

CHAPTER ONE

INTRODUCTION

1.1. General Introduction

Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Supplementary cementations materials and chemical admixtures may also be included in the paste.

All concrete structures contain discontinuities such as joints, bedding planes, shear zones faults etc. The study of the deformation through this media is considered as a challenge in strength of material.

The concrete mass deformation is mainly function of concrete material. The approach deals with the analysis of characteristics and concrete properties. Recently; the numerical modeling is considered as the most important tool used to analyze the deformations of the concrete models.

The main objective of thesis research is to evaluate and study the total axial deformation using physical and numerical concrete models when they are subjected to the same axial stress as well as; to find a method, which could be used in predicting the normal and shear stiffness in the concrete.

In this research, the deformation of concrete were reviewed and then physical and numerical models would were built to simulate the concrete cubes. For the Experimental models, 12 concrete cubes were tested using crushing machine to obtain compressive strength.

1.2 Objective of research:

The Objectives of research were summarized as follows:

1. Comparative between the axial deformation in the experimental and numerical models using computer programs (UDEC and phase2).
2. Comparative between the compressive strength in the experimental and numerical models using programs (UDEC).
3. Test of the experimental models to obtain Calculation the axial deformations of the concrete and compressive strength of concrete.

1.3 Research Methodology:

Research methodology was summarized as follows:

1. Design of concrete mixes according to the British code and prepared material to be mixed.
2. Tests of fresh and hardening concrete mix using slump and compressive strength.
3. For Experimental modeling, 12 concrete cubes were tested determine axial deformations and compressive strength at (7, 14, 21and 28) days respectively.
4. For numerical modeling, 12 concrete cubes were simulated using two computer programs (UDEC and phase2).

1.4 Flowchart Description

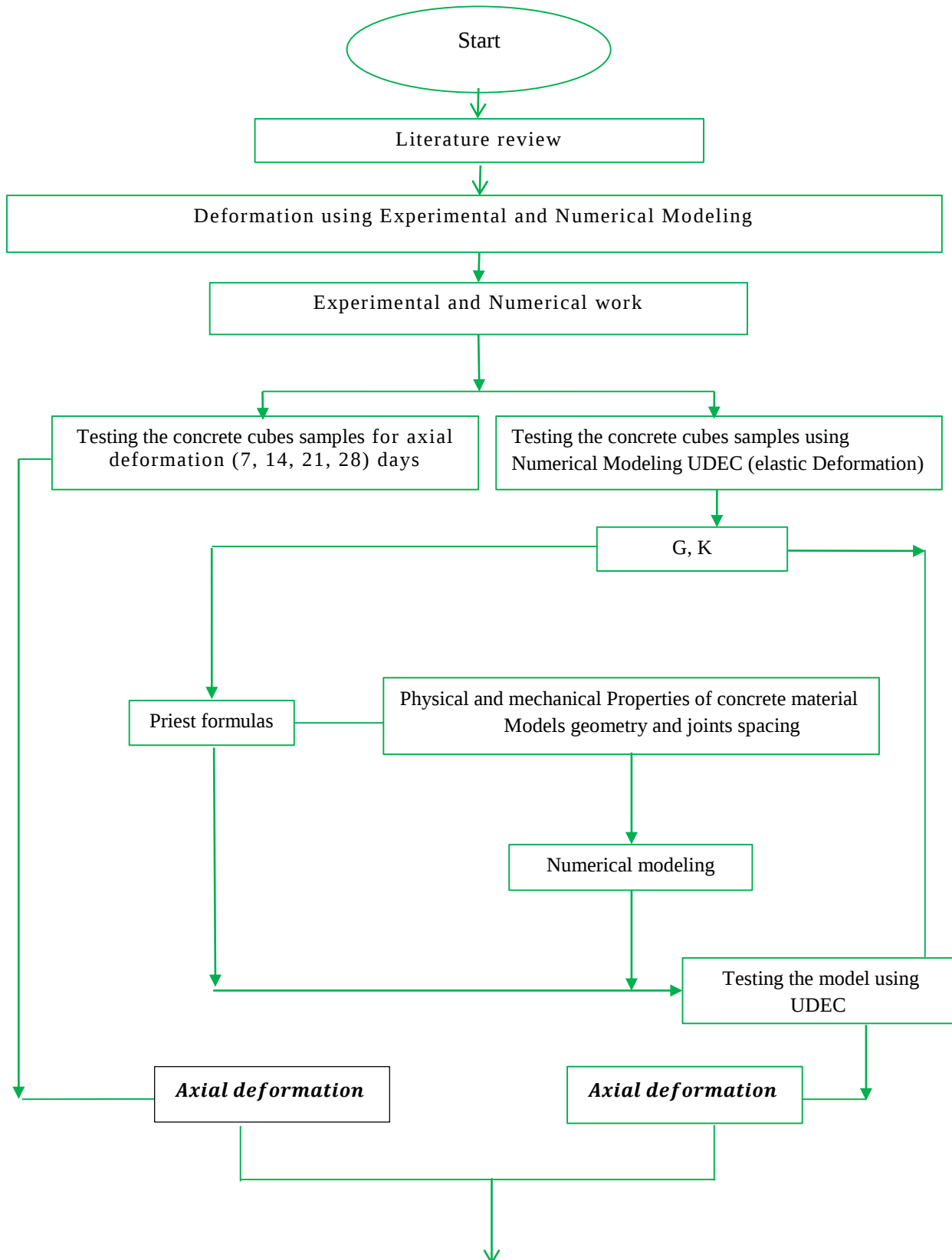
1.4.1 The Fact

Experimental and Numerical models would be used to predict the axial deformation of concrete.

1.4.2 The Output data analysis

Statistical analysis would be used to evaluate the variation in the axial deformation obtained models. Experimental and Simulation

1.4.3 Research Methodology Flow Chart



