743	-1396000	-3862901	-1260688	224732942.8	-1194833	83614333.33	-2316023.	281030218.5	-3323627	-9088114	299009455.7	-2324697	-4305614	428040953.6	11850913.75	-5744061
-2421294	173717583.6	-2910114	-2069745	39010149.54	-4092865	-8254743	-1396000	-1260688	-3862901	-1194833	224732938.6	-2316024.	83614334.37	-3323627	281030207.1	299009448.6	-9088113	-2324697	428040933.7	-4305614	11850913.77	-5744061
175391212.9	39010151.71	-2069746	-1707783	-2884415	272063624.8	79039405.77	15359311.85	-4704055	195496426.6	-3757124	2171504.947	-3049532	345379583.4	-3884789	-2244023	118536782	194980661.6	-2207855	527047857.7	-3410528	178184247.3	511411231.5
175391213.4	-2069746	39010146.28	-2884416	-1707783	272063625.6	79039407.12	15359312.02	195496426.5	-4704054	2171496.312	-3757124	345379582	-3049532	-2244025	-3884788	194980670.4	118536770.6	-2207855	-3410528	527047833.5	178184247.4	511411231.7
-1639319	-4092864	-4092865	272063618.7	272063622.1	-3434090	170264258.4	-2795466	62021460.87	62021462.06	187006304.2	187006308.8	-2934059	-2934059	282679406.8	282679415.1	172013622.5	172013617.5	397772362.2	-7067410	-7067410	215591556.7	-3926288
-2261626	-8254743	-8254743	79039398.52	79039405.76	170264261.7	29894793.81	94364459.01	97166058.07	97166057.16	-1292706	-1292706	25473128.79	25473126.11	-1173129	-1173129	-2673991	-2673992	338026083.4	641741097.9	641741073.6	150224782.2	80206369.06
144047986.6	-1396000	-1396000	15359311.08	15359312.18	-2795466	94364459.07	-3847781	12580384.15	12580387.36	18304873.14	18304879.62	-2042188	-2042188	334878487.4	334878493.6	451696287.4	451696284.3	-9697842	-1884163	-1884164	-2466650	-2540951
36694348.89	-3862901	-1260688	-4704055	195496425.6	62021464.77	97166057.74	12580385.79	94735744	90267629.69	-1614003	33899600.75	-9516768.	-5884121	-2199098	268137097.2	77526325.02	-2641908	233216247.4	450332165.4	-4418077	2484812.935	180030014.81
36694348.85	-1260688	-3862901	195496419.2	-4704055	62021464.74	97166057.69	12580385.8	90267629.46	94735744.15	33899595.46	-1614003	-5884120	-9516769.	268137084.1	-2199098	-2641908	77526316.29	233216247.3	-4418076	450332142.8	2484812.897	180030014.88
-4838173	224732938.8	-1194833	-3757124	2171502.336	187006304.3	-1292706	18304876.25	-1614003	33899598.71	251857095.7	161242122.2	147602134.8	269236750.1	-6021925	190207155	4140532.462	107911058.2	-2549111	440405142.8	5573991.542	394158655.1	282775283
-4838173	-1194833	224732940.6	2171506.582	-3757124	187006305	-1292706	18304876.41	33899600.87	-1614003	161242126.2	251857090.3	269236750.9	147602133.4	190207163.5	-6021925	107911052.1	4140536.477	-2549111	5573977.484	440405157	394158655	282775283.3
-7375605	83614335.65	-2316020.	-3049532	345379580.4	-2934059	25473124.86	-2042188	-9516771.	-5884121	147602138.2	269236751.8	-8392826	-2433994	-1896948	534642282.4	363976588.6	-1026713	110627299.4	-1544759	-1187717	3516261.674	-2574763
-7375605	-2316021.	83614336.75	345379583.6	-3049533	-2934059	25473124.53	-2042188	-5884121	-9516771.	269236754	147602136.4	-2433994	-8392826	534642288.6	-1896948	-1026713	363976593.4	110627298.7	-1187717	-1544759	3516261.606	-2574763
-4055610	281030212.5	-3323627	-3884789	-2244024	282679411.9	-1173129	334878490.6	-2199098	268137089.8	-6021925	190207157.9	-1896948	534642285.7	-5774208	91167062.52	-3313208	-6001908	69205156.46	611301858.8	790308771.3	-3557215	815898420.3
-4055609	-3323627	281030211.9	-2244024	-3884788	282679413.6	-1173129	334878490.9	268137094.2	-2199098	190207158.2	-6021925	534642287.7	-1896948	91167062.42	-5774208	-6001908	-3313208	69205162.94	790308774.9	611301855.4	-3557215	815898420.8
-3957182	-9088114	299009459.9	118536781.8	194980664.4	172013615.2	-2673991	451696285.2	77526321.69	-2641908	4140546.151	107911049.8	363976593.3	-1026713	-3313208	-6001908	405599715.3	-5870185	262838506.3	-7652437	417136687.6	-2464954	421853189.6
-3957182	299009451.2	-9088113	194980670.4	118536772.9	172013614	-2673992	451696285	-2641908	77526313.88	107911067.4	4140531.017	-1026713	363976586.4	-6001908	-3313208	-5870185	405599730.6	262838501.8	417136655.6	-7652433	-2464954	421853189.2
323545209.9	-2324697	-2324697	-2207856	-2207855	397772373.4	338026089.5	-9697842	233216251.5	233216254.3	-2549111	-2549111	110627302.8	110627303.8	69205139.04	69205179.96	262838520.3	262838493.4	-2758977	-2965069.	-2965136.	369134163.2	-9141170
-6908435.	-4305614	428040943.5	527047849.4	-3410528	-7067410	641741086.8	-1884163	450332153.7	-4418076	440405152	5573986.368	-1544759	-1187717	611301861.2	790308771.3	-7652435	417136675.7	-2965100.	-1171655	-7478845	243429523	-6712547
-6908437.	428040951.4	-4305614	-3410528	527047843.3	-7067410	641741081.8	-1884163	-4418077	450332152.7	5573984.937	440405159.9	-1187717	-1544759	790308769.9	611301860	417136678.9	-7652434	-2965112.	-7478845	-1171655	243429522.7	-6712547
-2264935	11850913.04	11850919.02	178184245.4	178184244.3	215591555.5	150224779.4	-2466650	2484812.582	2484808.097	394158660.9	394158652.2	3516266.096	3516259.582	-3557215	-3557215	-2464954	-2464954	369134156.2	243429518.7	243429526	-1133898	-7532400
-2192323	-5744061	-5744061	511411228.5	511411222.1	-3926288	80206366.57	-2540951	18003011	18003012.38	282775285.9	282775283.7	-2574763	-2574763	815898425.1	815898413.5	421853193.9	421853202.5	-9141170	-6712547	-6712547	-7532400	5174148.809

Table 21:CC matrix inverse for concrete mix proportions from observation point 25-36 [TEST C – MODEL 2]

324237365.9	149048468.2	149048465.2	-3522917	-3522917	-2508051	-2009550	-3511325	-1521278	-1521278	16068146.84	16068149	-1226476	-1226475	-2654241	-2654241	-1345575	-1345575	-6034053	-5567528	-5567528	-3085312	191818814.5
149048468.6	84496454.29	-4289537	-1197542	-2273474	-6472468.	-1182551	-1737487	-9449289	41162285.14	-1305540	111756728.2	-9975177	129446078.4	32305090.92	-1226523	-9872128	154080060.3	-1371347	374064148.3	-4979466	272502777.9	-3312533
149048468.4	-4289537	84496453.87	-2273474	-1197542	-6472468.	-1182551	-1737487	41162284.7	-9449289	111756727.3	-1305540	129446077.7	-9975177	-1226523	32305090.5	154080060	-9872128	-1371347	-4979466	374064144.1	272502777.7	-3312533
-3522917	-1197542	-2273474	446177162.9	298309203.5	270804808.2	362093133.8	399159164.8	117055476.1	237487622.6	-4641669	124483183.8	37893811.38	279826625.5	81338792.16	12665394.96	8844233.227	-2259142	92140780.79	71253926.19	868918407.7	-2537712	291840302
-3522917	-2273474	-1197542	298309200.8	446177166	270804808.3	362093133.8	399159165	237487625.8	117055473	124483185.3	-4641669	279826631.3	37893805.46	12665394.61	81338792.47	-2259142	8844225.755	92140780.91	868918392.2	71253941.68	-2537712	291840302
-2508051	-6472468.	-6472468.	270804812.9	270804812.9	-6248841	202682852.7	221491261.4	19808786.15	19808785.96	-5876547	-5876547	-2741444	-2741444	-2901255	-2901255	-6550997	-6550996	323358682	381612165.5	381612169.6	-6328440	1699664586
-2009550	-1182551	-1182551	362093132.4	362093134.6	202682849.6	-1546238	557605490.1	116134937.7	116134934.9	-5254400	-5254400	-1127034	-1127035	45439987.29	45439988.76	-3716699	-3716699	-2892109	417845420.8	417845439.2	149528617.9	702844148.6
-3511325	-1737487	-1737487	399159164.1	399159166.5	221491257	557605490.7	448308541	182366077.2	182366074.6	-2521564	-2521564	76981313.34	76981308.31	66954638.06	66954637.85	443774933.8	443774926.6	172927662.4	362809392.6	362809404.1	-3990427	291648872.7
-1521278	-9449289	41162285.29	117055476.3	237487626.5	19808785.39	116134937.8	182366077.8	97413577.94	-3322256	-4632766	-4631001	120605406	-1386967	5455338.424	-2144161	178764415.4	-2221625	125409224.2	-2634988	335556516.9	-2224916	268987495.9
-1521278	41162284.79	-9449289	237487625.8	117055476.5	19808785.37	116134937.7	182366077.6	-3322256	97413577.32	-4631000	-4632766	-1386967	120605405.2	-2144161	5455338.87	-2221625	178764414.6	125409224.1	335556512.1	-2634988	-2224916	268987495.9
16068147.03	-1305540	111756727.3	-4641669	124483185.5	-5876547	-5254400	-2521564	-4632766	-4631000	728351200.3	3300143.595	121254866.4	-3059865	277191526	-3880934	-3253812	26875359.7	31239324.5	-5133623	563945415.7	1200776157	-1996976
16068147.23	111756727.5	-1305540	124483185.6	-4641669	-5876547	-5254400	-2521564	-4631000	-4632766	3300145.674	728351198.3	-3059865	121254867	-3880934	277191527.2	26875357.44	-3253812	31239324.27	563945410.4	-5133623	1200776158	-1996976
-1226476	-9975177	129446077.6	37893811.44	279826631.4	-2741444	-1127034	76981313.65	120605406.2	-1386967	121254866.5	-3059865	151993886.1	-3084412	-1250460	39754365.73	178519185.3	183308876	115480171.7	-1345847	297446296.4	-1130428	-2616333
-1226476	129446077.5	-9975177	279826631.1	37893810.98	-2741444	-1127034	76981313.27	-1386967	120605405.9	-3059865	121254865.1	-3084412	151993886.3	39754364.92	-1250460	183308874.7	178519186.3	115480171.5	297446291.6	-1345847	-1130428	-2616333
-2654241	32305090.66	-1226523	81338793.52	12665395.59	-2901255	45439988.7	66954638.91	5455338.741	-2144161	277191526.5	-3880934	-1250460	39754365.88	-1985783	185286530	-4306203	343465304.3	45910400.89	-7762271	663143514.2	-2393817	-6152763
-2654241	-1226523	32305090.43	12665395.89	81338793.36	-2901255	45439988.77	66954638.99	-2144161	5455338.936	-3880934	277191526.3	39754365.4	-1250460	185286529.8	-1985783	343465303.4	-4306203	45910400.97	663143514.2	-7762271	-2393817	-6152763
-1345575	-9872129	154080059.4	8844233.163	-2259142	-6550996	-3716698	443774933.8	178764415.8	-2221625	-3253812	26875358.13	178519186	183308875.5	-4306203	343465303.6	14806390.61	-9278767	174049488.2	1481851071	186911263.8	537562290.7	1222655538
-1345575	154080059.2	-9872129	-2259142	8844233.023	-6550996	-3716698	443774933.6	-2221625	178764415.6	26875358.66	-3253812	183308875.9	178519185.8	343465303.4	-4306203	-9278767	14806390.14	174049488.2	186911261.8	1481851073	537562290.5	1222655539
-6034053	-1371347	-1371347	92140775.04	92140777.65	323358677.9	-2892109	172927657.8	125409223.2	125409220.4	31239325.46	31239323.79	115480172.1	115480166.7	45910400.1	45910400.56	174049489.1	174049482.7	-3002681	-5993918	-5993918	869780509.5	-1135317
-5567528	374064146.3	-4979466	71253940.45	868918406.9	381612164.3	417845435.3	362809404.4	-2634988	335556513.2	-5133623	563945405.6	-1345847	297446291.4	-7762271	663143516	1481851064	186911263.1	-5993918	596624294.3	-1775623	-1376711	-4039684
-5567528	-4979466	374064149.2	868918405.2	71253943.34	381612164.2	417845435.5	362809404.8	335556516.9	-2634988	563945414.7	-5133623	297446295.7	-1345848	663143511.1	-7762271	186911262.3	1481851066	-5993918	-1775623	596624326.3	-1376711	-4039684
-3085312	272502775.1	272502770.6	-2537711	-2537711	-6328440	149528626.8	-3990427	-2224916	-2224916	1200776155	1200776157	-1130428	-1130427	-2393817	-2393817	537562288.2	537562299.5	869780514.6	-1376711	-1376711	3171017721	-9529839
191818828.4	-3312533	-3312532	291840281.3	291840293.3	1699664570	702844140.2	291648857.9	268987494.2	268987480.8	-1996976	-1996976	-2616332	-2616333	-6152763	-6152763	1222655543	1222655516	-1135317	-4039685	-4039684	-9529839	11224331890

Table 22:CC matrix inverse for concrete mix proportions from observation point 37-48 **[TEST D – MODEL 2]**

- 4299169	- 9146917.	- 9146915.	3080621 47.2	3080621 47.4	- 1745108	- 5058083	3377543 5.01	3723180 1.11	3723179 9.61	3360729 11.2	3360729 11.3	1053806 18.9	1053806 17.1	2105247. 873	2105247. 704	8302209 76.8	8302209 75.3	5344686 92.1	1964467 58.7	1964467 59.2	2596694 709	8584168 83.7
- 9146920.	1348698 54.8	- 2911446	- 5063242	- 1200015	5000944 8.8	1834041 54.2	1188315 50.8	- 1065281	2898107 91.2	7973240 5.22	- 4632955	- 1078044	4279714 94.7	- 6192454	9335382 0.44	1819327 28.3	1026654 204	2504947 98.5	- 4858904	8115592 09	1413084 544	6653075 02.6
- 9146920.	- 2911446	1348698 57.3	- 1200015	- 5063242	5000944 8.79	1834041 54.3	1188315 50.9	2898107 93.5	- 1065281	- 4632955	7973241 2.2	4279714 98.6	- 1078044	9335382 2.21	- 6192454	1026654 211	1819327 22.5	2504947 99	8115592 37.5	- 4858904	1413084 546	6653075 03.9
3080621 42.5	- 5063243	- 1200016	- 2817668	- 3196737	2117517 47.4	2343555 57.2	- 5658377	3957676 8.51	1129117 86.4	- 5201284	3358782 88.1	3694736 9.52	1425331 93.5	3184788 2.04	1083251 9.61	1977381 57.3	- 7812465	- 1788477	- 4775534	3039359 32.4	- 5945383	- 1080467
3080621 42.5	- 1200016	- 5063243	- 3196737	- 2817667	2117517 47.4	2343555 57.2	- 5658377	1129117 87.8	3957676 7.1	3358782 81.2	- 5201284	1425331 96.4	3694736 6.66	1083252 1.42	3184788 0.24	- 7812465	1977381 51.5	- 1788477	3039359 63.5	- 4775535	- 5945383	- 1080467
- 1745108	5000945 0.88	5000944 9.9	2117517 47.8	2117517 47.3	- 9888473	- 2754533	- 1929851	- 5013655	- 5013655	4868320 78.1	4868320 73.3	- 5729191	- 5729191	- 4544259.	- 4544258.	- 4118288	- 4118287	1992341 4.21	3810406 12	3810406 32.2	- 4061737.	4695778 81
- 5058082	1834041 58.1	1834041 52.8	2343555 51.4	2343555 49.5	- 2754533	- 5762326	3533791 44.7	- 1940112	- 1940112	- 1302408	- 1302408	- 3083697	- 3083697	- 3226566	- 3226565	- 1421188	- 1421188	- 1457280	- 2960287	- 2960286	- 1638354	2653715 98.8
3377544 2.97	1188315 52.6	1188315 48.2	- 5658378	- 5658378	- 1929851	3533791 48.5	3781241 68.1	- 1279078	- 1279078	- 4345935	- 4345936	- 9919112	- 9919111	6003889. 415	6003892. 046	- 7201942	- 7201942	- 1163359	1218895 78.4	1218896 18.1	- 2775444	1513491 261
3723180 4.61	- 1065281	2898107 90.5	3957676 4.72	1129117 83	- 5013655	- 1940112	- 1279078	7313182 4.65	- 2904410	- 1301569	4862090 08.3	6188253 7.44	- 4474538	6759766 4.89	- 1047180	- 2911282	- 1118812	- 3181303	6677938 85.6	- 1220356	- 1783688	- 7493314
3723180 4.87	2898107 93.8	- 1065281	1129117 83.9	3957676 3.59	- 5013655	- 1940112	- 1279078	- 2904410	7313182 7.27	4862090 15.8	- 1301569	- 4474538	6188254 1.73	- 1047180	6759766 6.92	- 1118812	- 2911282	- 3181303	- 1220356	6677939 17.4	- 1783688	- 7493314
3360728 97.9	7973240 2.02	- 4632955	- 5201284	3358782 92.4	4868320 71.7	- 1302408	- 4345935	- 1301569	4862090 12.7	7808664 46.1	- 5463901	9693709 5.77	- 2097807	2025199 42.8	- 2037455	- 2111279	1951372 11.2	- 3034742	- 4013756	1080382 69.3	- 3681174	- 2054533
3360728 97.4	- 4632955	7973240 8.37	3358782 90.6	- 5201284	4868320 71.7	- 1302408	- 4345935	4862090 18.5	- 1301569	- 5463901	7808664 62	- 2097807	9693708 6.63	- 2037455	2025199 38.4	1951372 26.7	- 2111280	- 3034742	1080383 39	- 4013756	- 3681174	- 2054533
1053806 25.3	- 1078044	4279714 93.2	3694736 2.26	1425331 87.4	- 5729191	- 3083697	- 9919112	6188253 7.79	- 4474538	9693708 8.18	- 2097808	1895510 4.85	- 6839305	2482734 3.28	- 1094534	- 1111016	- 9767355	- 6122350	4649414 80.1	- 8761417	- 3426657	- 4522625
1053806 25.6	4279714 98.6	- 1078044	1425331 88.8	3694736 0.37	- 5729191	- 3083697	- 9919112	- 4474538	6188254 2.36	- 2097807	9693707 4.94	- 6839306	1895511 2.29	- 1094534	2482734 6.65	- 9767355	- 1111016	- 6122350	- 8761418	4649415 32.4	- 3426657	- 4522625
2105248. 369	- 6192454	9335382 0.83	3184788 0.77	1083251 9.9	- 4544259.	- 3226565	6003890. 688	6759766 5.51	- 1047180	2025199 40.6	- 2037455	2482734 4.3	- 1094534	- 5352786	3969588 2.84	- 6458948	- 1578131	- 5767133	- 1457350	1669838 274	- 2733073	- 1254021
2105248. 502	9335382 1.39	- 6192454	1083251 9.99	3184788 0.52	- 4544259.	- 3226565	6003890. 703	- 1047180	6759766 5.92	- 2037455	2025199 39.1	- 1094534	2482734 4.95	3969588 2.49	- 5352786	- 1578131	- 6458948	- 5767133	1669838 269	- 1457350	- 2733073	- 1254021
8302210 09.3	1819327 32.2	1026654 189	1977381 25.4	- 7812465	- 4118287	- 1421188	- 7201942	- 2911283	- 1118812	- 2111280	1951371 48.2	- 1111016	- 9767355	- 6458948	- 1578131	- 3460342	- 3367118	- 1919475	4567834 97.7	- 2670404	- 8954597	- 3494198
8302210 09.9	1026654 214	1819327 08	- 7812465	1977381 18	- 4118287	- 1421188	- 7201942	- 1118812	- 2911282	1951371 98.4	- 2111280	- 9767355	- 1111016	- 1578131	- 6458947	- 3367118	- 3460342	- 1919475	- 2670404	4567837 11	- 8954597	- 3494198
5344687 04.1	2504947 99.4	2504947 89.3	- 1788477	- 1788477	1992342 2.24	- 1457280	- 1163359	- 3181303	- 3181303	- 3034743	- 3034743	- 6122350	- 6122350	- 5767134	- 5767133	- 1919475	- 1919475	- 1304572	- 2346534	- 2346534	- 7169486	- 1489473
1964467 61.4	- 4858904	8115592 16.8	- 4775535	3039359 42	3810406 24.3	- 2960286	1218896 03.8	6677938 99.7	- 1220356	- 4013756	1080382 88.9	4649415 04.1	- 8761417	- 1457350	1669838 273	4567836 15.4	- 2670404	- 2346534	7983094 13.5	- 4530143	- 5632913	- 3107457
1964467 63.1	8115592 15.1	- 4858904	3039359 41.4	- 4775535	3810406 24.5	- 2960286	1218896 04	- 1220356	6677938 96.8	1080382 89.4	- 4013756	- 8761417	4649415 00.7	1669838 273	- 1457350	- 2670404	4567836 09.7	- 2346534	- 4530143	7983094 29.8	- 5632913	- 3107457
2596694 776	1413084 552	1413084 497	- 5945384	- 5945384	- 4061694.	- 1638354	- 2775444	- 1783688	- 1783688	- 3681175	- 3681176	- 3426657	- 3426657	- 2733074	- 2733073	- 8954597	- 8954597	- 7169486	- 5632913	- 5632913	- 3775305	- 1299213
8584169 05.1	6653075 09.3	6653074 57.1	- 1080467	- 1080467	4695779 03.7	2653716 58.6	1513491 292	- 7493314	- 7493314	- 2054533	- 2054533	- 4522625	- 4522624	- 1254021	- 1254021	- 3494198	- 3494198	- 1489473	- 3107457	- 3107457	- 1299213	1878214 770

Table 23:CC matrix inverse for concrete mix proportions from observation point 49-60 [TEST E – MODEL 2]

-5119663	92698390.06	-6787721	-26469366	331881661.4	-8831382	-8583441	-3973010	-9392163	38167785.92	-78325650	3.17639E-12	311430144.3	-18381417	88916020.88	254177947.9	340694617.1	551818114.4	-2943408	604722341.7	885817569.7	-62308687	9354056224
92698390.56	36157447.16	-9270084	-32387675	163923226.8	10318866.53	31822040.93	45670313.64	-1340363	92721116.6	-49694610	-5.97193E	217648205	-17450322	-1045581	25503556.68	280954581.5	-64804310	253706945.6	-25566487	-62478921	215374195.7	4328650696
-6787721	-9270084	289714740.3	811979911	-6178437	-4707518	-1612353	213240515	54749864.01	-2599509	620626419	8.60416E-13	-7545550	419613151.6	78516388.61	-3125025	-62758883	-61520500	-1093211	-81607419	-89081394	-27050015	-83437329
-2646936	-3238767	811979910	1927888688	-1257904	-5677361	-4458343	353652513.3	209112170.9	-7212741	2162378616	-1.80309E	-1653257	729058282.6	263152961.3	-9150371	-11436893	-14140740	-3581495	-17915654	-11535956	-92901367	-31608800
331881664.5	163923227.7	-6178437	-12579043	612364112.5	156458493	271418362	-2689093	-4711110	592001257	-19896605	-6.51494E	885359726.3	-40487901	-4450220	368744407.8	1528859647	1333690142	990583305.6	691526094	1046114435	1712233679	15472022213
-8831382	10318866.41	-4707518	-56773612	156458492.6	57633198.11	23978538.4	46380887.19	-1932994	27882377.36	-27995697	2.11253E-12	135733081.1	-41280591	53547233.48	112616301.4	66020338.95	141481569.2	-3022493	688271488.2	788742503	-73161314	-27594440
-8583441	31822039.63	-1612353	-44583433	271418354.5	2397854 38	123349415.3	6757851.513	-1987894	138929979.6	-94169635	-8.13686E	578373505.1	-17050591	-1730368	25654827.34	407474961.8	661305268.7	-9901482	-69448125	-35652510	274219491.1	8877737902
-3973010	45670310.24	213240522.3	353652535	-2689093	46380886.87	6757844.745	1642482269	-1137844	-2516276	81737502.04	8.75423E-13	55198777	572015743.4	170417093.4	-2043577.	-15022448	-17225647	-1143120	-11065306	-13998701	-26526536	-93520745
-9392163	-1340363	54749863.78	209112171	-4711110	-1932994	-1987895	-1137844	-5064914.	-6134520	390265998.3	8.30196E-13	-1087480	93481599.24	105475355.4	37915157.5	-66147527	203759815.7	-2738389	112893965.4	790422595.9	-27930040	-20768793
38167786.69	92721116.85	-2599509	-72127417	592001256.5	27882377.8	138929983.5	-2516276	-6134520	228979966.8	-52904864	-4.22429E	687742178	-39199459	-4477259	315609758.5	616781804.4	720957221.4	24787732.86	881303048.7	701837775.7	120379607.3	8347417477
-7828435	-4969201	620535277.8	2162115626	-1989488	-2798093	-9411998	81694376.49	390254442.4	-5289639	544957831.5	-115167.5	-1815380	1631054730	537267563.4	-6128003	378976057.9	-10902453	-1769846	776626512	-11795323	-23687507	-61780824
-41298.17	-25915.69	91127.67635	262955.4042	-171887.6	-14761.08	-49652.11	43097.10125	11552.47791	-84727.34	172259.0492	115167.5688	-229111.2	131871.7484	40306.31764	-80152.91	-110667.8	-264555.5	-93366.58	-3829.607	-208719.5	-124961.2	-3259189.
311430147.9	217648206.1	-7545550	-16532572	885359727	135733082.1	578373515.2	55198795.36	-1087480	687742179.3	-18156100	-2.38565E	1384164764	-49609941	-2709695	740882675.1	247215312.8	952724703.9	513389965.6	-18028173	1058101877	801357711.5	19006685481
-1838141	-1745032	419613150.3	729058281.4	-4048790	-4128059	-1705059	572015731.5	93481599	-3919945	1631186619	2.07547E-12	-4960994	218076237.5	307403535.5	-3153275	-15456523	-17540562	-6062545	-54726397	-96153503	-69716702	-20077247
88916021.31	-1045581	78516387.04	263152956.3	-4450220	53547233.05	-1730368	170417090.7	105475354.9	-4477259	537307868.2	-3.88133E	-2709695	307403532.8	-5901114	-2473604	-10751900	-48224677	354986030.9	1232349981	-16520468	1303765458	-80110282
254177949.8	25503557.82	-3125025	-91503713	368744411	112616301.5	25654832.47	-2043568.	37915156.73	315609759.8	-61288049	-5.36999E	740882678.1	-31532757	-2473604	100442041.2	166663192.5	-22257735	728608902.2	124464347.3	1793234087	1803819821	5031192961
340694617.5	280954581.6	-6275888	-11436893	1528859642	66020338.24	407474968.1	-1502244	-6614752	616781800.6	378865369.5	-2.81624E	247215303	-15456523	-1075190	166663186.6	1336537505	1960020156	2124803431	-64264183	783011424.7	94599713.52	-19122655
551818118.7	-6480430	-6152050	-14140740	1333690167	141481569.5	661305283.3	-1722564	203759811.6	720957230.7	-10905099	-2.18341E	952724731.5	-17540562	-4822467	-2225773	1960020184	3254745362	2602109785	49330392.93	1177628007	733423360.3	14749281705
-2943408	253706944.2	-1093211	-35814952	990583298.3	-3022493	-9901482	-1143120	-2738389	24787731.2	-17707801	6.48613E-12	513389957.2	-60625452	354986030.5	728608898.5	2124803431	2602109780	-1086118	-86774730	-23224940	-21787372	24088095089
604722347.9	-2556648	-8160742	-17915659	691526129	688271490.3	-6944812	-1106530	112893962.1	881303064.2	776622630.3	-2.30482E	-1802812	-54726400	1232349976	124464365.3	-64264180	49330404.89	-8677472	4813846555	4336722790	774206878.8	-17338211
885817571.3	-6247891	-8908139	-11535957	1046114512	788742501.7	-3565250	-1399870	790422583	701837801.4	-11797411	-4.83691E	1058101956	-96153508	-1652046	1793234133	783011518	1177628080	-2322494	4336722782	6260558684	1624753005	4845398307
-6230868	215374200.4	-2705001	-92901398	1712233703	-7316131	274219502.5	-2652653	-2793004	120379619.7	-23700006	1.08922E-11	801357739.7	-69716703	1303765455	1803819838	94599756	733423399.4	-2178737	774206875.1	1624753091	-36587758	20037314722
9354056291	4328650704	-8343732	-31608800	15472022158	-2759443	8877738039	-9352074	-2076879	8347417483	-61813421	-5.96513E	19006685424	-20077247	-8011028	5031192870	-19122655	14749281207	24088095266	-17338211	4845396913	20037314364	89379013317

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Table 24: Z matrix for concrete mix proportions from observation point 1-12 [TEST A – MODEL 3]

z1	z2	z3	z11	z12	z13	z22	z23	z33	z112	z113	z122	z123	z133	z223	z233	z1122	z1123	z1133	z1223	z1233	z2233	z11223	z11233	z12233	z112233
0.130435	0.217391	0.652174	0.017013	0.028355	0.085066	0.047259	0.141777	0.425331	0.003699	0.011096	0.006164	0.018493	0.055478	0.030821	0.092463	0.000804	0.002412	0.007236	0.00402	0.01206	0.020101	0.000524	0.001573	0.002622	0.000342
0.130435	0.434783	0.434783	0.017013	0.056711	0.056711	0.189036	0.189036	0.189036	0.007397	0.007397	0.024657	0.024657	0.024657	0.08219	0.08219	0.003216	0.003216	0.003216	0.01072	0.01072	0.035735	0.001398	0.001398	0.004661	0.000608
0.130435	0.652174	0.217391	0.017013	0.085066	0.028355	0.425331	0.141777	0.047259	0.011096	0.003699	0.055478	0.018493	0.006164	0.092463	0.030821	0.007236	0.002412	0.000804	0.01206	0.00402	0.020101	0.001573	0.000524	0.002622	0.000342
0.142857	0.214286	0.642857	0.020408	0.030612	0.091837	0.045918	0.137755	0.413265	0.004373	0.01312	0.00656	0.019679	0.059038	0.029519	0.088557	0.000937	0.002811	0.008434	0.004217	0.012651	0.018976	0.000602	0.001807	0.002711	0.000387
0.142857	0.428571	0.428571	0.020408	0.061224	0.061224	0.183673	0.183673	0.183673	0.008746	0.008746	0.026239	0.026239	0.026239	0.078717	0.078717	0.003748	0.003748	0.003748	0.011245	0.011245	0.033736	0.001606	0.001606	0.004819	0.000688
0.142857	0.642857	0.214286	0.020408	0.091837	0.030612	0.413265	0.137755	0.045918	0.01312	0.004373	0.059038	0.019679	0.00656	0.088557	0.029519	0.008434	0.002811	0.000937	0.012651	0.004217	0.018976	0.001807	0.000602	0.002711	0.000387
0.15493	0.211268	0.633803	0.024003	0.032732	0.098195	0.044634	0.133902	0.401706	0.005071	0.015213	0.006915	0.020745	0.062236	0.028289	0.084867	0.001071	0.003214	0.009642	0.004383	0.013148	0.01793	0.000679	0.002037	0.002778	0.00043
0.15493	0.422535	0.422535	0.024003	0.065463	0.065463	0.178536	0.178536	0.178536	0.010142	0.010142	0.027661	0.027661	0.027661	0.075438	0.075438	0.004285	0.004285	0.004285	0.011688	0.011688	0.031875	0.001811	0.001811	0.004938	0.000765
0.15493	0.633803	0.211268	0.024003	0.098195	0.032732	0.401706	0.133902	0.044634	0.015213	0.005071	0.062236	0.020745	0.006915	0.084867	0.028289	0.009642	0.003214	0.001071	0.013148	0.004383	0.01793	0.002037	0.000679	0.002778	0.00043
0.166667	0.208333	0.625	0.027778	0.034722	0.104167	0.043403	0.130208	0.390625	0.005787	0.017361	0.007234	0.021701	0.065104	0.027127	0.08138	0.001206	0.003617	0.010851	0.004521	0.013563	0.016954	0.000754	0.002261	0.002826	0.000471
0.166667	0.416667	0.416667	0.027778	0.069444	0.069444	0.173611	0.173611	0.173611	0.011574	0.011574	0.028935	0.028935	0.028935	0.072338	0.072338	0.004823	0.004823	0.004823	0.012056	0.012056	0.030141	0.002009	0.002009	0.005023	0.000837
0.166667	0.625	0.208333	0.027778	0.104167	0.034722	0.390625	0.130208	0.043403	0.017361	0.005787	0.065104	0.021701	0.007234	0.08138	0.027127	0.010851	0.003617	0.001206	0.013563	0.004521	0.016954	0.002261	0.000754	0.002826	0.000471

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Table 25: Z matrix values [for concrete mix proportions from observation point 13-24][TEST B – MODEL 3]

z1	z2	z3	z11	z12	z13	z22	z23	z33	z112	z113	z122	z123	z133	z223	z233	z1122	z1123	z1133	z1223	z1233	z2233	z11223	z11233	z12233	z112233
0.090909	0.227273	0.681818	0.008264	0.020661	0.061983	0.051653	0.154959	0.464876	0.001878	0.005635	0.004696	0.014087	0.042261	0.035218	0.105654	0.000427	0.001281	0.003842	0.003202	0.009605	0.024012	0.000291	0.000873	0.002183	0.000198
0.090909	0.454545	0.454545	0.008264	0.041322	0.041322	0.206612	0.206612	0.206612	0.003757	0.003757	0.018783	0.018783	0.018783	0.093914	0.093914	0.001708	0.001708	0.001708	0.008538	0.008538	0.042688	0.000776	0.000776	0.003881	0.000353
0.090909	0.681818	0.227273	0.008264	0.061983	0.020661	0.464876	0.154959	0.051653	0.005635	0.001878	0.042261	0.014087	0.004696	0.105654	0.035218	0.003842	0.001281	0.000427	0.009605	0.003202	0.024012	0.000873	0.000291	0.002183	0.000198
0.1	0.225	0.675	0.01	0.0225	0.0675	0.050625	0.151875	0.455625	0.00225	0.00675	0.005063	0.015188	0.045563	0.034172	0.102516	0.000506	0.001519	0.004556	0.003417	0.010252	0.023066	0.000342	0.001025	0.002307	0.000231
0.1	0.45	0.45	0.01	0.045	0.045	0.2025	0.2025	0.2025	0.0045	0.0045	0.02025	0.02025	0.02025	0.091125	0.091125	0.002025	0.002025	0.002025	0.009113	0.009113	0.041006	0.000911	0.000911	0.004101	0.00041
0.1	0.675	0.225	0.01	0.0675	0.0225	0.455625	0.151875	0.050625	0.00675	0.00225	0.045563	0.015188	0.005063	0.102516	0.034172	0.004556	0.001519	0.000506	0.010252	0.003417	0.023066	0.001025	0.000342	0.002307	0.000231
0.108911	0.222772	0.668317	0.011862	0.024262	0.072787	0.049627	0.148882	0.446647	0.002642	0.007927	0.005405	0.016215	0.048645	0.033167	0.099501	0.000589	0.001766	0.005298	0.003612	0.010837	0.022166	0.000393	0.00118	0.002414	0.000263
0.108911	0.445545	0.445545	0.011862	0.048525	0.048525	0.19851	0.19851	0.19851	0.005285	0.005285	0.02162	0.02162	0.02162	0.088445	0.088445	0.002355	0.002355	0.002355	0.009633	0.009633	0.039406	0.001049	0.001049	0.004292	0.000467
0.108911	0.668317	0.222772	0.011862	0.072787	0.024262	0.446647	0.148882	0.049627	0.007927	0.002642	0.048645	0.016215	0.005405	0.099501	0.033167	0.005298	0.001766	0.000589	0.010837	0.003612	0.022166	0.00118	0.000393	0.002414	0.000263
0.117647	0.220588	0.661765	0.013841	0.025952	0.077855	0.048659	0.145978	0.437933	0.003053	0.009159	0.005725	0.017174	0.051521	0.032201	0.096603	0.000673	0.00202	0.006061	0.003788	0.011365	0.021309	0.000446	0.001337	0.002507	0.000295
0.117647	0.441176	0.441176	0.013841	0.051903	0.051903	0.194637	0.194637	0.194637	0.006106	0.006106	0.022898	0.022898	0.022898	0.085869	0.085869	0.002694	0.002694	0.002694	0.010102	0.010102	0.037883	0.001188	0.001188	0.004457	0.000524
0.117647	0.661765	0.220588	0.013841	0.077855	0.025952	0.437933	0.145978	0.048659	0.009159	0.003053	0.051521	0.017174	0.005725	0.096603	0.032201	0.006061	0.00202	0.000673	0.011365	0.003788	0.021309	0.001337	0.000446	0.002507	0.000295

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[for concrete mix proportions from observation point 25-36][TEST C– MODEL 3]

z1	z2	z3	z12	z13	z23	z123	z11	z22	z33	z112	z113	z122	z133	z223	z233	z1122	z1123	z1133	z1223	z1233	z2233	z11223	z11233	z12233	z112233
0.069767	0.232558	0.697674	0.016225	0.048675	0.16225	0.01132	0.004867	0.054083	0.48675	0.001132	0.003396	0.003773	0.033959	0.037733	0.113198	0.000263	0.00079	0.002369	0.002633	0.007898	0.026325	0.000183663	0.000551	0.001837	0.000128
0.069767	0.465116	0.465116	0.03245	0.03245	0.216333	0.015093	0.004867	0.216333	0.216333	0.002264	0.002264	0.015093	0.015093	0.10062	0.10062	0.001053	0.001053	0.001053	0.00702	0.00702	0.0468	0.000489768	0.00049	0.003265	0.000228
0.069767	0.697674	0.232558	0.048675	0.016225	0.16225	0.01132	0.004867	0.48675	0.054083	0.003396	0.001132	0.033959	0.003773	0.113198	0.037733	0.002369	0.00079	0.000263	0.007898	0.002633	0.026325	0.000550989	0.000184	0.001837	0.000128
0.076923	0.230769	0.692308	0.017751	0.053254	0.159763	0.012289	0.005917	0.053254	0.47929	0.001365	0.004096	0.004096	0.036868	0.036868	0.110605	0.000315	0.000945	0.002836	0.002836	0.008508	0.025524	0.000218157	0.000654	0.001963	0.000151
0.076923	0.461538	0.461538	0.035503	0.035503	0.213018	0.016386	0.005917	0.213018	0.213018	0.002731	0.002731	0.016386	0.016386	0.098316	0.098316	0.00126	0.00126	0.00126	0.007563	0.007563	0.045377	0.000581751	0.000582	0.003491	0.000269
0.076923	0.692308	0.230769	0.053254	0.017751	0.159763	0.012289	0.005917	0.47929	0.053254	0.004096	0.001365	0.036868	0.004096	0.110605	0.036868	0.002836	0.000945	0.000315	0.008508	0.002836	0.025524	0.00065447	0.000218	0.001963	0.000151
0.083969	0.229008	0.687023	0.01923	0.057689	0.157333	0.013211	0.007051	0.052444	0.472	0.001615	0.004844	0.004404	0.039634	0.036031	0.108092	0.00037	0.001109	0.003328	0.003025	0.009076	0.024754	0.000254047	0.000762	0.002079	0.000175
0.083969	0.458015	0.458015	0.038459	0.038459	0.209778	0.017615	0.007051	0.209778	0.209778	0.003229	0.003229	0.017615	0.017615	0.096082	0.096082	0.001479	0.001479	0.001479	0.008068	0.008068	0.044007	0.000677458	0.000677	0.003695	0.00031
0.083969	0.687023	0.229008	0.057689	0.01923	0.157333	0.013211	0.007051	0.472	0.052444	0.004844	0.001615	0.039634	0.004404	0.108092	0.036031	0.003328	0.001109	0.00037	0.009076	0.003025	0.024754	0.000762141	0.000254	0.002079	0.000175
0.090909	0.227273	0.681818	0.020661	0.061983	0.154959	0.014087	0.008264	0.051653	0.464876	0.001878	0.005635	0.004696	0.042261	0.035218	0.105654	0.000427	0.001281	0.003842	0.003202	0.009605	0.024012	0.000291057	0.000873	0.002183	0.000198
0.090909	0.454545	0.454545	0.041322	0.041322	0.206612	0.018783	0.008264	0.206612	0.206612	0.003757	0.003757	0.018783	0.018783	0.093914	0.093914	0.001708	0.001708	0.001708	0.008538	0.008538	0.042688	0.000776152	0.000776	0.003881	0.000353
0.090909	0.681818	0.227273	0.061983	0.020661	0.154959	0.014087	0.008264	0.464876	0.051653	0.005635	0.001878	0.042261	0.004696	0.105654	0.035218	0.003842	0.001281	0.000427	0.009605	0.003202	0.024012	0.000873171	0.000291	0.002183	0.000198

Table 26: Z matrix values

[for concrete mix proportions from observation point 37-48] [TEST D – MODEL 3]

z1	z2	z3	z12	z13	z23	z123	z11	z22	z33	z112	z113	z122	z133	z223	z233	z1122	z1123	z1133	z1223	z1233	z2233	z11223	z11233	z12233	z112233
0.056604	0.235849	0.707547	0.01335	0.04005	0.166874	0.009446	0.003204	0.055625	0.500623	0.000756	0.002267	0.003149	0.028337	0.039357	0.118071	0.000178	0.000535	0.001604	0.002228	0.006683	0.027847	0.0001261	0.000378	0.001576	8.92E-05
0.056604	0.471698	0.471698	0.0267	0.0267	0.222499	0.012594	0.003204	0.222499	0.222499	0.001511	0.001511	0.012594	0.012594	0.104952	0.104952	0.000713	0.000713	0.000713	0.005941	0.005941	0.049506	0.000336266	0.000336	0.002802	0.000159
0.056604	0.707547	0.235849	0.04005	0.01335	0.166874	0.009446	0.003204	0.500623	0.055625	0.002267	0.000756	0.028337	0.003149	0.118071	0.039357	0.001604	0.000535	0.000178	0.006683	0.002228	0.027847	0.000378299	0.000126	0.001576	8.92E-05
0.0625	0.234375	0.703125	0.014648	0.043945	0.164795	0.0103	0.003906	0.054932	0.494385	0.000916	0.002747	0.003433	0.030899	0.038624	0.115871	0.000215	0.000644	0.001931	0.002414	0.007242	0.027157	0.000150874	0.000453	0.001697	0.000106
0.0625	0.46875	0.46875	0.029297	0.029297	0.219727	0.013733	0.003906	0.219727	0.219727	0.001831	0.001831	0.013733	0.013733	0.102997	0.102997	0.000858	0.000858	0.000858	0.006437	0.006437	0.04828	0.000402331	0.000402	0.003017	0.000189
0.0625	0.703125	0.234375	0.043945	0.014648	0.164795	0.0103	0.003906	0.494385	0.054932	0.002747	0.000916	0.030899	0.003433	0.115871	0.038624	0.001931	0.000644	0.000215	0.007242	0.002414	0.027157	0.000452623	0.000151	0.001697	0.000106
0.068323	0.232919	0.698758	0.015914	0.047741	0.162754	0.01112	0.004668	0.054251	0.488262	0.001087	0.003262	0.003707	0.03336	0.037909	0.113726	0.000253	0.00076	0.002279	0.00259	0.00777	0.026489	0.000176958	0.000531	0.00181	0.000124
0.068323	0.465839	0.465839	0.031827	0.031827	0.217006	0.014826	0.004668	0.217006	0.217006	0.002175	0.002175	0.014826	0.014826	0.10109	0.10109	0.001013	0.001013	0.001013	0.006907	0.006907	0.047091	0.000471889	0.000472	0.003217	0.00022
0.068323	0.698758	0.232919	0.047741	0.015914	0.162754	0.01112	0.004668	0.488262	0.054251	0.003262	0.001087	0.03336	0.003707	0.113726	0.037909	0.002279	0.00076	0.000253	0.00777	0.00259	0.026489	0.000530875	0.000177	0.00181	0.000124
0.074074	0.231481	0.694444	0.017147	0.05144	0.160751	0.011907	0.005487	0.053584	0.482253	0.00127	0.00381	0.003969	0.035722	0.037211	0.111633	0.000294	0.000882	0.002646	0.002756	0.008269	0.025841	0.000204175	0.000613	0.001914	0.000142
0.074074	0.462963	0.462963	0.034294	0.034294	0.214335	0.015877	0.005487	0.214335	0.214335	0.00254	0.00254	0.015877	0.015877	0.099229	0.099229	0.001176	0.001176	0.001176	0.00735	0.00735	0.045939	0.000544467	0.000544	0.003403	0.000252
0.074074	0.694444	0.231481	0.05144	0.017147	0.160751	0.011907	0.005487	0.482253	0.053584	0.00381	0.00127	0.035722	0.003969	0.111633	0.037211	0.002646	0.000882	0.000294	0.008269	0.002756	0.025841	0.000612525	0.000204	0.001914	0.000142

[for concrete mix proportions from observation point 49-60] [TEST E – MODEL 3]

z1	z2	z3	z12	z13	z23	z123	z11	z22	z33	z112	z113	z122	z133	z223	z233	z1122	z1123	z1133	z1223	z1233	z2233	z11223	z11233	z12233	z112233
0.047619	0.238095	0.714286	0.011338	0.034014	0.170068	0.008098	0.002268	0.056689	0.510204	0.00054	0.00162	0.002699	0.024295	0.040492	0.121477	0.000129	0.000386	0.001157	0.001928	0.005785	0.028923	9.18195E-05	0.000275	0.001377	6.56E-05
0.047619	0.47619	0.47619	0.022676	0.022676	0.226757	0.010798	0.002268	0.226757	0.226757	0.00108	0.00108	0.010798	0.010798	0.10798	0.10798	0.000514	0.000514	0.000514	0.005142	0.005142	0.051419	0.000244852	0.000245	0.002449	0.000117
0.047619	0.714286	0.238095	0.034014	0.011338	0.170068	0.008098	0.002268	0.510204	0.056689	0.00162	0.00054	0.024295	0.002699	0.121477	0.040492	0.001157	0.000386	0.000129	0.005785	0.001928	0.028923	0.000275458	9.18E-05	0.001377	6.56E-05
0.052632	0.236842	0.710526	0.012465	0.037396	0.168283	0.008857	0.00277	0.056094	0.504848	0.000656	0.001968	0.002952	0.026571	0.039856	0.119569	0.000155	0.000466	0.001398	0.002098	0.006293	0.028319	0.000110406	0.000331	0.00149	7.84E-05
0.052632	0.473684	0.473684	0.024931	0.024931	0.224377	0.011809	0.00277	0.224377	0.224377	0.001312	0.001312	0.011809	0.011809	0.106284	0.106284	0.000622	0.000622	0.000622	0.005594	0.005594	0.050345	0.000294415	0.000294	0.00265	0.000139
0.052632	0.710526	0.236842	0.037396	0.012465	0.168283	0.008857	0.00277	0.504848	0.056094	0.001968	0.000656	0.026571	0.002952	0.119569	0.039856	0.001398	0.000466	0.000155	0.006293	0.002098	0.028319	0.000331217	0.00011	0.00149	7.84E-05
0.057592	0.235602	0.706806	0.013569	0.040706	0.166525	0.00959	0.003317	0.055508	0.499575	0.000781	0.002344	0.003197	0.028771	0.039234	0.117701	0.000184	0.000552	0.001657	0.00226	0.006779	0.027731	0.00013013	0.00039	0.001597	9.2E-05
0.057592	0.471204	0.471204	0.027137	0.027137	0.222033	0.012787	0.003317	0.222033	0.222033	0.001563	0.001563	0.012787	0.012787	0.104623	0.104623	0.000736	0.000736	0.000736	0.006025	0.006025	0.049299	0.000347013	0.000347	0.002839	0.000164
0.057592	0.706806	0.235602	0.040706	0.013569	0.166525	0.00959	0.003317	0.499575	0.055508	0.002344	0.000781	0.028771	0.003197	0.117701	0.039234	0.001657	0.000552	0.000184	0.006779	0.00226	0.027731	0.00039039	0.00013	0.001597	9.2E-05
0.0625	0.234375	0.703125	0.014648	0.043945	0.164795	0.0103	0.003906	0.054932	0.494385	0.000916	0.002747	0.003433	0.030899	0.038624	0.115871	0.000215	0.000644	0.001931	0.002414	0.007242	0.027157	0.000150874	0.000453	0.001697	0.000106
0.0625	0.46875	0.46875	0.029297	0.029297	0.219727	0.013733	0.003906	0.219727	0.219727	0.001831	0.001831	0.013733	0.013733	0.102997	0.102997	0.000858	0.000858	0.000858	0.006437	0.006437	0.04828	0.000402331	0.000402	0.003017	0.000189
0.0625	0.703125	0.234375	0.043945	0.014648	0.164795	0.0103	0.003906	0.494385	0.054932	0.002747	0.000916	0.030899	0.003433	0.115871	0.038624	0.001931	0.000644	0.000215	0.007242	0.002414	0.027157	0.000452623	0.000151	0.001697	0.000106

Table 27:CC matrix for concrete mix proportions from observation point 1-12

[TEST A – MODEL 3]

0.131900626	0.560250248	0.560250248	0.01401451	0.058943058	0.058943058	0.292429194	0.208877996	0.292429194	0.006256404	0.006256404	0.030733881	0.021952772	0.030733881	0.093462612	0.093462612	0.003258884	0.002327775	0.003258884	0.009812499	0.009812499	0.035551298	0.001039415	0.001039415	0.003728561	0.000394554
0.560250248	2.807903695	2.005645496	0.058943058	0.292429194	0.208877996	1.61709075	0.89838375	0.89838375	0.030733881	0.021952772	0.168232701	0.093462612	0.093462612	0.462829655	0.342091484	0.017662498	0.009812499	0.009812499	0.048098815	0.035551298	0.153270093	0.005044523	0.003728561	0.015911369	0.001667003
0.560250248	2.005645496	2.807903695	0.058943058	0.208877996	0.292429194	0.89838375	0.89838375	1.61709075	0.021952772	0.030733881	0.093462612	0.093462612	0.168232701	0.342091484	0.462829655	0.009812499	0.009812499	0.017662498	0.035551298	0.048098815	0.153270093	0.003728561	0.005044523	0.015911369	0.001667003
0.01401451	0.058943058	0.058943058	0.001501701	0.006256404	0.006256404	0.030733881	0.021952772	0.030733881	0.000669745	0.000669745	0.003258884	0.002327775	0.003258884	0.009812499	0.009812499	0.000348523	0.000248945	0.000348523	0.001039415	0.001039415	0.003728561	0.000111052	0.000111052	0.000394554	4.21E-05
0.058943058	0.292429194	0.208877996	0.006256404	0.030733881	0.021952772	0.168232701	0.093462612	0.093462612	0.003258884	0.002327775	0.017662498	0.009812499	0.009812499	0.048098815	0.035551298	0.001870947	0.001039415	0.001039415	0.005044523	0.003728561	0.015911369	0.000533809	0.000394554	0.001667003	0.000176221
0.058943058	0.208877996	0.292429194	0.006256404	0.021952772	0.030733881	0.093462612	0.093462612	0.168232701	0.002327775	0.003258884	0.009812499	0.009812499	0.017662498	0.035551298	0.048098815	0.001039415	0.001039415	0.001870947	0.003728561	0.005044523	0.015911369	0.000394554	0.000533809	0.001667003	0.000176221
0.292429194	1.61709075	0.89838375	0.030733881	0.168232701	0.093462612	0.986028395	0.462829655	0.342091484	0.017662498	0.009812499	0.102471388	0.048098815	0.035551298	0.261460747	0.153270093	0.010747028	0.005044523	0.003728561	0.027142923	0.015911369	0.077769278	0.002843711	0.001667003	0.008064825	0.000844046
0.208877996	0.89838375	0.89838375	0.021952772	0.093462612	0.093462612	0.462829655	0.342091484	0.462829655	0.009812499	0.009812499	0.048098815	0.035551298	0.048098815	0.153270093	0.153270093	0.005044523	0.003728561	0.005044523	0.015911369	0.015911369	0.059589447	0.001667003	0.001667003	0.006179541	0.000646737
0.292429194	0.89838375	1.61709075	0.030733881	0.093462612	0.168232701	0.342091484	0.462829655	0.986028395	0.009812499	0.017662498	0.035551298	0.048098815	0.102471388	0.153270093	0.261460747	0.003728561	0.005044523	0.010747028	0.015911369	0.027142923	0.077769278	0.001667003	0.002843711	0.008064825	0.000844046
0.006256404	0.030733881	0.021952772	0.000669745	0.003258884	0.002327775	0.017662498	0.009812499	0.009812499	0.000348523	0.000248945	0.001870947	0.001039415	0.001039415	0.005044523	0.003728561	0.000199893	0.000111052	0.000111052	0.000533809	0.000394554	0.001667003	5.70E-05	4.21E-05	0.000176221	1.88E-05
0.006256404	0.021952772	0.030733881	0.000669745	0.002327775	0.003258884	0.009812499	0.009812499	0.017662498	0.000248945	0.000348523	0.001039415	0.001039415	0.001870947	0.003728561	0.005044523	0.000111052	0.000111052	0.000199893	0.000394554	0.000533809	0.001667003	4.21E-05	5.70E-05	0.000176221	1.88E-05
0.030733881	0.168232701	0.093462612	0.003258884	0.017662498	0.009812499	0.102471388	0.048098815	0.035551298	0.001870947	0.001039415	0.010747028	0.005044523	0.003728561	0.027142923	0.015911369	0.001137245	0.000533809	0.000394554	0.002843711	0.001667003	0.008064825	0.000300612	0.000176221	0.000844046	8.91E-05
0.021952772	0.093462612	0.093462612	0.002327775	0.009812499	0.009812499	0.048098815	0.035551298	0.048098815	0.001039415	0.001039415	0.005044523	0.003728561	0.005044523	0.015911369	0.015911369	0.000533809	0.000394554	0.000533809	0.001667003	0.001667003	0.006179541	0.000176221	0.000176221	0.000646737	6.83E-05
0.030733881	0.093462612	0.168232701	0.003258884	0.009812499	0.017662498	0.035551298	0.048098815	0.102471388	0.001039415	0.001870947	0.003728561	0.005044523	0.010747028	0.015911369	0.027142923	0.000394554	0.000533809	0.001137245	0.001667003	0.002843711	0.008064825	0.000176221	0.000300612	0.000844046	8.91E-05
0.093462612	0.462829655	0.342091484	0.009812499	0.048098815	0.035551298	0.261460747	0.153270093	0.153270093	0.005044523	0.003728561	0.027142923	0.015911369	0.015911369	0.077769278	0.059589447	0.002843711	0.001667003	0.001667003	0.008064825	0.006179541	0.026704953	0.000844046	0.000646737	0.002766402	0.00028922
0.093462612	0.342091484	0.462829655	0.009812499	0.035551298	0.048098815	0.153270093	0.153270093	0.261460747	0.003728561	0.005044523	0.015911369	0.015911369	0.027142923	0.059589447	0.077769278	0.001667003	0.001667003	0.002843711	0.006179541	0.008064825	0.026704953	0.000646737	0.000844046	0.002766402	0.00028922
0.003258884	0.017662498	0.009812499	0.000348523	0.001870947	0.001039415	0.010747028	0.005044523	0.003728561	0.000199893	0.000111052	0.001137245	0.000533809	0.000394554	0.002843711	0.001667003	0.000121385	5.70E-05	4.21E-05	0.000300612	0.000176221	0.000844046	3.21E-05	1.88E-05	8.91E-05	9.49E-06
0.002327775	0.009812499	0.009812499	0.000248945	0.001039415	0.001039415	0.005044523	0.003728561	0.005044523	0.000111052	0.000111052	0.000533809	0.000394554	0.000533809	0.001667003	0.001667003	5.70E-05	4.21E-05	5.70E-05	0.000176221	0.000176221	0.000646737	1.88E-05	1.88E-05	6.83E-05	7.28E-06
0.003258884	0.009812499	0.017662498	0.000348523	0.001039415	0.001870947	0.003728561	0.005044523	0.010747028	0.000111052	0.000199893	0.000394554	0.000533809	0.001137245	0.001667003	0.002843711	4.21E-05	5.70E-05	0.000121385	0.000176221	0.000300612	0.000844046	1.88E-05	3.21E-05	8.91E-05	9.49E-06
0.009812499	0.048098815	0.035551298	0.001039415	0.005044523	0.003728561	0.027142923	0.015911369	0.015911369	0.000533809	0.000394554	0.002843711	0.001667003	0.001667003	0.008064825	0.006179541	0.000300612	0.000176221	0.000176221	0.000844046	0.000646737	0.002766402	8.91E-05	6.83E-05	0.00028922	3.05E-05
0.009812499	0.035551298	0.048098815	0.001039415	0.003728561	0.005044523	0.015911369	0.015911369	0.027142923	0.000394554	0.000533809	0.001667003	0.001667003	0.002843711	0.006179541	0.008064825	0.000176221	0.000176221	0.000300612	0.000646737	0.000844046	0.002766402	6.83E-05	8.91E-05	0.00028922	3.05E-05
0.035551298	0.153270093	0.153270093	0.003728561	0.015911369	0.015911369	0.077769278	0.059589447	0.077769278	0.001667003	0.001667003	0.008064825	0.006179541	0.008064825	0.026704953	0.026704953	0.000844046	0.000646737	0.000844046	0.002766402	0.002766402	0.010599909	0.00028922	0.00028922	0.001096888	0.000114555
0.001039415	0.005044523	0.003728561	0.000111052	0.000533809	0.000394554	0.002843711	0.001667003	0.001667003	5.70E-05	4.21E-05	0.000300612	0.000176221	0.000176221	0.000844046	0.000646737	3.21E-05	1.88E-05	1.88E-05	8.91E-05	6.83E-05	0.00028922	9.49E-06	7.28E-06	3.05E-05	3.25E-06
0.001039415	0.003728561	0.005044523	0.000111052	0.000394554	0.000533809	0.001667003	0.001667003	0.002843711	4.21E-05	5.70E-05	0.000176221	0.000176221	0.000300612	0.000646737	0.000844046	1.88E-05	1.88E-05	3.21E-05	6.83E-05	8.91E-05	0.00028922	7.28E-06	9.49E-06	3.05E-05	3.25E-06
0.003728561	0.015911369	0.015911369	0.000394554	0.001667003	0.001667003	0.008064825	0.006179541	0.008064825	0.000176221	0.000176221	0.000844046	0.000646737	0.000844046	0.002766402	0.002766402	8.91E-05	6.83E-05	8.91E-05	0.00028922	0.00028922	0.001096888	3.05E-05	3.05E-05	0.000114555	1.21E-05
0.000394554	0.001667003	0.001667003	4.21E-05	0.000176221	0.000176221	0.000844046	0.000646737	0.000844046	1.88E-05	1.88E-05	8.91E-05	6.83E-05	8.91E-05	0.00028922	0.00028922	9.49E-06	7.28E-06	9.49E-06	3.05E-05	3.05E-05	0.000114555	3.25E-06	3.25E-06	1.21E-05	1.28E-06

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Table 28:CC matrix for concrete mix proportions from observation point 13-24 [TEST B – MODEL 3]

0.131900626	0.560250248	0.560250248	0.01401451	0.058943058	0.058943058	0.292429194	0.208877996	0.292429194	0.006256404	0.006256404	0.030733881	0.021952772	0.030733881	0.093462612	0.093462612	0.003258884	0.002327775	0.003258884	0.009812499	0.009812499	0.035551298	0.001039415	0.001039415	0.003728561	0.000394554
0.560250248	2.807903695	2.005645496	0.058943058	0.292429194	0.208877996	1.61709075	0.89838375	0.89838375	0.030733881	0.021952772	0.168232701	0.093462612	0.093462612	0.462829655	0.342091484	0.017662498	0.009812499	0.009812499	0.048098815	0.035551298	0.153270093	0.005044523	0.003728561	0.015911369	0.001667003
0.560250248	2.005645496	2.807903695	0.058943058	0.208877996	0.292429194	0.89838375	0.89838375	1.61709075	0.021952772	0.030733881	0.093462612	0.093462612	0.168232701	0.342091484	0.462829655	0.009812499	0.009812499	0.017662498	0.035551298	0.048098815	0.153270093	0.003728561	0.005044523	0.015911369	0.001667003
0.01401451	0.058943058	0.058943058	0.001501701	0.006256404	0.006256404	0.030733881	0.021952772	0.030733881	0.000669745	0.000669745	0.003258884	0.002327775	0.003258884	0.009812499	0.009812499	0.000348523	0.000248945	0.000348523	0.001039415	0.001039415	0.003728561	0.000111052	0.000111052	0.000394554	4.21E-05
0.058943058	0.292429194	0.208877996	0.006256404	0.030733881	0.021952772	0.168232701	0.093462612	0.093462612	0.003258884	0.002327775	0.017662498	0.009812499	0.009812499	0.048098815	0.035551298	0.001870947	0.001039415	0.001039415	0.005044523	0.003728561	0.015911369	0.000533809	0.000394554	0.001667003	0.000176221
0.058943058	0.208877996	0.292429194	0.006256404	0.021952772	0.030733881	0.093462612	0.093462612	0.168232701	0.002327775	0.003258884	0.009812499	0.009812499	0.017662498	0.035551298	0.048098815	0.001039415	0.001039415	0.001870947	0.003728561	0.005044523	0.015911369	0.000394554	0.000533809	0.001667003	0.000176221
0.292429194	1.61709075	0.89838375	0.030733881	0.168232701	0.093462612	0.986028395	0.462829655	0.342091484	0.017662498	0.009812499	0.102471388	0.048098815	0.035551298	0.261460747	0.153270093	0.010747028	0.005044523	0.003728561	0.027142923	0.015911369	0.077769278	0.002843711	0.001667003	0.008064825	0.000844046
0.208877996	0.89838375	0.89838375	0.021952772	0.093462612	0.093462612	0.462829655	0.342091484	0.462829655	0.009812499	0.009812499	0.048098815	0.035551298	0.048098815	0.153270093	0.153270093	0.005044523	0.003728561	0.005044523	0.015911369	0.015911369	0.059589447	0.001667003	0.001667003	0.006179541	0.000646737
0.292429194	0.89838375	1.61709075	0.030733881	0.093462612	0.168232701	0.342091484	0.462829655	0.986028395	0.009812499	0.017662498	0.035551298	0.048098815	0.102471388	0.153270093	0.261460747	0.003728561	0.005044523	0.010747028	0.015911369	0.027142923	0.077769278	0.001667003	0.002843711	0.008064825	0.000844046
0.006256404	0.030733881	0.021952772	0.000669745	0.003258884	0.002327775	0.017662498	0.009812499	0.009812499	0.000348523	0.000248945	0.001870947	0.001039415	0.001039415	0.005044523	0.003728561	0.000199893	0.000111052	0.000111052	0.000533809	0.000394554	0.001667003	5.70E-05	4.21E-05	0.000176221	1.88E-05
0.006256404	0.021952772	0.030733881	0.000669745	0.002327775	0.003258884	0.009812499	0.009812499	0.017662498	0.000248945	0.000348523	0.001039415	0.001039415	0.001870947	0.003728561	0.005044523	0.000111052	0.000111052	0.000199893	0.000394554	0.000533809	0.001667003	4.21E-05	5.70E-05	0.000176221	1.88E-05
0.030733881	0.168232701	0.093462612	0.003258884	0.017662498	0.009812499	0.102471388	0.048098815	0.035551298	0.001870947	0.001039415	0.010747028	0.005044523	0.003728561	0.027142923	0.015911369	0.001137245	0.000533809	0.000394554	0.002843711	0.001667003	0.008064825	0.000300612	0.000176221	0.000844046	8.91E-05
0.021952772	0.093462612	0.093462612	0.002327775	0.009812499	0.009812499	0.048098815	0.035551298	0.048098815	0.001039415	0.001039415	0.005044523	0.003728561	0.005044523	0.015911369	0.015911369	0.000533809	0.000394554	0.000533809	0.001667003	0.001667003	0.006179541	0.000176221	0.000176221	0.000646737	6.83E-05
0.030733881	0.093462612	0.168232701	0.003258884	0.009812499	0.017662498	0.035551298	0.048098815	0.102471388	0.001039415	0.001870947	0.003728561	0.005044523	0.010747028	0.015911369	0.027142923	0.000394554	0.000533809	0.001137245	0.001667003	0.002843711	0.008064825	0.000176221	0.000300612	0.000844046	8.91E-05
0.093462612	0.462829655	0.342091484	0.009812499	0.048098815	0.035551298	0.261460747	0.153270093	0.153270093	0.005044523	0.003728561	0.027142923	0.015911369	0.015911369	0.077769278	0.059589447	0.002843711	0.001667003	0.001667003	0.008064825	0.006179541	0.026704953	0.000844046	0.000646737	0.002766402	0.00028922
0.093462612	0.342091484	0.462829655	0.009812499	0.035551298	0.048098815	0.153270093	0.153270093	0.261460747	0.003728561	0.005044523	0.015911369	0.015911369	0.027142923	0.059589447	0.077769278	0.001667003	0.001667003	0.002843711	0.006179541	0.008064825	0.026704953	0.000646737	0.000844046	0.002766402	0.00028922
0.003258884	0.017662498	0.009812499	0.000348523	0.001870947	0.001039415	0.010747028	0.005044523	0.003728561	0.000199893	0.000111052	0.001137245	0.000533809	0.000394554	0.002843711	0.001667003	0.000121385	5.70E-05	4.21E-05	0.000300612	0.000176221	0.000844046	3.21E-05	1.88E-05	8.91E-05	9.49E-06
0.002327775	0.009812499	0.009812499	0.000248945	0.001039415	0.001039415	0.005044523	0.003728561	0.005044523	0.000111052	0.000111052	0.000533809	0.000394554	0.000533809	0.001667003	0.001667003	5.70E-05	4.21E-05	5.70E-05	0.000176221	0.000176221	0.000646737	1.88E-05	1.88E-05	6.83E-05	7.28E-06
0.003258884	0.009812499	0.017662498	0.000348523	0.001039415	0.001870947	0.003728561	0.005044523	0.010747028	0.000111052	0.000199893	0.000394554	0.000533809	0.001137245	0.001667003	0.002843711	4.21E-05	5.70E-05	0.000121385	0.000176221	0.000300612	0.000844046	1.88E-05	3.21E-05	8.91E-05	9.49E-06
0.009812499	0.048098815	0.035551298	0.001039415	0.005044523	0.003728561	0.027142923	0.015911369	0.015911369	0.000533809	0.000394554	0.002843711	0.001667003	0.001667003	0.008064825	0.006179541	0.000300612	0.000176221	0.000176221	0.000844046	0.000646737	0.002766402	8.91E-05	6.83E-05	0.00028922	3.05E-05
0.009812499	0.035551298	0.048098815	0.001039415	0.003728561	0.005044523	0.015911369	0.015911369	0.027142923	0.000394554	0.000533809	0.001667003	0.001667003	0.002843711	0.006179541	0.008064825	0.000176221	0.000176221	0.000300612	0.000646737	0.000844046	0.002766402	6.83E-05	8.91E-05	0.00028922	3.05E-05
0.035551298	0.153270093	0.153270093	0.003728561	0.015911369	0.015911369	0.077769278	0.059589447	0.077769278	0.001667003	0.001667003	0.008064825	0.006179541	0.008064825	0.026704953	0.026704953	0.000844046	0.000646737	0.000844046	0.002766402	0.002766402	0.010599909	0.00028922	0.00028922	0.001096888	0.000114555
0.001039415	0.005044523	0.003728561	0.000111052	0.000533809	0.000394554	0.002843711	0.001667003	0.001667003	5.70E-05	4.21E-05	0.000300612	0.000176221	0.000176221	0.000844046	0.000646737	3.21E-05	1.88E-05	1.88E-05	8.91E-05	6.83E-05	0.00028922	9.49E-06	7.28E-06	3.05E-05	3.25E-06
0.001039415	0.003728561	0.005044523	0.000111052	0.000394554	0.000533809	0.001667003	0.001667003	0.002843711	4.21E-05	5.70E-05	0.000176221	0.000176221	0.000300612	0.000646737	0.000844046	1.88E-05	1.88E-05	3.21E-05	6.83E-05	8.91E-05	0.00028922	7.28E-06	9.49E-06	3.05E-05	3.25E-06
0.003728561	0.015911369	0.015911369	0.000394554	0.001667003	0.001667003	0.008064825	0.006179541	0.008064825	0.000176221	0.000176221	0.000844046	0.000646737	0.000844046	0.002766402	0.002766402	8.91E-05	6.83E-05	8.91E-05	0.00028922	0.00028922	0.001096888	3.05E-05	3.05E-05	0.000114555	1.21E-05
0.000394554	0.001667003	0.001667003	4.21E-05	0.000176221	0.000176221	0.000844046	0.000646737	0.000844046	1.88E-05	1.88E-05	8.91E-05	6.83E-05	8.91E-05	0.00028922	0.00028922	9.49E-06	7.28E-06	9.49E-06	3.05E-05	3.05E-05	0.000114555	3.25E-06	3.25E-06	1.21E-05	1.28E-06

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Table 29:CC matrix for concrete mix proportions from observation point 25-36 **[TEST C – MODEL 3]**

0.0783	0.443204	0.443204	0.035943	0.035943	0.169692	0.01375	0.006414	0.237569	0.237569	0.002942	0.002942	0.01925	0.01925	0.077971	0.077971	0.001574	0.001125	0.001574	0.006313	0.006313	0.030455	0.000516	0.000516	0.002464	0.000201
0.443204	2.960092	2.114351	0.237569	0.169692	0.97233	0.077971	0.035943	1.750193	0.97233	0.01925	0.01375	0.140348	0.077971	0.514256	0.380102	0.011363	0.006313	0.006313	0.041203	0.030455	0.174824	0.003333	0.002464	0.013995	0.001131
0.443204	2.114351	2.960092	0.169692	0.237569	0.97233	0.077971	0.035943	0.97233	1.750193	0.01375	0.01925	0.077971	0.140348	0.380102	0.514256	0.006313	0.006313	0.011363	0.030455	0.041203	0.174824	0.002464	0.003333	0.013995	0.001131
0.035943	0.237569	0.169692	0.01925	0.01375	0.077971	0.006313	0.002942	0.140348	0.077971	0.001574	0.001125	0.011363	0.006313	0.041203	0.030455	0.000929	0.000516	0.000516	0.003333	0.002464	0.013995	0.000272	0.000201	0.001131	0.000092
0.035943	0.169692	0.237569	0.01375	0.01925	0.077971	0.006313	0.002942	0.077971	0.140348	0.001125	0.001574	0.006313	0.011363	0.030455	0.041203	0.000516	0.000516	0.000929	0.002464	0.003333	0.013995	0.000201	0.000272	0.001131	0.000092
0.169692	0.97233	0.97233	0.077971	0.077971	0.380102	0.030455	0.01375	0.514256	0.514256	0.006313	0.006313	0.041203	0.041203	0.174824	0.174824	0.003333	0.002464	0.003333	0.013995	0.013995	0.069771	0.001131	0.001131	0.005581	0.000451
0.01375	0.077971	0.077971	0.006313	0.006313	0.030455	0.002464	0.001125	0.041203	0.041203	0.000516	0.000516	0.003333	0.003333	0.013995	0.013995	0.000272	0.000201	0.000272	0.001131	0.001131	0.005581	0.000092	0.000092	0.000451	0.000037
0.006414	0.035943	0.035943	0.002942	0.002942	0.01375	0.001125	0.00053	0.01925	0.01925	0.000243	0.000243	0.001574	0.001574	0.006313	0.006313	0.00013	0.000093	0.00013	0.000516	0.000516	0.002464	0.000043	0.000043	0.000201	0.000017
0.237569	1.750193	0.97233	0.140348	0.077971	0.514256	0.041203	0.01925	1.095589	0.380102	0.011363	0.006313	0.087781	0.030455	0.298229	0.174824	0.007101	0.003333	0.002464	0.023875	0.013995	0.091057	0.00193	0.001131	0.007283	0.000588
0.237569	0.97233	1.750193	0.077971	0.140348	0.514256	0.041203	0.01925	0.380102	1.095589	0.006313	0.011363	0.030455	0.087781	0.174824	0.298229	0.002464	0.003333	0.007101	0.013995	0.023875	0.091057	0.001131	0.00193	0.007283	0.000588
0.002942	0.01925	0.01375	0.001574	0.001125	0.006313	0.000516	0.000243	0.011363	0.006313	0.00013	0.000093	0.000929	0.000516	0.003333	0.002464	0.000077	0.000043	0.000043	0.000272	0.000201	0.001131	0.000022	0.000017	0.000092	0.000008
0.002942	0.01375	0.01925	0.001125	0.001574	0.006313	0.000516	0.000243	0.006313	0.011363	0.000093	0.00013	0.000516	0.000929	0.002464	0.003333	0.000043	0.000043	0.000077	0.000201	0.000272	0.001131	0.000017	0.000022	0.000092	0.000008
0.01925	0.140348	0.077971	0.011363	0.006313	0.041203	0.003333	0.001574	0.087781	0.030455	0.000929	0.000516	0.007101	0.002464	0.023875	0.013995	0.00058	0.000272	0.000201	0.00193	0.001131	0.007283	0.000157	0.000092	0.000588	0.000048
0.01925	0.077971	0.140348	0.006313	0.011363	0.041203	0.003333	0.001574	0.030455	0.087781	0.000516	0.000929	0.002464	0.007101	0.013995	0.023875	0.000201	0.000272	0.00058	0.001131	0.00193	0.007283	0.000092	0.000157	0.000588	0.000048
0.077971	0.514256	0.380102	0.041203	0.030455	0.174824	0.013995	0.006313	0.298229	0.174824	0.003333	0.002464	0.023875	0.013995	0.091057	0.069771	0.00193	0.001131	0.001131	0.007283	0.005581	0.032095	0.000588	0.000451	0.002565	0.000207
0.077971	0.380102	0.514256	0.030455	0.041203	0.174824	0.013995	0.006313	0.174824	0.298229	0.002464	0.003333	0.013995	0.023875	0.069771	0.091057	0.001131	0.001131	0.00193	0.005581	0.007283	0.032095	0.000451	0.000588	0.002565	0.000207
0.001574	0.011363	0.006313	0.000929	0.000516	0.003333	0.000272	0.00013	0.007101	0.002464	0.000077	0.000043	0.00058	0.000201	0.00193	0.001131	0.000048	0.000022	0.000017	0.000157	0.000092	0.000588	0.000013	0.000008	0.000048	0.000004
0.001125	0.006313	0.006313	0.000516	0.000516	0.002464	0.000201	0.000093	0.003333	0.003333	0.000043	0.000043	0.000272	0.000272	0.001131	0.001131	0.000022	0.000017	0.000022	0.000092	0.000092	0.000451	0.000008	0.000008	0.000037	0.000003
0.001574	0.006313	0.011363	0.000516	0.000929	0.003333	0.000272	0.00013	0.002464	0.007101	0.000043	0.000077	0.000201	0.00058	0.001131	0.00193	0.000017	0.000022	0.000048	0.000092	0.000157	0.000588	0.000008	0.000013	0.000048	0.000004
0.006313	0.041203	0.030455	0.003333	0.002464	0.013995	0.001131	0.000516	0.023875	0.013995	0.000272	0.000201	0.00193	0.001131	0.007283	0.005581	0.000157	0.000092	0.000092	0.000588	0.000451	0.002565	0.000048	0.000037	0.000207	0.000017
0.006313	0.030455	0.041203	0.002464	0.003333	0.013995	0.001131	0.000516	0.013995	0.023875	0.000201	0.000272	0.001131	0.00193	0.005581	0.007283	0.000092	0.000092	0.000157	0.000451	0.000588	0.002565	0.000037	0.000048	0.000207	0.000017
0.030455	0.174824	0.174824	0.013995	0.013995	0.069771	0.005581	0.002464	0.091057	0.091057	0.001131	0.001131	0.007283	0.007283	0.032095	0.032095	0.000588	0.000451	0.000588	0.002565	0.002565	0.013076	0.000207	0.000207	0.001044	0.000084
0.000516	0.003333	0.002464	0.000272	0.000201	0.001131	0.000092	0.000043	0.00193	0.001131	0.000022	0.000017	0.000157	0.000092	0.000588	0.000451	0.000013	0.000008	0.000008	0.000048	0.000037	0.000207	0.000004	0.000003	0.000017	0.000001
0.000516	0.002464	0.003333	0.000201	0.000272	0.001131	0.000092	0.000043	0.001131	0.00193	0.000017	0.000022	0.000092	0.000157	0.000451	0.000588	0.000008	0.000008	0.000013	0.000037	0.000048	0.000207	0.000003	0.000004	0.000017	0.000001
0.002464	0.013995	0.013995	0.001131	0.001131	0.005581	0.000451	0.000201	0.007283	0.007283	0.000092	0.000092	0.000588	0.000588	0.002565	0.002565	0.000048	0.000037	0.000048	0.000207	0.000207	0.001044	0.000017	0.000017	0.000084	0.000007
0.000201	0.001131	0.001131	0.000092	0.000092	0.000451	0.000037	0.000017	0.000588	0.000588	0.000008	0.000008	0.000048	0.000048	0.000207	0.000207	0.000004	0.000003	0.000004	0.000017	0.000017	0.000084	0.000001	0.000001	0.000007	0.000001

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Table 30:CC matrix for concrete mix proportions from observation point 37-48 **[TEST D – MODEL 3]**

0.05179571	0.36635339	0.36635339	0.02417154	0.02417154	0.14257577	0.00940057	0.00345262	0.19960608	0.19960608	0.00161018	0.00161018	0.0131608	0.0131608	0.0665876	0.0665876	0.00087612	0.0006258	0.00087612	0.00438738	0.00438738	0.02643509	0.00029188	0.00029188	0.00174059	0.00011572
0.36635339	3.05748063	2.18391474	0.19960608	0.14257577	1.02066948	0.0665876	0.02417154	1.83720507	1.02066948	0.0131608	0.00940057	0.11985768	0.0665876	0.54859708	0.4054848	0.00789729	0.00438738	0.00438738	0.03576513	0.02643509	0.18952485	0.00235491	0.00174059	0.01234725	0.00081244
0.36635339	2.18391474	3.05748063	0.14257577	0.19960608	1.02066948	0.0665876	0.02417154	1.02066948	1.83720507	0.00940057	0.0131608	0.0665876	0.11985768	0.4054848	0.54859708	0.00438738	0.00438738	0.00789729	0.02643509	0.03576513	0.18952485	0.00174059	0.00235491	0.01234725	0.00081244
0.02417154	0.19960608	0.14257577	0.0131608	0.00940057	0.0665876	0.00438738	0.00161018	0.11985768	0.0665876	0.00087612	0.0006258	0.00789729	0.00438738	0.03576513	0.02643509	0.00052538	0.00029188	0.00029188	0.00235491	0.00174059	0.01234725	0.00015656	0.00011572	0.00081244	5.40E-05
0.02417154	0.14257577	0.19960608	0.00940057	0.0131608	0.0665876	0.00438738	0.00161018	0.0665876	0.11985768	0.0006258	0.00087612	0.00438738	0.00789729	0.02643509	0.03576513	0.00029188	0.00029188	0.00052538	0.00174059	0.00235491	0.01234725	0.00011572	0.00015656	0.00081244	5.40E-05
0.14257577	1.02066948	1.02066948	0.0665876	0.0665876	0.4054848	0.02643509	0.00940057	0.54859708	0.54859708	0.00438738	0.00438738	0.03576513	0.03576513	0.18952485	0.18952485	0.00235491	0.00174059	0.00235491	0.01234725	0.01234725	0.07686381	0.00081244	0.00081244	0.00500407	0.00032904
0.00940057	0.0665876	0.0665876	0.00438738	0.00438738	0.02643509	0.00174059	0.0006258	0.03576513	0.03576513	0.00029188	0.00029188	0.00235491	0.00235491	0.01234725	0.01234725	0.00015656	0.00011572	0.00015656	0.00081244	0.00081244	0.00500407	5.40E-05	5.40E-05	0.00032904	2.18E-05
0.00345262	0.02417154	0.02417154	0.00161018	0.00161018	0.00940057	0.0006258	0.00023226	0.0131608	0.0131608	0.00010825	0.00010825	0.00087612	0.00087612	0.00438738	0.00438738	5.89E-05	4.20E-05	5.89E-05	0.00029188	0.00029188	0.00174059	1.96E-05	1.96E-05	0.00011572	7.77E-06
0.19960608	1.83720507	1.02066948	0.11985768	0.0665876	0.54859708	0.03576513	0.0131608	1.1687503	0.4054848	0.00789729	0.00438738	0.07619527	0.02643509	0.3233071	0.18952485	0.00501699	0.00235491	0.00174059	0.02106296	0.01234725	0.10031379	0.00138592	0.00081244	0.00653074	0.00042942
0.19960608	1.02066948	1.83720507	0.0665876	0.11985768	0.54859708	0.03576513	0.0131608	0.4054848	1.1687503	0.00438738	0.00789729	0.02643509	0.07619527	0.18952485	0.3233071	0.00174059	0.00235491	0.00501699	0.01234725	0.02106296	0.10031379	0.00081244	0.00138592	0.00653074	0.00042942
0.00161018	0.0131608	0.00940057	0.00087612	0.0006258	0.00438738	0.00029188	0.00010825	0.00789729	0.00438738	5.89E-05	4.20E-05	0.00052538	0.00029188	0.00235491	0.00174059	3.53E-05	1.96E-05	1.96E-05	0.00015656	0.00011572	0.00081244	1.05E-05	7.77E-06	5.40E-05	3.62E-06
0.00161018	0.00940057	0.0131608	0.0006258	0.00087612	0.00438738	0.00029188	0.00010825	0.00438738	0.00789729	4.20E-05	5.89E-05	0.00029188	0.00052538	0.00174059	0.00235491	1.96E-05	1.96E-05	3.53E-05	0.00011572	0.00015656	0.00081244	7.77E-06	1.05E-05	5.40E-05	3.62E-06
0.0131608	0.11985768	0.0665876	0.00789729	0.00438738	0.03576513	0.00235491	0.00087612	0.07619527	0.02643509	0.00052538	0.00029188	0.00501699	0.00174059	0.02106296	0.01234725	0.00033354	0.00015656	0.00011572	0.00138592	0.00081244	0.00653074	9.21E-05	5.40E-05	0.00042942	2.85E-05
0.0131608	0.0665876	0.11985768	0.00438738	0.00789729	0.03576513	0.00235491	0.00087612	0.02643509	0.07619527	0.00029188	0.00052538	0.00174059	0.00501699	0.01234725	0.02106296	0.00011572	0.00015656	0.00033354	0.00081244	0.00138592	0.00653074	5.40E-05	9.21E-05	0.00042942	2.85E-05
0.0665876	0.54859708	0.4054848	0.03576513	0.02643509	0.18952485	0.01234725	0.00438738	0.3233071	0.18952485	0.00235491	0.00174059	0.02106296	0.01234725	0.10031379	0.07686381	0.00138592	0.00081244	0.00081244	0.00653074	0.00500407	0.03592987	0.00042942	0.00032904	0.00233752	0.0001536
0.0665876	0.4054848	0.54859708	0.02643509	0.03576513	0.18952485	0.01234725	0.00438738	0.18952485	0.3233071	0.00174059	0.00235491	0.01234725	0.02106296	0.07686381	0.10031379	0.00081244	0.00081244	0.00138592	0.00500407	0.00653074	0.03592987	0.00032904	0.00042942	0.00233752	0.0001536
0.00087612	0.00789729	0.00438738	0.00052538	0.00029188	0.00235491	0.00015656	5.89E-05	0.00501699	0.00174059	3.53E-05	1.96E-05	0.00033354	0.00011572	0.00138592	0.00081244	2.24E-05	1.05E-05	7.77E-06	9.21E-05	5.40E-05	0.00042942	6.17E-06	3.62E-06	2.85E-05	1.91E-06
0.0006258	0.00438738	0.00438738	0.00029188	0.00029188	0.00174059	0.00011572	4.20E-05	0.00235491	0.00235491	1.96E-05	1.96E-05	0.00015656	0.00015656	0.00081244	0.00081244	1.05E-05	7.77E-06	1.05E-05	5.40E-05	5.40E-05	0.00032904	3.62E-06	3.62E-06	2.18E-05	1.46E-06
0.00087612	0.00438738	0.00789729	0.00029188	0.00052538	0.00235491	0.00015656	5.89E-05	0.00174059	0.00501699	1.96E-05	3.53E-05	0.00011572	0.00033354	0.00081244	0.00138592	7.77E-06	1.05E-05	2.24E-05	5.40E-05	9.21E-05	0.00042942	3.62E-06	6.17E-06	2.85E-05	1.91E-06
0.00438738	0.03576513	0.02643509	0.00235491	0.00174059	0.01234725	0.00081244	0.00029188	0.02106296	0.01234725	0.00015656	0.00011572	0.00138592	0.00081244	0.00653074	0.00500407	9.21E-05	5.40E-05	5.40E-05	0.00042942	0.00032904	0.00233752	2.85E-05	2.18E-05	0.0001536	1.02E-05
0.00438738	0.02643509	0.03576513	0.00174059	0.00235491	0.01234725	0.00081244	0.00029188	0.01234725	0.02106296	0.00011572	0.00015656	0.00081244	0.00138592	0.00500407	0.00653074	5.40E-05	5.40E-05	9.21E-05	0.00032904	0.00042942	0.00233752	2.18E-05	2.85E-05	0.0001536	1.02E-05
0.02643509	0.18952485	0.18952485	0.01234725	0.01234725	0.07686381	0.00500407	0.00174059	0.10031379	0.10031379	0.00081244	0.00081244	0.00653074	0.00653074	0.03592987	0.03592987	0.00042942	0.00032904	0.00042942	0.00233752	0.00233752	0.01487458	0.0001536	0.0001536	0.00096703	6.35E-05
0.00029188	0.00235491	0.00174059	0.00015656	0.00011572	0.00081244	5.40E-05	1.96E-05	0.00138592	0.00081244	1.05E-05	7.77E-06	9.21E-05	5.40E-05	0.00042942	0.00032904	6.17E-06	3.62E-06	3.62E-06	2.85E-05	2.18E-05	0.0001536	1.91E-06	1.46E-06	1.02E-05	6.83E-07
0.00029188	0.00174059	0.00235491	0.00011572	0.00015656	0.00081244	5.40E-05	1.96E-05	0.00081244	0.00138592	7.77E-06	1.05E-05	5.40E-05	9.21E-05	0.00032904	0.00042942	3.62E-06	3.62E-06	6.17E-06	2.18E-05	2.85E-05	0.0001536	1.46E-06	1.91E-06	1.02E-05	6.83E-07
0.00174059	0.01234725	0.01234725	0.00081244	0.00081244	0.00500407	0.00032904	0.00011572	0.00653074	0.00653074	5.40E-05	5.40E-05	0.00042942	0.00042942	0.00233752	0.00233752	2.85E-05	2.18E-05	2.85E-05	0.0001536	0.0001536	0.00096703	1.02E-05	1.02E-05	6.35E-05	4.21E-06
0.00011572	0.00081244	0.00081244	5.40E-05	5.40E-05	0.00032904	2.18E-05	7.77E-06	0.00042942	0.00042942	3.62E-06	3.62E-06	2.85E-05	2.85E-05	0.0001536	0.0001536	1.91E-06	1.46E-06	1.91E-06	1.02E-05	1.02E-05	6.35E-05	6.83E-07	6.83E-07	4.21E-06	2.82E-07

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Table 31:CC matrix for concrete mix proportions from observation point 48-60 **[TEST E – MODEL 3]**

0.03678211	0.31212232	0.31212232	0.01735765	0.01735765	0.12281861	0.00682619	0.0020668	0.17194606	0.17194606	0.00097479	0.00097479	0.00955667	0.00955667	0.05799621	0.05799621	0.00053639	0.00038314	0.00053639	0.00322153	0.00322153	0.02327924	0.00018071	0.00018071	0.00129235	7.25E-05
0.31212232	3.12512918	2.23223513	0.17194606	0.12281861	1.05470826	0.05799621	0.01735765	1.89847486	1.05470826	0.00955667	0.00682619	0.10439318	0.05799621	0.57310943	0.42360262	0.00579875	0.00322153	0.00322153	0.03149544	0.02327924	0.20016169	0.00174847	0.00129235	0.01099345	0.00060995
0.31212232	2.23223513	3.12512918	0.12281861	0.17194606	1.05470826	0.05799621	0.01735765	1.05470826	1.89847486	0.00682619	0.00955667	0.05799621	0.10439318	0.42360262	0.57310943	0.00322153	0.00322153	0.00579875	0.02327924	0.03149544	0.20016169	0.00129235	0.00174847	0.01099345	0.00060995
0.01735765	0.17194606	0.12281861	0.00955667	0.00682619	0.05799621	0.00322153	0.00097479	0.10439318	0.05799621	0.00053639	0.00038314	0.00579875	0.00322153	0.03149544	0.02327924	0.00032529	0.00018071	0.00018071	0.00174847	0.00129235	0.01099345	9.80E-05	7.25E-05	0.00060995	3.42E-05
0.01735765	0.12281861	0.17194606	0.00682619	0.00955667	0.05799621	0.00322153	0.00097479	0.05799621	0.10439318	0.00038314	0.00053639	0.00322153	0.00579875	0.02327924	0.03149544	0.00018071	0.00018071	0.00032529	0.00129235	0.00174847	0.01099345	7.25E-05	9.80E-05	0.00060995	3.42E-05
0.12281861	1.05470826	1.05470826	0.05799621	0.05799621	0.42360262	0.02327924	0.00682619	0.57310943	0.57310943	0.00322153	0.00322153	0.03149544	0.03149544	0.20016169	0.20016169	0.00174847	0.00129235	0.00174847	0.01099345	0.01099345	0.08206564	0.00060995	0.00060995	0.00450461	0.00024978
0.00682619	0.05799621	0.05799621	0.00322153	0.00322153	0.02327924	0.00129235	0.00038314	0.03149544	0.03149544	0.00018071	0.00018071	0.00174847	0.00174847	0.01099345	0.01099345	9.80E-05	7.25E-05	9.80E-05	0.00060995	0.00060995	0.00450461	3.42E-05	3.42E-05	0.00024978	1.40E-05
0.0020668	0.01735765	0.01735765	0.00097479	0.00097479	0.00682619	0.00038314	0.00011723	0.00955667	0.00955667	5.53E-05	5.53E-05	0.00053639	0.00053639	0.00322153	0.00322153	3.04E-05	2.17E-05	3.04E-05	0.00018071	0.00018071	0.00129235	1.02E-05	1.02E-05	7.25E-05	4.10E-06
0.17194606	1.89847486	1.05470826	0.10439318	0.05799621	0.57310943	0.03149544	0.00955667	1.22097226	0.42360262	0.00579875	0.00322153	0.06709898	0.02327924	0.3414523	0.20016169	0.003725	0.00174847	0.00129235	0.01875353	0.01099345	0.10710261	0.0010405	0.00060995	0.00587889	0.00032599
0.17194606	1.05470826	1.89847486	0.05799621	0.10439318	0.57310943	0.03149544	0.00955667	0.42360262	1.22097226	0.00322153	0.00579875	0.02327924	0.06709898	0.20016169	0.3414523	0.00129235	0.00174847	0.003725	0.01099345	0.01875353	0.10710261	0.00060995	0.0010405	0.00587889	0.00032599
0.00097479	0.00955667	0.00682619	0.00053639	0.00038314	0.00322153	0.00018071	5.53E-05	0.00579875	0.00322153	3.04E-05	2.17E-05	0.00032529	0.00018071	0.00174847	0.00129235	1.84E-05	1.02E-05	1.02E-05	9.80E-05	7.25E-05	0.00060995	5.55E-06	4.10E-06	3.42E-05	1.93E-06
0.00097479	0.00682619	0.00955667	0.00038314	0.00053639	0.00322153	0.00018071	5.53E-05	0.00322153	0.00579875	2.17E-05	3.04E-05	0.00018071	0.00032529	0.00129235	0.00174847	1.02E-05	1.02E-05	1.84E-05	7.25E-05	9.80E-05	0.00060995	4.10E-06	5.55E-06	3.42E-05	1.93E-06
0.00955667	0.10439318	0.05799621	0.00579875	0.00322153	0.03149544	0.00174847	0.00053639	0.06709898	0.02327924	0.00032529	0.00018071	0.003725	0.00129235	0.01875353	0.01099345	0.00020884	9.80E-05	7.25E-05	0.0010405	0.00060995	0.00587889	5.83E-05	3.42E-05	0.00032599	1.83E-05
0.00955667	0.05799621	0.10439318	0.00322153	0.00579875	0.03149544	0.00174847	0.00053639	0.02327924	0.06709898	0.00018071	0.00032529	0.00129235	0.003725	0.01099345	0.01875353	7.25E-05	9.80E-05	0.00020884	0.00060995	0.0010405	0.00587889	3.42E-05	5.83E-05	0.00032599	1.83E-05
0.05799621	0.57310943	0.42360262	0.03149544	0.02327924	0.20016169	0.01099345	0.00322153	0.3414523	0.20016169	0.00174847	0.00129235	0.01875353	0.01099345	0.10710261	0.08206564	0.0010405	0.00060995	0.00060995	0.00587889	0.00450461	0.03878051	0.00032599	0.00024978	0.00212741	0.0001179
0.05799621	0.42360262	0.57310943	0.02327924	0.03149544	0.20016169	0.01099345	0.00322153	0.20016169	0.3414523	0.00129235	0.00174847	0.01099345	0.01875353	0.08206564	0.10710261	0.00060995	0.00060995	0.0010405	0.00450461	0.00587889	0.03878051	0.00024978	0.00032599	0.00212741	0.0001179
0.00053639	0.00579875	0.00322153	0.00032529	0.00018071	0.00174847	9.80E-05	3.04E-05	0.003725	0.00129235	1.84E-05	1.02E-05	0.00020884	7.25E-05	0.0010405	0.00060995	1.18E-05	5.55E-06	4.10E-06	5.83E-05	3.42E-05	0.00032599	3.30E-06	1.93E-06	1.83E-05	1.03E-06
0.00038314	0.00322153	0.00322153	0.00018071	0.00018071	0.00129235	7.25E-05	2.17E-05	0.00174847	0.00174847	1.02E-05	1.02E-05	9.80E-05	9.80E-05	0.00060995	0.00060995	5.55E-06	4.10E-06	5.55E-06	3.42E-05	3.42E-05	0.00024978	1.93E-06	1.93E-06	1.40E-05	7.91E-07
0.00053639	0.00322153	0.00579875	0.00018071	0.00032529	0.00174847	9.80E-05	3.04E-05	0.00129235	0.003725	1.02E-05	1.84E-05	7.25E-05	0.00020884	0.00060995	0.0010405	4.10E-06	5.55E-06	1.18E-05	3.42E-05	5.83E-05	0.00032599	1.93E-06	3.30E-06	1.83E-05	1.03E-06
0.00322153	0.03149544	0.02327924	0.00174847	0.00129235	0.01099345	0.00060995	0.00018071	0.01875353	0.01099345	9.80E-05	7.25E-05	0.0010405	0.00060995	0.00587889	0.00450461	5.83E-05	3.42E-05	3.42E-05	0.00032599	0.00024978	0.00212741	1.83E-05	1.40E-05	0.0001179	6.60E-06
0.00322153	0.02327924	0.03149544	0.00129235	0.00174847	0.01099345	0.00060995	0.00018071	0.01099345	0.01875353	7.25E-05	9.80E-05	0.00060995	0.0010405	0.00450461	0.00587889	3.42E-05	3.42E-05	5.83E-05	0.00024978	0.00032599	0.00212741	1.40E-05	1.83E-05	0.0001179	6.60E-06
0.02327924	0.20016169	0.20016169	0.01099345	0.01099345	0.08206564	0.00450461	0.00129235	0.10710261	0.10710261	0.00060995	0.00060995	0.00587889	0.00587889	0.03878051	0.03878051	0.00032599	0.00024978	0.00032599	0.00212741	0.00212741	0.01622987	0.0001179	0.0001179	0.00088981	4.93E-05
0.00018071	0.00174847	0.00129235	9.80E-05	7.25E-05	0.00060995	3.42E-05	1.02E-05	0.0010405	0.00060995	5.55E-06	4.10E-06	5.83E-05	3.42E-05	0.00032599	0.00024978	3.30E-06	1.93E-06	1.93E-06	1.83E-05	1.40E-05	0.0001179	1.03E-06	7.91E-07	6.60E-06	3.73E-07
0.00018071	0.00129235	0.00174847	7.25E-05	9.80E-05	0.00060995	3.42E-05	1.02E-05	0.00060995	0.0010405	4.10E-06	5.55E-06	3.42E-05	5.83E-05	0.00024978	0.00032599	1.93E-06	1.93E-06	3.30E-06	1.40E-05	1.83E-05	0.0001179	7.91E-07	1.03E-06	6.60E-06	3.73E-07
0.00129235	0.01099345	0.01099345	0.00060995	0.00060995	0.00450461	0.00024978	7.25E-05	0.00587889	0.00587889	3.42E-05	3.42E-05	0.00032599	0.00032599	0.00212741	0.00212741	1.83E-05	1.40E-05	1.83E-05	0.0001179	0.0001179	0.00088981	6.60E-06	6.60E-06	4.93E-05	2.76E-06
7.25E-05	0.00060995	0.00060995	3.42E-05	3.42E-05	0.00024978	1.40E-05	4.10E-06	0.00032599	0.00032599	1.93E-06	1.93E-06	1.83E-05	1.83E-05	0.0001179	0.0001179	1.03E-06	7.91E-07	1.03E-06	6.60E-06	6.60E-06	4.93E-05	3.73E-07	3.73E-07	2.76E-06	1.56E-07

Table 32:CC matrix inverse for concrete mix proportions from observation point 1-12 for the 1st half from [1-13] **[TEST A_1 – MODEL 3]**

-63662.08159	-34104.55038	-29307.60201	-300864.7087	-772487.369	-727352.1203	-319695.6669	-1347652.365	-448561.4951	3034179.676	3215471.308	1901295.288	688425.031
14072.23814	8391.439018	-128.0503158	55510.54703	190498.0235	-74739.12487	-370080.4185	86546.71105	392033.1653	471284.9987	-569784.4154	-1375060.152	98063.53649
13702.23335	-598.1758997	7216.60593	39873.5936	-86538.21393	172068.2297	375515.1776	50932.26907	-367667.0547	-507389.3279	507046.9929	1231868.169	174644.853
483015.8337	75915.27871	65486.7777	-1396541.335	1002827.732	904704.3109	980240.2324	-1502918.564	1260392.803	-2929031.861	-3323157.422	-2280669.521	1181657.666
89476.25268	17768.29004	8019.015837	-241664.5308	-101219.8238	-569194.5504	-712971.8463	-881914.6754	207014.5838	-1494497.989	-1291969.48	-1837475.681	3130579.631
89564.80149	26602.89297	-421.9188751	-237922.3263	-392570.7859	-270609.2725	-285249.5208	-873391.4983	-217332.2513	-608811.1864	-2201147.039	331428.2622	3112252.343
-3370.374022	-19499.31363	4515.383387	-142437.025	-250656.511	-24698.41434	258327.4133	-324411.9888	-386806.4459	-6738.650464	900851.6089	933156.6816	697579.2912
-58688.85638	5852.862935	16122.14856	405147.9815	194967.6116	291592.9502	281149.9253	825285.1133	5274.537094	-2403046.243	-2014937.928	342878.584	-2270001.401
-2828.659409	7591.517057	-20167.1051	-119543.3587	15043.84836	-246141.4342	-426769.9744	-272269.789	318941.1632	899744.2648	-149340.596	-834157.3578	585458.5312
3418356.155	1853352.339	-1110825.535	-1091134.761	8253171.032	1797984.219	-2400310.773	-2408960.508	3183278.885	24157982.34	19019846.1	-11283551.72	38984533.54
3425323.218	-1107420.856	1880921.667	-796696.3004	1968899.441	8651455.289	3640652.603	-1738352.802	-2592099.271	17639085.31	23690479.01	876302.1468	37542533.66
191019.875	65095.99604	17622.14474	-117331.3424	2916432.877	-1105996.774	2040006.234	1708072.367	-826124.4477	-2259408.515	-1142339.79	2656179.989	-2378008.629
284914.1692	54569.91347	150974.9426	3749394.736	3129102.521	4036192.744	3918196.409	6957399.609	1328359.512	-8103699.896	-4460253.335	-1428402.466	-17671076.67
190433.3055	4020.120546	76090.26328	-142120.6425	-1245672.94	3008187.122	-506925.5527	1651612.706	1698447.245	-1529320.723	-1716818.924	-4373460.921	-2256604.083
-52285.93297	-6905.068678	903.1808506	226169.7967	-230633.8816	938550.3466	221795.9079	828294.9062	250813.2934	96669.15301	-117123.3255	1266022.993	-2943870.883
-52106.97089	-8805.109409	3598.847036	233733.0008	850770.8975	-128233.4763	525715.9496	845520.7229	-46284.69375	-522802.525	454872.222	-1388777.829	-2980911.354
-3060170.776	-2715313.257	1885738.849	2459300.473	-4912207.238	2578568.26	1892560.205	7598990.051	-1375953.823	-20021946.26	-25704454.46	1610004.9	-34601963.38
-6883532.412	-890013.7675	-1465889.311	6970067.012	-1464983.842	-6883488.261	-7127058.102	16032578.87	8343335.368	-55804776.14	-77568908.07	-10008048.28	-121613522.9
-3067817.848	2009038.235	-2872609.818	2136123.827	3586276.535	-6544670.778	-5290689.95	6862928.773	5515789.1	-19387826.24	-24309913.56	-4601057.369	-33019219.46
-78534.70103	799155.1786	-754538.4021	-1792967.681	-3664852.877	4749510.677	-2288022.595	-3687275.476	1763622.621	1503112.733	2858756.828	310582.6914	2357221.17
-88529.56736	-626988.9683	627170.8011	-2215365.615	5750407.847	-5482316.889	-2450237.191	-4649321.362	1544831.8	9844663.978	-2831296.561	-11765146.7	4425897.144
-343402.8084	-44666.38225	-106348.1699	-1740761.524	-2769543.003	-3349916.735	-2329068.59	-4002001.692	-672041.2441	3997284.06	1666137.031	680549.5323	8526256.12
-32478667.47	-2901529.257	-1228977.313	38556357.72	-106341074.3	2183928.025	6046604.121	49787421.52	-41230035.65	-103916123.9	5783472.299	118955818.8	-237683043.9
-32433422.07	-3587507.026	-341848.5691	40468496	-19105939.36	-81354719.39	25694057.52	54142473.03	-59152729.09	-93155264.63	-16980358.87	90510756.95	-247047660.1
6291204.339	-169027.164	142874.0722	-8227874.141	2539357.102	5474085.359	4192849.12	-17888200.32	-4186105.167	55543573.65	67331293.66	2196658.334	101666456.2
80509471.79	9647034.886	2616868.614	-151834651.6	128848970.9	62701020.49	-70939313.27	-149451763.6	117919962.8	249318537.3	-16373360.33	-235461445.4	837907313.2

Table 33:CC matrix inverse for concrete mix proportions from observation point 1-12 for the 2nd half from [14-26] **[TEST A_2 – MODEL 3]**

1577451.32	2869632.421	3579703.314	-13840561.92	10650347.91	-14540197.64	13404586.97	14779311.47	-3506732.776	34950269.18	42953742.98	-55927911.57	-198793602.2
1242203.569	2208460.122	-2364240.493	-278171.4099	-874136.0228	2352031.778	2323393.29	-6243773.104	-338132.2808	21098999.98	-33356481.59	7922235.814	18716618.3
-1337820.458	-2232606.873	2235779.03	1983675.606	-347802.9543	-543745.8748	-5910117.557	2455091.55	-460852.7176	-31120348.17	22159363.39	7381510.38	7953748.692
-1576637.105	-2818406.05	-4362090.584	20114728.31	-12725861.29	21635726.92	-56283869.14	-59272501.66	5591459.234	27414783.11	10015339.11	286703635.3	-148006380.7
1575964.48	5689072.75	152194.2937	261164.0892	14712662.23	2325761.166	2985597.946	-7397635.342	-7728118.012	52550863.98	-19507190.95	22409821.56	-216472428.8
-599378.1451	2854926.234	2948300.609	-280136.622	14586701.25	3018772.891	-2183902.681	-2339502.259	-7698748.803	10776235.7	21478526.3	22539226.89	-213896680.4
-688085.4446	-1053444.923	2501343.664	-1135963.626	4794368.467	-4638511.199	-1321649.424	5560557.742	-1117860.585	-5019777.341	35047570.36	-4925468.544	-98038990.41
-350405.1344	-2586648.688	-1066532.1	9229604.797	-17825537.85	7731827.774	-4577784.401	-1634780.331	4255246.961	-37937011.42	-20803210.52	-12265553.12	327716590.9
1039838.702	2662082.762	-1446902.379	-4447476.382	4023777.592	-398876.703	5756374.299	-2198778.669	-938188.7116	35757689.74	-10556213.98	-4133806.173	-82281346.43
313918.6906	16203979.36	3389690.893	-26008648.27	44789098.5	-76329007.67	-231242362.6	-285488312.7	-81430203.55	134000620.8	667222093.7	1422441741	-4529364121
-12352533.78	104687.4165	16495961.35	-68598450.49	34878427.65	-21802509.35	-293332129.4	-232160998.2	-79119419.89	616027373.8	123123437.9	1432623415	-4326702984
-5225039.543	-14022675.09	4637408.957	14430592.44	-27169860.26	16725103.25	-45013280	-11315678.65	5093444.644	-166208953.8	98692664.11	120100865.9	243065735.4
-7936745.838	-29254178.17	-14983771.33	60538903.41	-140048359.2	46478213.81	-83427592.52	-55799537.06	37851764.72	-266732097.9	-105885021	280084684.4	1566550574
1847252.808	2942963.165	-12076241.47	18016303.98	-26335463.17	12134419.95	-14471256.54	-41119975.59	4898895.639	80786781.56	-143077126.8	119243652.5	226003332.3
-2064538.552	-2544954.514	-2391148.805	4136683.836	-11672044.29	1415399.866	-2703688.876	3407218.264	5643239.127	-38624936.89	3475318.416	-7645278.146	185820539.3
577249.3349	-3925550.879	-1087433.811	3042684.886	-11926618.46	2816015.243	398439.5778	80009.7881	5702595.94	-14183436.85	-22560614.87	-7383742.748	191026270.7
4592494.67	-4764051.843	-27920207.81	-9325478.219	91579841.69	64434593.98	111124037.6	259121100.9	71162833.9	387248741.7	-1077765689	-1022554380	2949137941
28869547.81	-22020848.17	-107265138.7	-124114542.9	588268241.1	-40122998.63	936838500	771802281.2	312527929.1	-472875844.5	-1433696030	-4184508131	7400911801
11359601.27	-5509948.746	-23889160.44	37421232.18	102457827.4	4586125.741	304136982.6	75725853.04	68626509.96	-809620215.4	187233598	-1033729820	2726696395
-2017701.152	1171699.526	-7063795.443	-122592246.9	208362148.6	-31087770.52	150563972.1	62917360.17	25414124.48	399267364.6	-174479949.1	-313396133.9	-1699514270
10784788.61	17252408.84	-18850751.52	-61493420.26	222579879.9	-109310840.2	112123284.8	113928557.9	22099101.57	119922618.5	193912414.6	-328002643.2	-1990249541
4844712.518	16899760.51	7769280.357	-31998028.61	82563525.9	-23001729.58	67259676.32	49582716.25	-17924339.43	146001432.2	43088385.7	-238893227.2	-749435290.4
-73859478.95	-152697598	151840488.2	1018129795	-2845588086	344123207.3	2394553274	2198586289	402731318.2	-7327350124	-796659083.9	-14000292005	52409650020
-48704362.86	-221888516	201594166.5	741543676.4	-2909949830	698228455.9	1465395712	3070838852	417737978.2	-5101109117	-3426006602	-13934170314	53725769238
-18859923.13	27832065.36	74001415.56	-22458348.34	-224856593.2	-67949195.84	-582893441.1	-493507806.8	-220315238.3	677371941.7	1197763904	2937976278	-8256250194
239147986.4	800227732.2	-240416452.8	-1773173485	7451190904	-747822561.2	-6418556684	-8433283775	-1971046531	17905235998	6175747345	41745002901	-1.4442E+11

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Table 34:CC matrix inverse for concrete mix proportions from observation point 13-24 for the 1st half from [1-13] **[TEST B_1 – MODEL 3]**

43460362.03	-46352507.31	-46352511.44	-24800672.04	115162150.3	115162154.5	55277596.73	-142878583	55277598.97	1400514.977	1400519.145	-124554008.1	-14666854.86
-46352510.03	-85709449.06	240502897.8	16562498.15	93712745.98	-230888612.3	2706040.96	-19497524.46	-175754296.3	208301422	-114521754.8	81018645.09	-75243667.7
-46352510.5	240502893.3	-85709442.7	16562498.31	-230888605.7	93712737.71	-175754294.8	-19497524.81	2706037.517	-114521749.1	208301417.2	10635235.35	-75243668.71
-24800672.62	16562498.39	16562499.81	-78334120.26	84600468.43	84600466.86	-13892196.4	-37243523.21	-13892197.13	-101065367	-101065368.4	-76418942.57	2224805.513
115162154.7	93712742.36	-230888614	84600468.22	-144924842.4	-212499830.2	-88399830.48	315599616.6	212128163.3	-370337187.1	-6083167.631	-27992908	126591762.7
115162155.5	-230888610.8	93712736.23	84600467.97	-212499835.9	-144924834.3	212128163	315599617.2	-88399826.93	-6083172.832	-370337183.7	337976723.9	126591764.2
55277598.89	2706042.129	-175754298.5	-13892195.78	-88399835.88	212128163.6	64607758.13	43119741.45	127280306	-147820622.7	31698884.67	-9151368.54	92747420.01
-142878584.8	-19497521.68	-19497520.6	-37243522.47	315599612	315599613.7	43119738.23	-148255442.8	43119736.85	84500319.43	84500318.22	-182391653.1	75663766.19
55277599.04	-175754292.7	2706035.722	-13892195.84	212128155.6	-88399827.17	127280303.7	43119741.58	64607761.19	31698878.67	-147820617.1	-69943913.34	92747420.4
1400516.889	208301417.7	-114521751.7	-101065368.4	-370337180.2	-6083169.321	-147820618.5	84500316.51	31698882.48	314993218	228087228.1	73783395.09	-43860468.86
1400517.36	-114521755.1	208301419.3	-101065368.5	-6083164.789	-370337183.1	31698884.48	84500316.86	-147820618.5	228087229.9	314993215.1	198113428.8	-43860467.85
-124554009.6	81018645.51	10635240.03	-76418942.89	-27992906.34	337976720.7	-9151370.238	-182391657	-69943917.22	73783399.9	198113429.5	-3771882.726	-73710077.81
-14666854.3	-75243665.55	-75243669.67	2224806.516	126591755.9	126591763.9	92747418.77	75663769.58	92747419.94	-43860471.16	-43860467.41	-73710073.99	190203020.3
-124554009.8	10635236.14	81018649.88	-76418942.85	337976725.4	-27992911.22	-69943915.4	-182391657.2	-9151372.576	198113433.6	73783396.14	-161284194.4	-73710078.03
166985701.9	327792879.7	-459293621.3	-18966329.03	-194211314.6	-67139955.01	-249769001.1	9283557.296	366401806.1	-463844555.1	298441439.4	-308476646.7	-49866073.9
166985703.5	-459293616.8	327792869.3	-18966329.57	-67139958.75	-194211305.8	366401805	9283558.527	-249768993.3	298441430.1	-463844549.5	393976015.7	-49866070.66
-204492562.9	-54871723.22	194632118.4	101229611.8	-2372360.47	163514803.6	55480934.48	-106052277.1	-182680893.7	155001918.3	234433184.4	223995012.2	84455741.29
-109593679.1	1080583.565	1080587.317	365430578.6	-63942968.31	-63942968.58	-5043014.625	335543307	-5043017.654	-248460570.8	-248460575.1	282595484.9	-394031455.4
-204492563.5	194632112.5	-54871715.04	101229612	163514809.3	-2372367.983	-182680891	-106052277.6	55480929.21	234433192	155001912.1	-260340890.4	84455740.08
129736627.1	199363827.5	-267714243.8	-140124339.4	-264329658	33255345.52	-144978422.2	-84117564.52	199558635.4	34324310.18	-46654319.22	45522138.41	-120543383.7
129736628.1	-267714239.3	199363819.7	-140124339.7	33255342.99	-264329652.7	199558633.3	-84117563.81	-144978416.4	-46654326.53	34324315.42	-13327246.64	-120543381.9
197403802	-204675046.1	-204675059.4	87570556.69	-140036247.6	-140036227.3	210203874.4	531273490.1	210203879.7	-298516490.8	-298516478.5	152890317.9	358274273.1
-183226114.1	-250094681.7	286216358.6	243176366.1	423717324.2	-239044941.6	311955286.1	-334256393.7	-342448460.5	229115675.8	-261592059.1	133065648.1	321555478.7
-183226116	286216358.6	-250094675.5	243176366.7	-239044939.4	423717317.3	-342448462.6	-334256395.1	311955281.4	-261592054.3	229115674.9	128162898.4	321555475.4
-37428334.74	-23366094.02	-23366094.34	-358555247.7	94606989.81	94606991.61	32801029.17	-45824491.84	32801028.92	518327705.4	518327705.8	-128500198.8	234838827.3
-550596841.1	-3473769.809	-3473753.243	400051801.6	612804389.7	612804375.9	-30103791.54	139362282.9	-30103801.31	-5651047.618	-5651064.239	56573015.27	-206492381.6

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Table 35: CC matrix inverse for concrete mix proportions from observation point 13-24 for the 2nd half from [14-26] [TEST B_2 – MODEL 3]

-124554007.2	166985695.8	166985705.8	-204492559.5	-109593679.9	-204492562.5	129736623.7	129736629.5	197403797	-183226108.2	-183226117	-37428334.19	-550596838.9
10635235.3	327792884.3	-459293624.1	-54871723.78	1080586.202	194632115.4	199363829.5	-267714244.5	-204675047.4	-250094685.7	286216360.9	-23366095.31	-3473766.092
81018646.07	-459293608.5	327792867.5	194632110.6	1080586.03	-54871717.59	-267714235.4	199363820	-204675049.9	286216346.5	-250094670.4	-23366095.61	-3473765.837
-76418942.73	-18966327.82	-18966331.48	101229611.8	365430578.5	101229613	-140124338.5	-140124340.7	87570554.77	243176365.3	243176368.1	-358555248.1	400051800.5
337976723.7	-194211317.9	-67139949.24	-2372362.501	-63942968.65	163514803.3	-264329660.9	33255348.78	-140036234.9	423717325	-239044945.3	94606992.34	612804388.4
-27992909.67	-67139962.85	-194211302.3	163514807.3	-63942968.6	-2372368.675	33255340.37	-264329651.6	-140036231.2	-239044933.1	423717312.1	94606992.84	612804388
-69943913.73	-249769007.9	366401811.5	55480936.77	-5043016.931	-182680892.9	-144978425.7	199558637.7	210203872.5	311955292.6	-342448465.7	32801030.47	-30103791.32
-182391655.5	9283553.728	9283555.339	-106052272.9	335543306.5	-106052274.1	-84117565.76	-84117565.74	531273479.4	-334256389.6	-334256394.3	-45824492.3	139362282.1
-9151369.362	366401793.7	-249768989.6	-182680887	-5043016.803	55480930.33	199558627.4	-144978415.2	210203873.5	-342448449.3	311955275.8	32801030.58	-30103791.42
198113429.9	-463844546	298441432.8	155001911.2	-248460572.2	234433187.4	34324316.09	-46654323.8	-298516479.3	229115666.2	-261592052.7	518327704.9	-5651057.831
73783395.06	298441441.2	-463844553.1	234433184	-248460572	155001913.1	-46654319.27	34324312.01	-298516476.8	-261592061.4	229115674.1	518327705.2	-5651058.08
-161284194.7	-308476640.5	393976010.9	223995010.6	282595483.3	-260340888.4	45522143.52	-13327248.62	152890312.5	133065643.7	128162903.8	-128500200.7	56573008.44
-73710076.26	-49866082.78	-49866067.09	84455746.07	-394031456	84455740.19	-120543388.8	-120543380.1	358274267.4	321555487.2	321555471.1	234838828.5	-206492377.7
-3771882.922	393976021.6	-308476651.6	-260340891.8	282595483.4	223995014.3	-13327242	45522136.62	152890312.1	128162895	133065652.3	-128500200.8	56573008.52
393976019.8	-279654244.2	633431300.9	-27159990.51	-338500772.7	-98416227.72	-119163111.2	538313727.7	-166133359.5	-57960368.68	574716129.3	34446847.72	87004457.1
-308476645.8	633431286.8	-279654226.1	-98416225.45	-338500772.4	-27159997.4	538313718.5	-119163100.2	-166133351.6	574716140	-57960381.33	34446848.74	87004456.25
-260340892.8	-27159984.67	-98416234.66	726808510.2	-430397674.7	-106089665.6	-112586018.8	418815684	55101736.7	-761812814.4	98523957.83	134666077.6	-330216539.7
282595481.2	-338500770.2	-338500774.1	-430397675.9	1044686036	-430397675.6	181498039.8	181498037.3	57775934.14	922711232.4	922711233.5	-364348609.4	972951738.2
223995010.9	-98416219.21	-27160001.71	-106089669.5	-430397674.7	726808515.9	418815693.7	-112586029.1	55101733.76	98523946.44	-761812802.4	134666077.2	-330216539.4
-13327242.69	-119163110.9	538313727.9	-112586022.8	181498038.4	418815688.3	-620369911.9	1147646400	-177298933.3	-573731474	646228224.3	172029078.8	-188688111
45522140.58	538313717.5	-119163098.3	418815690	181498038.6	-112586027	1147646393	-620369904.2	-177298928.9	646228230.8	-573731481.6	172029079.4	-188688111.5
152890314.8	-166133379.2	-166133336.9	55101743.77	57775932.92	55101728.88	-177298946	-177298921.1	126808137	148194801	148194762.2	159045866.3	-571583562.2
128162897.5	-57960365.13	574716124.9	-761812810.9	922711234.8	98523955.18	-573731471.2	646228220.8	148194783.2	-711265609.8	554297319.5	-204159923.4	379297648.4
133065650.2	574716132.2	-57960376.83	98523954.29	922711234.9	-761812805.3	646228225.8	-573731478.2	148194775.5	554297310.4	-711265599.4	-204159924.5	379297649.4
-128500199.9	34446845.22	34446848.21	134666079.7	-364348609.7	134666078.4	172029077.6	172029079	159045861.9	-204159920.2	-204159925.3	-768229513.1	-1455261480
56573009.25	87004469.88	87004433.64	-330216539.9	972951738.7	-330216528.8	-188688103.6	-188688124.6	-571583576	379297642.4	379297659.4	-1455261480	1462643744

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Table 36: **CC matrix inverse for concrete mix proportions from observation point 25-36 for the 1st half from [1-13]** **[TEST C_1 – MODEL 3]**

363691.392	-97321.846	-97321.846	-127783.21	-127783.21	-72917.283	-166209.81	-146736.2	112634.786	112634.786	-221468.02	-221468.02	-87345.265
-97321.846	677853.201	-282217.34	-1123586.4	512899.487	-56660.046	-175416.74	-298298.99	-703573.95	288442.778	-234959.84	-187194.86	1007479.11
-97321.846	-282217.34	677853.201	512899.487	-1123586.4	-56660.046	-175416.74	-298298.99	288442.778	-703573.95	-187194.86	-234959.84	-196996.41
-127783.21	-1123586.4	512899.487	2386891.79	-1236479.6	204623.523	623526.552	711296.873	1202323.37	-584860.83	775961.124	350250.76	-2083767.5
-127783.21	512899.487	-1123586.4	-1236479.6	2386891.79	204623.523	623526.552	711296.873	-584860.82	1202323.37	350250.76	775961.124	1038553.74
-72917.283	-56660.046	-56660.046	204623.523	204623.523	-106734.15	256072.779	41882.0118	49103.9506	49103.9505	130677.795	130677.795	-132769.3
-166209.81	-175416.74	-175416.74	623526.552	623526.552	256072.779	279397.108	595061.563	200275.161	200275.161	173488.929	173488.929	-627177.21
-146736.2	-298298.99	-298298.99	711296.873	711296.873	41882.0118	595061.563	472885.761	344451.758	344451.757	880876	880876	-830162.98
112634.786	-703573.95	288442.778	1202323.37	-584860.83	49103.9505	200275.161	344451.757	738233.215	-301355.34	275958.494	124206.446	-1109595.5
112634.786	288442.778	-703573.95	-584860.82	1202323.37	49103.9505	200275.161	344451.757	-301355.34	738233.215	124206.446	275958.494	262356.159
-221468.02	-234959.84	-187194.86	775961.124	350250.76	130677.795	173488.929	880876	275958.494	124206.446	77919.5579	-49477.143	-584828.89
-221468.02	-187194.86	-234959.84	350250.76	775961.124	130677.795	173488.929	880876	124206.446	275958.494	-49477.143	77919.5579	69855.2949
-87345.265	1007479.11	-196996.41	-2083767.5	1038553.74	-132769.3	-627177.21	-830162.98	-1109595.5	262356.159	-584828.89	69855.295	1980881.06
-87345.265	-196996.41	1007479.11	1038553.74	-2083767.5	-132769.3	-627177.21	-830162.98	262356.159	-1109595.5	69855.295	-584828.89	-877266.84
134306.375	-300793.7	-365951.89	234926.546	786052.727	305428.902	16157.2467	372437.903	285730.597	425047.774	160025.453	688627.074	-328251.45
134306.375	-365951.89	-300793.7	786052.727	234926.546	305428.902	16157.2467	372437.903	425047.774	285730.597	688627.074	160025.453	-995961.31
172384.338	-926105.67	1530383.79	1774828.69	-3137549.4	-225651.38	-332870.1	-528832.79	916024.17	-1548135.9	-241804.75	-643297.05	-1269958.7
-127412.73	91567.4254	91567.4254	-117898.53	-117898.53	181537.375	-109743.78	-228571.62	-102366.65	-102366.65	411567.035	411567.035	177974.986
172384.338	1530383.79	-926105.67	-3137549.4	1774828.69	-225651.38	-332870.1	-528832.79	-1548135.9	916024.171	-643297.05	-241804.75	2319356.13
-324885.23	-12957.63	223012.282	-168742.82	398975.089	-71426.967	-114824.4	584330.376	-36977.57	-248585.47	-34730.008	-396360.61	679048.681
-324885.23	223012.282	-12957.63	398975.089	-168742.82	-71426.967	-114824.4	584330.376	-248585.47	-36977.57	-396360.61	-34730.008	-291102.39
463790.6	-29137.859	-29137.86	-345515.06	-345515.06	-286085.47	186851.786	478620.893	49996.3348	49996.3348	-331400.51	-331400.51	-61978.233
-129024.91	1439724.54	-970201.35	-2755238.4	2348450.91	-114523.43	-482030.25	-136992.91	-1549048.7	1053681.28	-988251.89	628784.841	2427122.96
-129024.91	-970201.35	1439724.54	2348450.91	-2755238.4	-114523.43	-482030.25	-136992.91	1053681.28	-1549048.7	628784.84	-988251.89	-2050326.7
970334.687	1068686.15	1068686.15	-2544091.3	-2544091.3	-318391.56	-1820248	-3363818.7	-1099295.5	-1099295.5	-1506424.2	-1506424.2	1529412.29
505973.654	217949.494	217949.494	-1035151.9	-1035151.9	-239636.14	-343647.53	-574681.94	-212816.07	-212816.07	-69665.27	-69665.27	489393.632

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Table 37:CC matrix inverse for concrete mix proportions from observation point 25-36 for the 2nd half from [14-26] **[TEST C_2 – MODEL 3]**

-87345.265	134306.375	134306.375	172384.338	-127412.73	172384.338	-324885.23	-324885.23	463790.6	-129024.91	-129024.91	970334.687	505973.654
-196996.41	-300793.7	-365951.89	-926105.67	91567.4254	1530383.79	-12957.63	223012.282	-29137.859	1439724.54	-970201.35	1068686.15	217949.494
1007479.11	-365951.89	-300793.7	1530383.79	91567.4254	-926105.67	223012.282	-12957.63	-29137.86	-970201.35	1439724.54	1068686.15	217949.494
1038553.74	234926.546	786052.727	1774828.69	-117898.53	-3137549.4	-168742.82	398975.089	-345515.06	-2755238.4	2348450.91	-2544091.3	-1035151.9
-2083767.5	786052.727	234926.546	-3137549.4	-117898.53	1774828.69	398975.089	-168742.82	-345515.06	2348450.91	-2755238.4	-2544091.3	-1035151.9
-132769.3	305428.902	305428.902	-225651.38	181537.375	-225651.38	-71426.967	-71426.967	-286085.47	-114523.43	-114523.43	-318391.56	-239636.14
-627177.21	16157.2466	16157.2466	-332870.1	-109743.78	-332870.1	-114824.4	-114824.4	186851.786	-482030.25	-482030.25	-1820248	-343647.53
-830162.98	372437.903	372437.903	-528832.79	-228571.62	-528832.79	584330.376	584330.376	478620.893	-136992.91	-136992.91	-3363818.7	-574681.94
262356.159	285730.597	425047.774	916024.171	-102366.65	-1548135.9	-36977.57	-248585.47	49996.3348	-1549048.7	1053681.28	-1099295.5	-212816.07
-1109595.5	425047.774	285730.597	-1548135.9	-102366.65	916024.17	-248585.47	-36977.57	49996.3348	1053681.28	-1549048.7	-1099295.5	-212816.07
69855.2951	160025.453	688627.074	-241804.75	411567.035	-643297.05	-34730.008	-396360.61	-331400.51	-988251.89	628784.841	-1506424.2	-69665.27
-584828.89	688627.074	160025.453	-643297.05	411567.035	-241804.75	-396360.61	-34730.008	-331400.51	628784.84	-988251.89	-1506424.2	-69665.27
-877266.84	-328251.45	-995961.31	-1269958.7	177974.986	2319356.13	679048.681	-291102.39	-61978.233	2427122.96	-2050326.7	1529412.29	489393.632
1980881.06	-995961.31	-328251.45	2319356.13	177974.986	-1269958.7	-291102.39	679048.681	-61978.233	-2050326.7	2427122.96	1529412.29	489393.632
-995961.31	488903.709	122411.612	-250321.24	-282860.17	-497436.78	180487.139	89616.2041	170648.97	29363.2602	-589841.51	-1923229	-284650.13
-328251.45	122411.612	488903.709	-497436.78	-282860.17	-250321.24	89616.2041	180487.139	170648.97	-589841.51	29363.2606	-1923229	-284650.13
2319356.13	-250321.24	-497436.78	3528894.68	-278134.18	-2074753	-637852.79	-71139.719	24428.8072	-3285703.8	4008939.65	2459563.48	613482.382
177974.986	-282860.17	-282860.17	-278134.19	445295.039	-278134.18	147569.809	147569.809	-277338.59	321468.973	321468.973	-152876.51	-337269.28
-1269958.7	-497436.78	-250321.24	-2074753	-278134.19	3528894.68	-71139.719	-637852.79	24428.8072	4008939.65	-3285703.8	2459563.48	613482.382
-291102.39	180487.139	89616.2041	-637852.79	147569.809	-71139.719	104689.168	21457.5426	-817455.38	660742.263	-231100.91	-236593.8	45708.1314
679048.681	89616.2041	180487.139	-71139.719	147569.809	-637852.79	21457.5426	104689.168	-817455.38	-231100.91	660742.262	-236593.8	45708.1314
-61978.233	170648.97	170648.97	24428.8072	-277338.59	24428.8073	-817455.38	-817455.38	704095.791	-257083.34	-257083.34	222643.721	286812.757
-2050326.7	29363.2604	-589841.51	-3285703.8	321468.973	4008939.65	660742.263	-231100.91	-257083.34	3928068.77	-3672361.7	905076.371	68853.7191
2427122.96	-589841.51	29363.2604	4008939.65	321468.973	-3285703.8	-231100.91	660742.263	-257083.34	-3672361.7	3928068.77	905076.371	68853.7191
1529412.29	-1923229	-1923229	2459563.48	-152876.51	2459563.48	-236593.8	-236593.79	222643.721	905076.372	905076.371	7964417.96	2666808.36
489393.632	-284650.13	-284650.13	613482.382	-337269.28	613482.382	45708.1314	45708.1315	286812.757	68853.7193	68853.719	2666808.36	1227886.52

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Table 38: **CC matrix inverse for concrete mix proportions from observation point 37-48 for the 1st half from [1-12]** **[TEST D_1 – MODEL 3]**

-6861888.7	-851095.36	-851095.36	1418038.32	1418038.33	6184144.08	692635.86	7049882.47	366182.318	366182.312	14541241.5	14541241.6	8594693.43
-851095.36	-3521820.6	960216.835	-5432307.5	639285.579	4947224.24	16670105.2	-5550672.5	3111262.01	-1231132.3	-18214925	26007623.2	5052401.56
-851095.36	960216.83	-3521820.6	639285.573	-5432307.5	4947224.25	16670105.2	-5550672.5	-1231132.3	3111262.01	26007623.1	-18214925	313728.68
1418038.33	-5432307.5	639285.581	-12381182	-4142382	9468563.97	39429247.2	-5870737.4	2527286.49	931609.161	24318291.7	-89360072	17099572.1
1418038.33	639285.571	-5432307.5	-4142382	-12381182	9468563.97	39429247.2	-5870737.4	931609.171	2527286.48	-89360072	24318291.8	-2662392.5
6184144.08	4947224.25	4947224.23	9468563.98	9468563.96	-16237181	-45655986	26159722.1	-3782489.9	-3782489.8	-9261855.5	-9261855.7	-17259366
692635.852	16670105.3	16670105.2	39429247.2	39429247.1	-45655986	-163416716	-17240085	-13557397	-13557397	58811274	58811273.4	-39055656
7049882.47	-5550672.5	-5550672.5	-5870737.4	-5870737.4	26159722.1	-17240085	998442.783	4254581.58	4254581.56	1099576.76	1099577.02	-11048348
366182.315	3111262.01	-1231132.3	2527286.49	931609.164	-3782489.8	-13557397	4254581.57	-3042169.4	1684721.36	21988394.1	-28503124	-2304659.3
366182.315	-1231132.3	3111262.01	931609.168	2527286.48	-3782489.8	-13557397	4254581.57	1684721.35	-3042169.4	-28503124	21988394.1	-701240.13
14541241.5	-18214925	26007623.1	24318291.8	-89360072	-9261855.6	58811273.7	1099576.88	21988394.1	-28503124	-6969332.4	-82074076	-23790016
14541241.5	26007623.2	-18214925	-89360072	24318291.8	-9261855.6	58811273.7	1099576.88	-28503124	21988394.1	-82074076	-6969332.6	36640604.2
8594693.43	5052401.57	313728.67	17099572.1	-2662392.6	-17259366	-39055656	-11048348	-2304659.3	-701240.12	-23790016	36640604.1	-29726538
8594693.43	313728.686	5052401.55	-2662392.5	17099572.1	-17259366	-39055656	-11048348	-701240.14	-2304659.3	36640604.3	-23790017	-5147007.7
-1063702.5	830909.599	-62200.058	12977255	-12801488	-2721624.4	-13268336	-1297315.1	813141.339	-1264997.1	-16525483	10285615	-6689035
-1063702.5	-62200.056	830909.597	-12801488	12977255	-2721624.4	-13268336	-1297315.1	-1264997.1	813141.341	10285615	-16525483	12649616.8
-19932990	55349623.8	-15691882	45861646.3	49188711.6	-74624897	-228373418	157834738	-49840747	20162217.6	96628520.5	3084309.89	-67280750
20180.4738	23787728.7	23787728.6	144982186	144982186	-115384238	-97380079	-255211559	-15850791	-15850791	160962085	160962083	-180559117
-19932990	-15691882	55349623.8	49188711.7	45861646.2	-74624897	-228373418	157834738	20162217.5	-49840747	3084310.73	96628519.6	30456456.1
-1192963.4	10151925.4	-15613920	-33783149	25016348.8	-2848883.3	-2869559.7	6196167.57	-7208791.3	13244239.6	-119400413	156099581	35437549.8
-1192963.4	-15613920	10151925.4	25016348.8	-33783149	-2848883.3	-2869559.7	6196167.57	13244239.6	-7208791.3	156099581	-119400413	-24723566
-8871113.4	-8378257.1	-8378257	-14075149	-14075149	26719686	77380919.2	-43787710	6489616.7	6489616.66	13658577.6	13658578	24609232.1
20491697	-14731778	-34588198	-142365803	82733397.2	20725244.8	60657163.3	61102894.3	33281545.2	17029218.3	-106735468	-2393764	142746778
20491697	-34588198	-14731778	82733397.2	-142365803	20725244.8	60657163.3	61102894.3	17029218.4	33281545.1	-2393764.6	-106735467	-66595492
-17875880	-19235235	-19235235	-68276513	-68276513	56662533.7	171924541	84226828.8	15362236.9	15362236.9	-132153372	-132153371	89626883.6
167400186	-90405911	-90405911	-286017910	-286017909	159684091	629315485	-171602567	71210842.1	71210841.8	-260953340	-260953337	145701089

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Table 39:CC matrix inverse for concrete mix proportions from observation point 37-48 for the 2nd half from [13-26] **[TEST D_2 – MODEL 3]**

8594693.42	-1063702.5	-1063702.5	-19932990	20180.4766	-19932990	-1192963.4	-1192963.4	-8871113.4	20491697	20491697	-17875880	167400186
313728.675	830909.598	-62200.058	55349623.8	23787728.7	-15691882	10151925.4	-15613920	-8378257	-14731778	-34588198	-19235235	-90405911
5052401.56	-62200.058	830909.598	-15691882	23787728.7	55349623.8	-15613920	10151925.3	-8378257	-34588198	-14731778	-19235235	-90405911
-2662392.6	12977255	-12801488	45861646.3	144982186	49188711.6	-33783149	25016348.7	-14075149	-142365803	82733397.2	-68276513	-286017910
17099572.1	-12801488	12977255	49188711.7	144982186	45861646.2	25016348.8	-33783149	-14075149	82733397.2	-142365803	-68276513	-286017910
-17259366	-2721624.4	-2721624.4	-74624897	-115384238	-74624897	-2848883.4	-2848883.3	26719686	20725244.8	20725244.9	56662533.7	159684091
-39055656	-13268336	-13268336	-228373419	-97380079	-228373418	-2869559.9	-2869559.5	77380919.2	60657163.3	60657163.5	171924541	629315485
-11048348	-1297315.1	-1297315.1	157834738	-255211559	157834738	6196167.63	6196167.49	-43787710	61102894.2	61102894.2	84226828.8	-171602567
-701240.13	813141.34	-1264997.1	-49840747	-15850791	20162217.6	-7208791.3	13244239.7	6489616.68	33281545.1	17029218.4	15362236.9	71210842
-2304659.3	-1264997.1	813141.34	20162217.5	-15850791	-49840747	13244239.6	-7208791.3	6489616.68	17029218.4	33281545.2	15362236.9	71210842
36640604.2	-16525483	10285615	96628520	160962084	3084310.42	-119400413	156099581	13658577.8	-106735467	-2393764.3	-132153372	-260953339
-23790016	10285615	-16525483	3084310.21	160962084	96628520.2	156099581	-119400413	13658577.8	-2393764.3	-106735467	-132153372	-260953339
-5147007.7	-6689035	12649616.8	-67280751	-180559117	30456456.2	35437549.8	-24723566	24609232.1	142746778	-66595492	89626883.6	145701089
-29726538	12649616.8	-6689035	30456456	-180559117	-67280750	-24723566	35437549.9	24609232.1	-66595492	142746778	89626883.6	145701089
12649616.8	-7836009.8	8734824.38	-7521070.4	10455681.3	-2758691.3	-8603559.3	23728576.3	4959004.84	-79070463	126654397	11088272.4	174921051
-6689035	8734824.38	-7836009.8	-2758691.3	10455681.3	-7521070.4	23728576.3	-8603559.3	4959004.84	126654397	-79070463	11088272.4	174921051
30456456.2	-7521070.4	-2758691.3	-532274696	99600581.3	-434695042	110909227	-25215310	125890857	-160757158	3743668.45	219681744	1078281521
-180559117	10455681.3	10455681.3	99600580.4	-1.474E+09	99600582.2	-181418835	-181418835	153841989	404061572	404061573	557921748	379513123
-67280750	-2758691.3	-7521070.4	-434695043	99600581.3	-532274694	-25215310	110909227	125890857	3743668.22	-160757158	219681744	1078281521
-24723566	-8603559.3	23728576.3	110909227	-181418835	-25215310	-24100382	37976298.3	-243248.48	127238356	-44483973	134664055	-85923.193
35437549.8	23728576.3	-8603559.3	-25215310	-181418835	110909227	37976298.3	-24100382	-243248.48	-44483973	127238356	134664055	-85923.194
24609232.1	4959004.84	4959004.83	125890857	153841989	125890857	-243248.4	-243248.59	-44445794	17990779	17990778.9	-84214699	-464106827
-66595492	-79070463	126654397	-160757158	404061572	3743667.66	127238356	-44483973	17990779.1	-221699049	-24103201	-113504757	-82174292
142746778	126654397	-79070463	3743668.58	404061572	-160757159	-44483973	127238356	17990779.1	-24103201	-221699049	-113504757	-82174292
89626883.5	11088272.4	11088272.4	219681745	557921748	219681743	134664055	134664055	-84214699	-113504757	-113504757	-444424696	-501367109
145701089	174921051	174921051	1078281523	379513123	1078281519	-85922.544	-85923.9	-464106827	-82174292	-82174293	-501367109	-3.008E+09

Table 40:CC matrix inverse for concrete mix proportions from observation point 49-60 for the 1st half from [1-13] **[TEST E_1 – MODEL 3]**

-26545760	-8904795.5	-8904795.5	40539268	40539267.9	24204659.5	-12761780	27754891.5	5116625.56	5116625.56	45286793.3	45286793.9	-19182504	-19182504
-8904795.5	-2542956.7	-2159301.6	18645258.5	1714568.74	6531635.65	-8010649.7	23628788.6	916404.533	1689102.64	-53489164	63683934.4	12551418.1	-9440873.5
-8904795.5	-2159301.6	-2542956.7	1714568.76	18645258.5	6531635.64	-8010649.7	23628788.6	1689102.64	916404.533	63683934.2	-53489164	-9440873.5	12551418.1
40539268	18645258.5	1714568.75	-52303654	-50908244	-30557700	38545152.5	-67465265	-14075089	3999990.18	-52958176	-5453302.6	-1162411.8	15854185.1
40539268	1714568.76	18645258.5	-50908244	-52303654	-30557700	38545152.5	-67465265	3999990.18	-14075089	-5453301.9	-52958177	15854185	-1162411.8
24204659.5	6531635.65	6531635.64	-30557700	-30557700	-18745893	18432500.1	-46617479	-3514265	-3514265	-18718905	-18718905	3765037.1	3765037.1
-12761780	-8010649.7	-8010649.7	38545152.5	38545152.4	18432500.1	-15334788	17637676.5	5290277.98	5290277.98	-47430499	-47430498	-21300834	-21300834
27754891.4	23628788.5	23628788.5	-67465265	-67465265	-46617479	17637676.6	-12145104	-17789655	-17789655	-68026777	-68026778	35202318.2	35202318.3
5116625.56	916404.534	1689102.64	-14075089	3999990.19	-3514265	5290277.99	-17789655	293431.999	-1779387.3	61858602.4	-64559598	-14203334	7971812.23
5116625.56	1689102.64	916404.533	3999990.18	-14075089	-3514265	5290277.99	-17789655	-1779387.3	293431.999	-64559598	61858602.3	7971812.23	-14203334
45286793.6	-53489164	63683934.3	-52958176	-5453302.3	-18718905	-47430498	-68026778	61858602.3	-64559598	36206513.7	-167375029	74118884.1	-66103962
45286793.6	63683934.3	-53489164	-5453302.3	-52958176	-18718905	-47430498	-68026778	-64559598	61858602.3	-167375029	36206513.3	-66103962	74118884.1
-19182504	12551418	-9440873.5	-1162411.7	15854185.1	3765037.16	-21300834	35202318.3	-14203334	7971812.24	74118884.2	-66103962	-1032950.6	38015697.4
-19182504	-9440873.5	12551418	15854185.1	-1162411.7	3765037.15	-21300834	35202318.3	7971812.24	-14203334	-66103962	74118884.2	38015697.4	-1032950.6
24089385.1	6795644.18	5451858.84	-26773603	-33141967	-17853728	18014824.1	-45982380	-4077031	-2222834.8	-45548191	-756925.08	6862535.91	1420627.1
24089385.1	5451858.85	6795644.17	-33141967	-26773603	-17853728	18014824.1	-45982380	-2222834.8	-4077031	-756924.68	-45548192	1420627.1	6862535.91
106305184	-102789634	88219289.2	-40547601	-92660678	-37660302	72434463.1	-133379109	120810041	-84471017	-61387271	-316984476	641859.293	-111003966
-167866974	-31801214	-31801214	107809087	107809087	126926464	-84084658	387397457	10798240.4	10798240.4	280456745	280456747	72549861.7	72549861.7
106305184	88219289.2	-102789634	-92660678	-40547601	-37660302	72434463	-133379108	-84471017	120810041	-316984476	-61387270	-111003966	641859.293
33302756.8	-10177036	18855626.1	-25993322	-29877448	-16609407	6138322.49	-81552888	15213925.4	-17389549	-92244020	-13463477	14320334.7	-11321354
33302756.8	18855626.1	-10177036	-29877448	-25993322	-16609407	6138322.48	-81552888	-17389549	15213925.4	-13463477	-92244021	-11321354	14320334.7
-92445955	-23627770	-23627770	119686421	119686420	70453326.6	-61125081	138918267	11905598.8	11905598.8	99121626.1	99121627.7	-30570790	-30570790
-247189335	-50264845	-33268915	196082272	188879613	138531062	-41427811	403160095	12319610.8	27873723.6	335935098	526990180	119062762	60545170.9
-247189335	-33268915	-50264844	188879614	196082271	138531062	-41427811	403160095	27873723.6	12319610.8	526990177	335935101	60545170.9	119062762
-60410564	6871590.9	6871590.9	15605097.3	15605097.3	6973227.26	-84166063	157304091	-10057200	-10057200	33064686.1	33064686	14643188.8	14643188.8
-488588455	-58365806	-58365806	455331557	455331556	132710927	-156555773	684022486	10125908	10125908	836804018	836804023	24707411.7	24707411.7

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Table 41:CC matrix inverse for concrete mix proportions from observation point 49-60 for the2nd half from [14-26] **[TEST E_2 – MODEL 3]**

-19182504	24089385.1	24089385.1	106305183	-167866974	106305184	33302756.7	33302756.9	-92445955	-247189335	-247189335	-60410564	-488588454
-9440873.5	6795644.17	5451858.84	-102789634	-31801214	88219289.3	-10177036	18855626.1	-23627770	-50264845	-33268915	6871590.92	-58365806
12551418	5451858.84	6795644.17	88219289	-31801214	-102789634	18855626	-10177036	-23627770	-33268916	-50264844	6871590.92	-58365806
15854185.1	-26773603	-33141967	-40547601	107809087	-92660679	-25993321	-29877448	119686420	196082272	188879613	15605097.3	455331556
-1162411.6	-33141967	-26773603	-92660677	107809087	-40547602	-29877448	-25993322	119686421	188879614	196082272	15605097.2	455331556
3765037.18	-17853728	-17853728	-37660301	126926464	-37660302	-16609407	-16609407	70453326.6	138531063	138531062	6973227.2	132710927
-21300834	18014824.1	18014824.1	72434462.6	-84084658	72434463.4	6138322.42	6138322.53	-61125081	-41427811	-41427810	-84166063	-156555773
35202318.4	-45982380	-45982380	-133379107	387397457	-133379109	-81552888	-81552888	138918267	403160095	403160095	157304091	684022485
7971812.24	-4077031	-2222834.8	120810041	10798240.4	-84471017	15213925.4	-17389549	11905598.8	12319610.8	27873723.5	-10057200	10125907.9
-14203334	-2222834.8	-4077031	-84471017	10798240.4	120810041	-17389549	15213925.4	11905598.8	27873723.6	12319610.7	-10057200	10125907.9
-66103962	-45548191	-756924.9	-61387270	280456746	-316984476	-92244020	-13463477	99121627	335935100	526990179	33064686	836804021
74118884.2	-756924.87	-45548191	-316984476	280456746	-61387271	-13463477	-92244020	99121626.9	526990179	335935099	33064686.1	836804021
38015697.4	6862535.96	1420627.15	641859.293	72549861.4	-111003966	14320334.8	-11321354	-30570790	119062762	60545170.5	14643188.8	24707411
-1032950.6	1420627.15	6862535.96	-111003966	72549861.4	641859.298	-11321354	14320334.8	-30570790	60545170.5	119062762	14643188.8	24707411.1
1420627.18	-16927659	-18361758	-62874339	100955465	8134536.36	-29444976	-6778715.6	69627443.8	194218302	26649730	9593133.71	360368658
6862535.99	-18361758	-16927659	8134537.02	100955465	-62874340	-6778715.5	-29444976	69627443.8	26649730.1	194218302	9593133.71	360368658
-111003967	-62874339	8134536.62	419197657	-24381137	220562326	-68459725	42134228.2	225062175	-402652611	-219285834	250096339	98727644.9
72549861.3	100955465	100955465	-24381139	-442928175	-24381135	158221327	158221328	-482588114	-427774476	-427774475	-159757002	-1.617E+09
641859.317	8134536.67	-62874339	220562325	-24381137	419197657	42134228.1	-68459725	225062175	-219285834	-402652611	250096339	98727644.7
-11321354	-29444976	-6778715.5	-68459725	158221327	42134227.9	3074667.49	-102213892	77642689.6	239617753	115359630	95603887.3	409620316
14320334.8	-6778715.5	-29444976	42134228.5	158221327	-68459725	-102213892	3074667.41	77642689.6	115359630	239617753	95603887.3	409620316
-30570790	69627443.8	69627443.8	225062174	-482588114	225062176	77642689.4	77642689.7	-278618463	-481732536	-481732536	-95314363	-1.116E+09
60545170.4	194218302	26649730	-402652614	-427774475	-219285833	239617753	115359630	-481732536	-153163170	-485080184	-437603819	-1.53E+09
119062762	26649730.1	194218302	-219285837	-427774475	-402652609	115359630	239617753	-481732536	-485080184	-153163169	-437603819	-1.53E+09
14643188.8	9593133.76	9593133.76	250096339	-159757002	250096339	95603887.4	95603887.4	-95314363	-437603819	-437603819	294355607	-569235117
24707410.6	360368658	360368658	98727640.2	-1.617E+09	98727649.3	409620316	409620317	-1.116E+09	-1.53E+09	-1.53E+09	-569235116	-4.038E+09

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Appendix 2 Aggregates analysis Results

Table 1: Specific Gravity for fine aggregate

SAMPLE	MASS OF FINE AGGREGATE M.P (g)	MASS OF WATER M.W (g)	SPECIFIC GRAVITY M.P / M.W
A	200	77	2.6
B	213	83	2.56
C	205	75	2.71
Mean = (2.6 + 2.56 + 2.71) / 3 = **2.62**			

Table 2: Specific Gravity for coarse aggregate

SAMPLE	MASS OF COARSE AGGREGATE M.P (g)	MASS OF WATER M.W (g)	SPECIFIC GRAVITY M.P / M.W
A	500	183	2.73
B	493	186	2.65
C	525	194	2.70
Mean = (2.70+ 2.65 + 2.73) / 3 = **2.7**			

Table 3: Non- Compacted Bulk Density of fine aggregate

SAMPLE	**MASS (g)**	**VOLUME (m^3)**	**BULK DENSITY (kg / m^3)**
A	1901	$1.179 * 10^{-3}$	1612.38
B	1839	$1.179 * 10^{-3}$	1559.80
C	1890	$1.179 * 10^{-3}$	1603.05
Mean Bulk Density =1591.74 kg/m^3			

Table 4: Compacted Bulk Density of fine aggregate

SAMPLE	MASS (g)	VOLUME (m^3)	BULK DENSITY (kg / m^3)
A	1961	$1.179 * 10^{-3}$	1663.27
B	1970	$1.179 * 10^{-3}$	1671
C	1958	$1.179 * 10^{-3}$	1661
Mean Bulk Density = 1665.09 kg/m^3			

Table 5: Non-compacted Bulk Density of coarse aggregate

SAMPLE	MASS (g)	VOLUME (m^3)	BULK DENSITY (kg / m^3)
A	1499	$1.179 * 10^{-3}$	1271
B	1409	$1.179 * 10^{-3}$	1195.08
C	1473	$1.179 * 10^{-3}$	1249.36
Mean Bulk Density = 1238.48 kg/m^3			

Table 6: Compacted Bulk Density of coarse aggregate

SAMPLE	MASS (g)	VOLUME (m^3)	BULK DENSITY (kg / m^3)
A	1567	$1.179 * 10^{-3}$	1330.79
B	1548	$1.179 * 10^{-3}$	1312.98
C	1461	$1.179 * 10^{-3}$	1239.19
Mean Bulk Density = 1294.32 kg/m^3			

Table 7: Water Absorption of coarse aggregates

SAMPLE	MASS OF SATURATED COARSE AGGREGATES (g), R	MASS OF BONE DRY COARSE AGGREGATES (g), B	MASS OF ABSORBED WATER (g) = R - B	WATER ABSORPTION = { R – B} / B * 100
A	809	775	34	4.38
B	906	870	36	4.14
C	1017	975	42	4.31
D	913	875	38	4.34
E	658	630	28	4.45
Mean water Absorption = 4.33				

Table 8:Sieve Analysis of fine aggregate

SIEVE SIZE (mm)	MASS RETAINED (g)	PERCENTAGE RETAINED (g)	CUMMULATIVE MASS RETAINED (g)	PERCENTAGE CUMMULATIVE MASS RETAINED (%)	PERCENTAGE CUMMULATIVE MASS PASSING (%)
4.75	0	0	0	0	100
2.36	46	9.2	46	9	91
1.18	65	13	111	22	78
.600	185	37	296	60	40
.425	80	16	376	75	25
300µm	55	11	431	86	14
212	35	7	466	93	7
150	14	2.8	480	96	4
75	6	1.2	486	97	3
RECIEVER	14	2.8	-	-	-

Table 9: Sieve Analysis coarse aggregate

SIEVE SIZE (mm)	MASS RETAINED (g)	PERCENTAGE RETAINED (g)	CUMMULATIVE MASS RETAINED (g)	PERCENTAGE CUMMULATIVE MASS RETAINED (%)	PERCENTAGE CUMMULATIVE MASS PASSING (%)
37.5	384	19.2	384	19.2	81
25	518	25.9	902	45.1	55
19	290	14.5	1192	59.6	40
13.2	390	19.5	1582	79.1	21
9.5	269	13.45	1851	92.5	8
6.7	92	4.6	1943	97.15	3
4.75	19	.95	1962	98.1	2
< 4.75	38	1.9			
RECIEVER	-	-	-	-	-

Appendix 3 Concrete Analysis Results

Table 1: Experimental test result of 28th days' concrete cube strengths

S/N	Points of observation	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Cube strength Y_I [N / mm^2]
1	u1	32.44	28	29.33	29.78	29.89
2	u2	29.33	35.11	30.67	31.11	31.56
3	u3	34.67	34.22	32.89	31.56	33.33
4	u4	23.56	25.78	25.78	28	25.78
5	u5	28.44	28	29.33	28	28.44
6	u6	31.11	30.67	17.78	30.22	27.44
7	u7	21.33	24.89	24.89	25.78	24.22
8	u8	24	25.78	28.44	26.67	26.22
9	u9	27.11	26.67	25.78	26.22	26.44
10	u10	19.56	18.22	20	16	18.44
11	u11	22.67	24.44	23.56	20	22.67
12	u12	24.44	25.78	24	25.78	25
13	u13	29.78	31.11	24.89	25.33	27.78
14	u14	23.11	23.11	23.11	24	23.33
15	u15	10.67	11.11	10.67	12.44	11.22
16	u16	27.56	20.44	26.67	25.78	25.11

Table 1: Experimental test result of 28th days' concrete cube strengths cont.

17	u17	23.56	23.56	24	23.56	23.67
18	u18	21.33	18.67	21.78	17.78	19.89
19	u19	19.56	23.56	25.33	24.44	23.22
20	u20	24.89	25.33	24	27.56	25.44
21	u21	13.33	12.89	13.33	15.11	13.67
22	u22	24	21.78	24	23.11	23.22
23	u23	23.11	23.11	24	22.67	23.22
24	u24	20.44	20	23.11	23.11	21.67
25	u25	16	17.33	15.56	15.33	16.06
26	u26	9.33	12.89	10.22	5.78	9.56
27	u27	5.33	8.89	6.22	4.89	6.33
28	u28	20.89	18.22	19.11	13.33	17.89
29	u29	13.33	13.33	12.89	12	12.89
30	u30	6.22	4.89	3.11	3.11	4.33
31	u31	11.11	25.78	12.44	15.11	16.11
32	u32	19.11	19.11	16	15.11	17.33
33	u33	8.89	7.56	6.22	5.78	7.11
34	u34	21.33	22.22	24.44	24.89	23.22
35	u35	16.89	16	17.33	12.89	15.78
36	u36	9.33	7.56	8	10.67	8.89
37	u37	6.22	6.67	7.11	5.78	6.44
38	u38	5.78	6.22	6.67	4.89	5.89
39	u39	1.33	2.67	1.33	1.78	1.78
40	u40	8.89	8.89	8.44	3.56	7.44
41	u41	6.67	0.89	5.78	3.11	4.11
42	u42	8.44	4.89	5.33	5.33	6
43	u43	15.11	8.89	12	9.78	11.44
44	u44	11.56	11.56	10.67	8.44	10.56
45	u45	6.67	4.44	8	5.33	6.11
46	u46	16.89	12.44	7.56	6.67	10.89
47	u47	13.33	14.22	15.11	13.78	14.11
48	u48	4.89	4.44	4.44	4.89	4.67
49	u49	1.78	2.67	3.56	2.22	2.56
50	u50	4.44	5.33	5.33	5.33	5.11
51	u51	0.89	0.89	0.44	0.89	0.78
52	u52	4.44	5.78	4.89	4.89	5
53	u53	1.78	2.22	3.56	2.67	2.56
54	u54	0.89	0.89	0.89	1.33	1
55	u55	4	4	3.11	4.44	3.89

Table 1: Experimental test result of 28th days' concrete cube strengths cont.

56	u56	6.22	3.56	4	4.89	4.67
57	u57	0.89	1.33	1.78	0.89	1.22
58	u58	6.67	7.56	7.56	6.67	7.11
59	u59	4.89	5.33	5.33	6.22	5.44
60	u60	1.78	1.78	1.78	2.67	2

Table 2: Experimental test result of 28th days' concrete cubes SSD density.

S/N	Points of observation	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Cube SSD Density [KN / M^3]
1	u1	2525.63	2599.111	2616.889	2544.593	2571.556
2	u2	2422.815	2477.63	2504.889	2447.407	2463.185
3	u3	2354.963	2385.185	2464	2389.926	2398.519
4	u4	2512	2640.593	2674.963	2597.333	2606.222
5	u5	2567.111	2527.407	2498.074	2534.222	2531.704
6	u6	2226.667	2311.704	2286.815	2367.704	2298.222
7	u7	2522.667	2529.185	2306.37	2419.852	2444.519
8	u8	2360.889	2352.593	2385.185	2318.222	2354.222
9	u9	2140.444	2197.333	2153.185	2192.593	2170.889
10	u10	2257.185	2430.519	2295.111	2318.815	2325.407
11	u11	2306.667	2295.704	2280.593	2260.741	2285.926
12	u12	2166.222	2228.741	2170.667	2160	2181.407
13	u13	2213.333	2319.704	2290.37	2143.407	2241.704
14	u14	2289.185	2244.444	2265.185	2176.296	2243.778
15	u15	2104.889	2113.185	2176	2180.444	2143.63
16	u16	2444.741	2462.222	2457.185	2513.481	2469.407
17	u17	2400	2590.815	2402.667	2421.333	2453.704
18	u18	2365.926	2360.296	2354.37	2318.815	2349.852
19	u19	2513.778	2538.074	2553.481	2545.185	2537.63
20	u20	2603.259	2594.37	2565.333	2670.222	2608.296
21	u21	2344.889	2308.148	2444.741	2234.667	2333.111
22	u22	2519.704	2563.556	2558.222	2456.889	2524.593
23	u23	2352.593	2313.481	2358.519	2324.148	2337.185
24	u24	2217.481	2180.741	2109.63	2188.444	2174.074
25	u25	2375.111	2370.37	2363.852	2293.333	2350.667
26	u26	2030.222	1810.963	2036.148	2145.778	2005.778
27	u27	2311.111	2305.185	2264.296	2322.963	2300.889
28	u28	2190.815	2274.37	2195.556	2168.889	2207.407
29	u29	2166.519	2214.519	2351.704	2153.481	2221.556

Table 2: Experimental test result of 28th days' concrete cubes SSD density cont.

30	u30	2192.593	2149.333	2174.815	2205.63	2180.593
31	u31	2459.852	2445.037	2414.815	2437.037	2439.185
32	u32	2501.926	2401.778	2425.481	2435.556	2441.185
33	u33	2287.407	2279.704	2317.63	2311.111	2298.963
34	u34	2616.889	2545.185	2561.778	2562.963	2571.704
35	u35	2462.222	2486.519	2446.222	2482.37	2469.333
36	u36	2270.222	2267.259	2256	2282.667	2269.037
37	u37	2417.778	2589.037	2653.037	2414.815	2518.667
38	u38	2375.111	2433.185	2422.222	2368	2399.63
39	u39	2247.704	2225.778	2193.185	2216.889	2220.889
40	u40	2609.185	2410.37	2360.889	2415.407	2448.963
41	u41	2382.815	2380.148	2386.074	2379.259	2382.074
42	u42	2313.778	2277.926	2209.481	2308.444	2277.407
43	u43	2393.481	2299.556	2232.889	2291.556	2304.37
44	u44	2273.185	2295.111	2233.185	2301.63	2275.778
45	u45	2096	2119.704	2129.185	2107.852	2113.185
46	u46	2574.815	2564.741	2549.926	2536.296	2556.444
47	u47	2363.259	2403.556	2369.185	2364.444	2375.111
48	u48	2379.259	2311.704	2237.037	2389.333	2329.333
49	u49	2550.519	2613.926	2474.074	2459.259	2524.444
50	u50	2445.63	2383.407	2405.926	2444.444	2419.852
51	u51	2423.111	2468.741	2412.444	2385.185	2422.37
52	u52	2533.333	2529.185	2530.37	2546.963	2534.963
53	u53	2460.444	2425.481	2442.074	2402.963	2432.741
54	u54	2255.407	2261.926	2258.074	2249.481	2256.222
55	u55	2532.741	2301.926	2346.963	2360.889	2385.63
56	u56	2349.037	2398.519	2372.444	2420.148	2385.037
57	u57	2232.889	2124.444	2188.741	2155.852	2175.481
58	u58	2215.704	2388.741	2437.63	2357.63	2349.926
59	u59	2357.037	2432	2404.741	2358.519	2388.074
60	u60	2112	2118.519	2208.593	2228.148	2166.815

Table 3: Experimental Tests, Regression Mode1, Model 2 and model3 Results

S / N	Experimental compressive strength Test Results (Nmm^{-2})	Model 1 compressive strength Test Results (Nmm^{-2})	Model 2 compressive strength Test Results (Nmm^{-2})	Model 3 compressive strength Test Results (Nmm^{-2})
1	29.89	30.18	28.96	29.16
2	31.56	33.17	31.74	32.36
3	33.33	32.4	30.85	32.1
4	25.78	25.61	27.35	27.22
5	28.44	28.05	28.29	27.66
6	27.44	28.39	30.38	29.2
7	24.22	22.34	24.05	23.75
8	26.22	24.7	25.75	25.12
9	26.44	26.1	28.16	26.82
10	18.44	20.23	18.01	18.2
11	22.67	22.93	23.04	23.74
12	25	25.35	22.86	24.09
13	27.78	27.21	27.26	27.56
14	23.33	23.63	24.36	23.58
15	11.22	12.75	12.04	12.35
16	25.11	25.61	25.62	25.22
17	23.67	23.87	23.07	23.95
18	19.89	15.46	16.28	15.88
19	23.22	24.03	23.92	23.68
20	25.44	24.03	23.23	24.08
21	13.67	17.96	18.57	18.33
22	23.22	22.49	22.53	22.86
23	23.22	24.13	25	24.05
24	21.67	20.28	19.56	19.9
25	16.06	15.87	16	15.46
26	9.56	10.69	10.51	10.44
27	6.33	5.31	5.39	5.18
28	17.89	16.85	16.73	17.29
29	12.89	12.42	12.62	12.67
30	4.33	6.11	5.87	6.08
31	16.11	18.82	18.68	19.24

Table 3: Experimental Tests, Regression Mode1, Model 2 and model3 Results cont.

32	17.33	14.76	14.92	15
33	7.11	7.2	6.9	7.11
34	23.22	21.74	21.88	21.3
35	15.78	17.69	17.51	17.44
36	8.89	8.59	8.5	8.28
37	6.44	6.62	7.58	6.45
38	5.89	3.87	3.13	3.77
39	1.78	3.3	3.19	2.88
40	7.44	8.49	6.95	8.16
41	4.11	7.25	8.12	7.42
42	6	4.34	4.24	4.6
43	11.44	10.15	8.8	9.91
44	10.56	10.35	11.15	10.49
45	6.11	5.18	5.2	5.49
46	10.89	11.61	12.88	11.69
47	14.11	13.21	12.26	12.99
48	4.67	5.85	5.93	5.59
49	2.56	2.88	3.64	2.95
50	5.11	4.15	4.4	4.28
51	0.78	0.84	0.62	0.89
52	5	3.89	3.11	3.82
53	2.56	4.13	3.86	3.98
54	1	0.87	1.12	0.83
55	3.89	5.14	4.4	5.08
56	4.67	4.44	4.19	4.3
57	1.22	1.27	1.51	1.22
58	7.11	6.65	7.39	6.7
59	5.44	5.06	5.32	5.22
60	2	2.02	1.78	2.05

Appendix4 Tables for tests to analyse regression models

Table 1: Standard Response Error of the Replicates

Regression Model's result versus Experimental Test results

LEGEND $S_I^2 = 1/(n_I-1) * [\sum y_I^2 - 1/n_I * (\sum y_I)^2]$, $n_I = 4$

S/N	Replicate values Y_i	$\tilde{Y}$	Y_i^2	$\sum Y_i$	$\sum Y_i^2$	$(\sum Y_i)^2$	S_i^2
1	32.44 28 29.33 29.78	29.8875	1052.3536 784 860.2489 886.8484	119.55	3583.451	14292.2	3.466758
2	29.33 35.11 30.67 31.11	31.555	860.2489 1232.7121 940.6489 967.8321	126.22	4001.442	15931.49	6.189967
3	34.67 34.22 32.89 31.56	33.335	1202.0089 1171.0084 1081.7521 996.0336	133.34	4450.803	17779.56	1.971367
4	29.78 31.11 24.89 25.33	27.7775	886.8484 967.8321 619.5121 641.6089	111.11	3115.802	12345.43	9.814492
5	23.11 23.11 23.11 24	23.3325	534.0721 534.0721 534.0721 576	93.33	2178.216	8710.489	0.198025
6	10.67 11.11 10.67 12.44	11.2225	113.8489 123.4321 113.8489 154.7536	44.89	505.8835	2015.112	0.701825
7	16 17.33 15.56 15.33	16.055	256 300.3289 242.1136 235.0089	64.22	1033.451	4124.208	0.799767
8	9.33 12.89 10.22 5.78	9.555	87.0489 166.1521 104.4484 33.4084	38.22	391.0578	1460.768	8.6219
9	5.33 8.89 6.22 4.89	6.3325	28.4089 79.0321 38.6884 23.9121	25.33	170.0415	641.6089	3.213092

Table 1 : Regression Model's result versus Experimental Test results cont.

10	6.22 6.67 7.11 5.78	6.445	38.6884 44.4889 50.5521 33.4084	25.78	167.1378	664.6084	0.328567
11	5.78 6.22 6.67 4.89	5.89	33.4084 38.6884 44.4889 23.9121	23.56	140.4978	555.0736	0.576467
12	1.33 2.67 1.78 1.78	1.89	1.7689 7.1289 3.1684 3.1684	7.56	15.2346	57.1536	0.3154
13	1.78 2.67 3.56 2.22	2.5575	3.1684 7.1289 12.6736 4.9284	10.23	27.8993	104.6529	0.578692
14	4.44 5.33 5.33 5.33	5.1075	19.7136 28.4089 28.4089 28.4089	20.43	104.9403	417.3849	0.198025
15	0.89 0.89 0.44 0.89	0.7775	0.7921 0.7921 0.1936 0.7921	3.11	2.5699	9.6721	0.050625
16	23.56 25.78 25.78 28	25.78	555.0736 664.6084 664.6084 784	103.12	2668.29	10633.73	3.2856
17	28.44 28 29.33 28	28.4425	808.8336 784 860.2489 784	113.77	3237.083	12943.61	0.393092
18	31.11 30.67 17.78 30.22	27.445	967.8321 940.6489 316.1284 913.2484	109.78	3137.858	12051.65	41.64857
19	27.56 20.44 26.67 25.78	25.1125	759.5536 417.7936 711.2889 664.6084	100.45	2553.245	10090.2	10.23129

Table 1 : Regression Model's result versus Experimental Test results cont.

20	23.56 23.56 24 23.56	23.67	555.0736 555.0736 576 555.0736	94.68	2241.221	8964.302	0.0484
21	21.33 18.67 21.78 17.78	19.89	454.9689 348.5689 474.3684 316.1284	79.56	1594.035	6329.794	3.862067
22	20.89 18.22 19.11 13.33	17.8875	436.3921 331.9684 365.1921 177.6889	71.55	1311.242	5119.403	10.46363
23	13.33 13.33 12.89 12	12.8875	177.6889 177.6889 166.1521 144	51.55	665.5299	2657.403	0.393092
24	6.22 4.89 3.11 3.11	4.3325	38.6884 23.9121 9.6721 9.6721	17.33	81.9447	300.3289	2.287492
25	8.89 8.89 8.44 6.22	8.11	79.0321 79.0321 71.2336 38.6884	32.44	267.9862	1052.354	1.6326
26	6.67 0.89 5.78 3.11	4.1125	44.4889 0.7921 33.4084 9.6721	16.45	88.3615	270.6025	6.903625
27	8.44 4.89 5.33 5.33	5.9975	71.2336 23.9121 28.4089 28.4089	23.99	151.9635	575.5201	2.694492
28	4.44 5.78 4.89 4.89	5	19.7136 33.4084 23.9121 23.9121	20	100.9462	400	0.3154
29	1.78 2.22 3.56 2.67	2.5575	3.1684 4.9284 12.6736 7.1289	10.23	27.8993	104.6529	0.578692

Table 1 : Regression Model's result versus Experimental Test results cont.

30	0.89 0.89 0.89 1.33	1	0.7921 0.7921 0.7921 1.7689	4	4.1452	16	0.0484
31	21.33 24.89 24.89 25.78	24.2225	454.9689 619.5121 619.5121 664.6084	96.89	2358.602	9387.672	3.894492
32	24 25.78 28.44 26.67	26.2225	576 664.6084 808.8336 711.2889	104.89	2760.731	11001.91	3.417625
33	27.11 26.67 25.78 26.22	26.445	734.9521 711.2889 664.6084 687.4884	105.78	2798.338	11189.41	0.328567
34	19.56 23.56 25.33 24.44	14.96	228.312 221.712 221.712	44.89	671.736	2015.112	0.016
35	24.89 25.33 24 27.56	25.445	619.5121 641.6089 576 759.5536	101.78	2596.675	10359.17	2.294167
36	13.33 12.89 13.33 15.11	13.665	177.6889 166.1521 177.6889 228.3121	54.66	749.842	2987.716	0.971033
37	11.11 25.78 12.44 15.11	16.11	123.4321 664.6084 154.7536 228.3121	64.44	1171.106	4152.514	44.32593
38	19.11 19.11 16 15.11	17.3325	365.1921 365.1921 256 228.3121	69.33	1214.696	4806.649	4.344692
39	8.89 7.56 6.22 8	7.6675	79.0321 57.1536 38.6884 64	30.67	238.8741	940.6489	1.237292

Table 1 : Regression Model's result versus Experimental Test results cont.

40	15.11 8.89 12 9.78	11.445	228.3121 79.0321 144 95.6484	45.78	546.9926	2095.808	7.680167
41	11.56 11.56 10.67 8.44	10.5575	133.6336 133.6336 113.8489 71.2336	42.23	452.3497	1783.373	2.168825
42	6.67 4.44 8 5.33	6.11	44.4889 19.7136 64 28.4089	24.44	156.6114	597.3136	2.427667
43	4 4 3.11 4.44	3.8875	16 16 9.6721 19.7136	15.55	61.3857	241.8025	0.311692
44	6.22 3.56 4 4.89	4.6675	38.6884 12.6736 16 23.9121	18.67	91.2741	348.5689	1.377292
45	0.89 1.33 1.78 0.89	1.2225	0.7921 1.7689 3.1684 0.7921	4.89	6.5215	23.9121	0.181158
46	19.56 18.22 20 16	18.445	382.5936 331.9684 400 256	73.78	1370.562	5443.488	3.229967
47	22.67 24.44 23.56 20	22.6675	513.9289 597.3136 555.0736 400	90.67	2066.316	8221.049	3.684625
48	24.44 25.78 24 25.78	25	597.3136 664.6084 576 664.6084	100	2502.53	10000	0.843467
49	24 21.78 24 23.11	23.2225	576 474.3684 576 534.0721	92.89	2160.441	8628.552	1.100825

Table 1 : Regression Model's result versus Experimental Test result cont.

50	23.11 23.11 24 22.67	23.2225	534.0721 534.0721 576 513.9289	92.89	2158.073	8628.552	0.311692
51	20.44 20 23.11 23.11	21.665	417.7936 400 534.0721 534.0721	86.66	1885.938	7509.956	2.8163
52	21.33 22.22 24.44 24.89	23.22	454.9689 493.7284 597.3136 619.5121	92.88	2165.523	8626.694	2.9498
53	16.89 16 17.33 12.89	15.7775	285.2721 256 300.3289 166.1521	63.11	1007.753	3982.872	4.011692
54	9.33 7.56 8 10.67	8.89	87.0489 57.1536 64 113.8489	35.56	322.0514	1264.514	1.974333
55	16.89 12.44 7.56 6.67	10.89	285.2721 154.7536 57.1536 44.4889	43.56	541.6682	1897.474	22.43327
56	13.33 14.22 15.11 13.78	14.11	177.6889 202.2084 228.3121 189.8884	56.44	798.0978	3185.474	0.576467
57	4.89 4.44 4.44 4.89	4.665	23.9121 19.7136 19.7136 23.9121	18.66	87.2514	348.1956	0.0675
58	6.67 7.56 7.56 6.67	7.115	44.4889 57.1536 57.1536 44.4889	28.46	203.285	809.9716	0.264033

Table 1 : Regression Model's result versus Experimental Test results cont.

59	4.89 5.33 5.33 6.22	5.4425	23.9121 28.4089 28.4089 38.6884	21.77	119.4183	473.9329	0.311692
60	1.78 1.78 1.78 2.67	2.0025	3.1684 3.1684 3.1684 7.1289	8.01	16.6341	64.1601	0.198025
						TOTAL =	**241.6**

Table 2: Fisher Test to Analyse Regression Model 1

RESPONSE SYMBOL	Y_P	Y_M	$Y_P - \ddot{y}_P$	$Y_M - \ddot{y}_M$	$(Y_P - \ddot{Y}_p)^2$	$(Y_M - \ddot{y}_M)^2$
U1	29.89	30.18	15.4375	15.704833	238.316406	246.641789
U2	31.56	33.17	17.1075	18.694833	292.666556	349.496792
U3	33.33	32.4	18.8775	17.924833	356.360006	321.299649
U4	25.78	25.61	11.3275	11.134833	128.312256	123.984513
U5	28.44	28.05	13.9875	13.574833	195.650156	184.276099
U6	27.44	28.39	12.9875	13.914833	168.675156	193.622586
U7	24.22	22.34	9.7675	7.8648333	95.4040563	61.8556028
U8	26.22	24.7	11.7675	10.224833	138.474056	104.547216
U9	26.44	26.1	11.9875	11.624833	143.700156	135.136749
U10	18.44	20.23	3.9875	5.7548333	15.9001563	33.1181063
U11	22.67	22.93	8.2175	8.4548333	67.5273063	71.4842061
U12	25	25.35	10.5475	10.874833	111.249756	118.261999
U13	27.78	27.21	13.3275	12.734833	177.622256	162.175979
U14	23.33	23.63	8.8775	9.1548333	78.8100063	83.8109728
U15	11.22	12.75	-3.2325	-1.7251667	10.4490563	2.97620014
U16	25.11	25.61	10.6575	11.134833	113.582306	123.984513
U17	23.67	23.87	9.2175	9.3948333	84.9623063	88.2628927
U18	19.89	15.46	5.4375	0.9848333	29.5664063	0.96989663
U19	23.22	24.03	8.7675	9.5548333	76.8690563	91.2948394
U20	25.44	24.03	10.9875	9.5548333	120.725156	91.2948394
U21	13.67	17.96	-0.7825	3.4848333	0.61230625	12.1440631

Table 2: Fisher Test to Analyse Regression Model 1 cont.

U22	23.22	22.49	8.7675	8.0148333	76.8690563	64.2375528
U23	23.22	24.13	8.7675	9.6548333	76.8690563	93.2158061
U24	21.67	20.28	7.2175	5.8048333	52.0923063	33.6960896
U25	16.06	15.87	1.6075	1.3948333	2.58405625	1.94555993
U26	9.56	10.69	-4.8925	-3.7851667	23.9365563	14.3274869
U27	6.33	5.31	-8.1225	-9.1651667	65.9750063	84.0002806
U28	17.89	16.85	3.4375	2.3748333	11.8164063	5.6398332
U29	12.89	12.42	-1.5625	-2.0551667	2.44140625	4.22371016
U30	4.33	6.11	-10.1225	-8.3651667	102.465006	69.9760139
U31	16.11	18.82	1.6575	4.3448333	2.74730625	18.8775764
U32	17.33	14.76	2.8775	0.2848333	8.28000625	0.08113001
U33	7.11	7.2	-7.3425	-7.2751667	53.9123063	52.9280505
U34	23.22	21.74	8.7675	7.2648333	76.8690563	52.7778029
U35	15.78	17.69	1.3275	3.2148333	1.76225625	10.3351531
U36	8.89	8.59	-5.5625	-5.8851667	30.9414063	34.6351871
U37	6.44	6.62	-8.0125	-7.8551667	64.2001563	61.7036439
U38	5.89	3.87	-8.5625	-10.605167	73.3164063	112.469561
U39	1.78	3.3	-12.6725	-11.175167	160.592256	124.884351
U40	7.44	8.49	-7.0125	-5.9851667	49.1751563	35.8222204
U41	4.11	7.25	-10.3425	-7.2251667	106.967306	52.2030338
U42	6	4.34	-8.4525	-10.135167	71.4447563	102.721604
U43	11.44	10.15	-3.0125	-4.3251667	9.07515625	18.707067
U44	10.56	10.35	-3.8925	-4.1251667	15.1515563	17.0170003
U45	6.11	5.18	-8.3425	-9.2951667	69.5973063	86.400124
U46	10.89	11.61	-3.5625	-2.8651667	12.6914063	8.20918022
U47	14.11	13.21	-0.3425	-1.2651667	0.11730625	1.60064678
U48	4.67	5.85	-9.7825	-8.6251667	95.6973063	74.3935006
U49	2.56	2.88	-11.8925	-11.595167	141.431556	134.447891
U50	5.11	4.15	-9.3425	-10.325167	87.2823063	106.609067
U51	0.78	0.84	-13.6725	-13.635167	186.937256	185.917771
U52	5	3.89	-9.4525	-10.585167	89.3497563	112.045754
U53	2.56	4.13	-11.8925	-10.345167	141.431556	107.022474
U54	1	0.87	-13.4525	-13.605167	180.969756	185.100561
U55	3.89	5.14	-10.5625	-9.3351667	111.566406	87.1453373
U56	4.67	4.44	-9.7825	-10.035167	95.6973063	100.704571
U57	1.22	1.27	-13.2325	-13.205167	175.099056	174.376428
U58	7.11	6.65	-7.3425	-7.8251667	53.9123063	61.2332339
U59	5.44	5.06	-9.0125	-9.4151667	81.2251563	88.645364
U60	2	2.02	-12.4525	-12.455167	155.064756	155.131178
TOTAL	867.15	868.51			5462.98933	5336.0483
MEAN	**14.4525**	**14.4751667**				

Table 3: Fisher Test to Analyse Regression Model 2

RESPONSE SYMBOL	Y_P	Y_M	Y_P - $ÿ_P$	Y_M - $ÿ_M$	$(Y_P - Ÿ_p)^2$	$(Y_M - ÿ_M)^2$
U1	29.89	28.96	15.4375	14.507333	238.316406	210.462719
U2	31.56	31.74	17.1075	17.287333	292.666556	298.851893
U3	33.33	30.85	18.8775	16.397333	356.360006	268.872539
U4	25.78	27.35	11.3275	12.897333	128.312256	166.341206
U5	28.44	28.29	13.9875	13.837333	195.650156	191.471793
U6	27.44	30.38	12.9875	15.927333	168.675156	253.679946
U7	24.22	24.05	9.7675	9.5973333	95.4040563	92.1088065
U8	26.22	25.75	11.7675	11.297333	138.474056	127.62974
U9	26.44	28.16	11.9875	13.707333	143.700156	187.890986
U10	18.44	18.01	3.9875	3.5573333	15.9001563	12.6546202
U11	22.67	23.04	8.2175	8.5873333	67.5273063	73.7422932
U12	25	22.86	10.5475	8.4073333	111.249756	70.6832532
U13	27.78	27.26	13.3275	12.807333	177.622256	164.027786
U14	23.33	24.36	8.8775	9.9073333	78.8100063	98.1552531
U15	11.22	12.04	-3.2325	-2.4126667	10.4490563	5.82096061
U16	25.11	25.62	10.6575	11.167333	113.582306	124.709333
U17	23.67	23.07	9.2175	8.6173333	84.9623063	74.2584332
U18	19.89	16.28	5.4375	1.8273333	29.5664063	3.33914699
U19	23.22	23.92	8.7675	9.4673333	76.8690563	89.6303998
U20	25.44	23.23	10.9875	8.7773333	120.725156	77.0415799
U21	13.67	18.57	-0.7825	4.1173333	0.61230625	16.9524335
U22	23.22	22.53	8.7675	8.0773333	76.8690563	65.2433132
U23	23.22	25	8.7675	10.547333	76.8690563	111.24624
U24	21.67	19.56	7.2175	5.1073333	52.0923063	26.0848534
U25	16.06	16	1.6075	1.5473333	2.58405625	2.39424034
U26	9.56	10.51	-4.8925	-3.9426667	23.9365563	15.5446207
U27	6.33	5.39	-8.1225	-9.0626667	65.9750063	82.1319277
U28	17.89	16.73	3.4375	2.2773333	11.8164063	5.18624696
U29	12.89	12.62	-1.5625	-1.8326667	2.44140625	3.35866723
U30	4.33	5.87	-10.1225	-8.5826667	102.465006	73.6621677
U31	16.11	18.68	1.6575	4.2273333	2.74730625	17.8703468
U32	17.33	14.92	2.8775	0.4673333	8.28000625	0.21840041
U33	7.11	6.9	-7.3425	-7.5526667	53.9123063	57.0427743
U34	23.22	21.88	8.7675	7.4273333	76.8690563	55.1652799
U35	15.78	17.51	1.3275	3.0573333	1.76225625	9.34728691
U36	8.89	8.5	-5.5625	-5.9526667	30.9414063	35.4342408
U37	6.44	7.58	-8.0125	-6.8726667	64.2001563	47.2335476
U38	5.89	3.13	-8.5625	-11.322667	73.3164063	128.202781

Table 3: Fisher Test to Analyse Regression Model 2cont.

U39	1.78	3.19	-12.6725	-11.262667	160.592256	126.847661
U40	7.44	6.95	-7.0125	-7.5026667	49.1751563	56.2900076
U41	4.11	8.12	-10.3425	-6.3326667	106.967306	40.1026675
U42	6	4.24	-8.4525	-10.212667	71.4447563	104.298561
U43	11.44	8.8	-3.0125	-5.6526667	9.07515625	31.9526408
U44	10.56	11.15	-3.8925	-3.3026667	15.1515563	10.9076073
U45	6.11	5.2	-8.3425	-9.2526667	69.5973063	85.6118411
U46	10.89	12.88	-3.5625	-1.5726667	12.6914063	2.47328055
U47	14.11	12.26	-0.3425	-2.1926667	0.11730625	4.80778726
U48	4.67	5.93	-9.7825	-8.5226667	95.6973063	72.6358477
U49	2.56	3.64	-11.8925	-10.812667	141.431556	116.913761
U50	5.11	4.4	-9.3425	-10.052667	87.2823063	101.056108
U51	0.78	0.62	-13.6725	-13.832667	186.937256	191.342668
U52	5	3.11	-9.4525	-11.342667	89.3497563	128.656088
U53	2.56	3.86	-11.8925	-10.592667	141.431556	112.204588
U54	1	1.12	-13.4525	-13.332667	180.969756	177.760001
U55	3.89	4.4	-10.5625	-10.052667	111.566406	101.056108
U56	4.67	4.19	-9.7825	-10.262667	95.6973063	105.322328
U57	1.22	1.51	-13.2325	-12.942667	175.099056	167.512621
U58	7.11	7.39	-7.3425	-7.0626667	53.9123063	49.8812609
U59	5.44	5.32	-9.0125	-9.1326667	81.2251563	83.4056011
U60	2	1.78	-12.4525	-12.672667	155.064756	160.596481
TOTAL	**867.15**	**867.16**			**5462.98933**	**5375.32757**
MEAN	**14.4525**	**14.4526667**				

Table 4: Fisher Test To Analyse Regression Model 3

LEGEND $\ddot{y}_P = \sum Y_P / N$, $\ddot{y}_M = \sum Y_M / N$, N = 60

RESPONSE SYMBOL	Y_P	Y_M	$Y_P - \ddot{y}_P$	$Y_M - \ddot{y}_M$	$(Y_P - \ddot{Y}_p)^2$	$(Y_M - \ddot{y}_M)^2$
U1	29.89	29.16	15.4375	14.708167	238.316406	216.330168
U2	31.56	32.36	17.1075	17.908167	292.666556	320.702435
U3	33.33	32.1	18.8775	17.648167	356.360006	311.457788
U4	25.78	27.22	11.3275	12.768167	128.312256	163.026081
U5	28.44	27.66	13.9875	13.208167	195.650156	174.455668
U6	27.44	29.2	12.9875	14.748167	168.675156	217.508421
U7	24.22	23.75	9.7675	9.2981667	95.4040563	86.455904
U8	26.22	25.12	11.7675	10.668167	138.474056	113.809781
U9	26.44	26.82	11.9875	12.368167	143.700156	152.971548
U10	18.44	18.2	3.9875	3.7481667	15.9001563	14.0487536

Table 4: Fisher Test to Analyse regression Model 3 Cont.

U11	22.67	23.74	8.2175	9.2881667	67.5273063	86.2700406
U12	25	24.09	10.5475	9.6381667	111.249756	92.8942573
U13	27.78	27.56	13.3275	13.108167	177.622256	171.824034
U14	23.33	23.58	8.8775	9.1281667	78.8100063	83.3234273
U15	11.22	12.35	-3.2325	-2.1018333	10.4490563	4.41770322
U16	25.11	25.22	10.6575	10.768167	113.582306	115.953414
U17	23.67	23.95	9.2175	9.4981667	84.9623063	90.2151707
U18	19.89	15.88	5.4375	1.4281667	29.5664063	2.03966012
U19	23.22	23.68	8.7675	9.2281667	76.8690563	85.1590606
U20	25.44	24.08	10.9875	9.6281667	120.725156	92.701594
U21	13.67	18.33	-0.7825	3.8781667	0.61230625	15.040177
U22	23.22	22.86	8.7675	8.4081667	76.8690563	70.6972673
U23	23.22	24.05	8.7675	9.5981667	76.8690563	92.124804
U24	21.67	19.9	7.2175	5.4481667	52.0923063	29.6825204
U25	16.06	15.46	1.6075	1.0081667	2.58405625	1.01640009
U26	9.56	10.44	-4.8925	-4.0118333	23.9365563	16.0948064
U27	6.33	5.18	-8.1225	-9.2718333	65.9750063	85.9668927
U28	17.89	17.29	3.4375	2.8381667	11.8164063	8.05519022
U29	12.89	12.67	-1.5625	-1.7818333	2.44140625	3.17492991
U30	4.33	6.08	-10.1225	-8.3718333	102.465006	70.0875928
U31	16.11	19.24	1.6575	4.7881667	2.74730625	22.9265403
U32	17.33	15	2.8775	0.5481667	8.28000625	0.30048673
U33	7.11	7.11	-7.3425	-7.3418333	53.9123063	53.9025162
U34	23.22	21.3	8.7675	6.8481667	76.8690563	46.8973872
U35	15.78	17.44	1.3275	2.9881667	1.76225625	8.92914023
U36	8.89	8.28	-5.5625	-6.1718333	30.9414063	38.0915263
U37	6.44	6.45	-8.0125	-8.0018333	64.2001563	64.0293362
U38	5.89	3.77	-8.5625	-10.681833	73.3164063	114.101563
U39	1.78	2.88	-12.6725	-11.571833	160.592256	133.907326
U40	7.44	8.16	-7.0125	-6.2918333	49.1751563	39.5871663
U41	4.11	7.42	-10.3425	-7.0318333	106.967306	49.4466796
U42	6	4.6	-8.4525	-9.8518333	71.4447563	97.0586194
U43	11.44	9.91	-3.0125	-4.5418333	9.07515625	20.6282497
U44	10.56	10.49	-3.8925	-3.9618333	15.1515563	15.6961231
U45	6.11	5.49	-8.3425	-8.9618333	69.5973063	80.3144561
U46	10.89	11.69	-3.5625	-2.7618333	12.6914063	7.62772318
U47	14.11	12.99	-0.3425	-1.4618333	0.11730625	2.1369566
U48	4.67	5.59	-9.7825	-8.8618333	95.6973063	78.5320894
U49	2.56	2.95	-11.8925	-11.501833	141.431556	132.292169
U50	5.11	4.28	-9.3425	-10.171833	87.2823063	103.466193

Table 4: Fisher Test to Analyse regression Model 3 Cont.

U51	0.78	0.89	-13.6725	-13.561833	186.937256	183.923322
U52	5	3.82	-9.4525	-10.631833	89.3497563	113.035879
U53	2.56	3.98	-11.8925	-10.471833	141.431556	109.659293
U54	1	0.83	-13.4525	-13.621833	180.969756	185.554342
U55	3.89	5.08	-10.5625	-9.3718333	111.566406	87.8312594
U56	4.67	4.3	-9.7825	-10.151833	95.6973063	103.059719
U57	1.22	1.22	-13.2325	-13.231833	175.099056	175.081412
U58	7.11	6.7	-7.3425	-7.7518333	53.9123063	60.0909195
U59	5.44	5.22	-9.0125	-9.2318333	81.2251563	85.2267461
U60	2	2.05	-12.4525	-12.401833	155.064756	153.805469
TOTAL	**867.15**	**867.11**			**5462.98933**	**5354.6461**
MEAN	**14.4525**	**14.4518333**				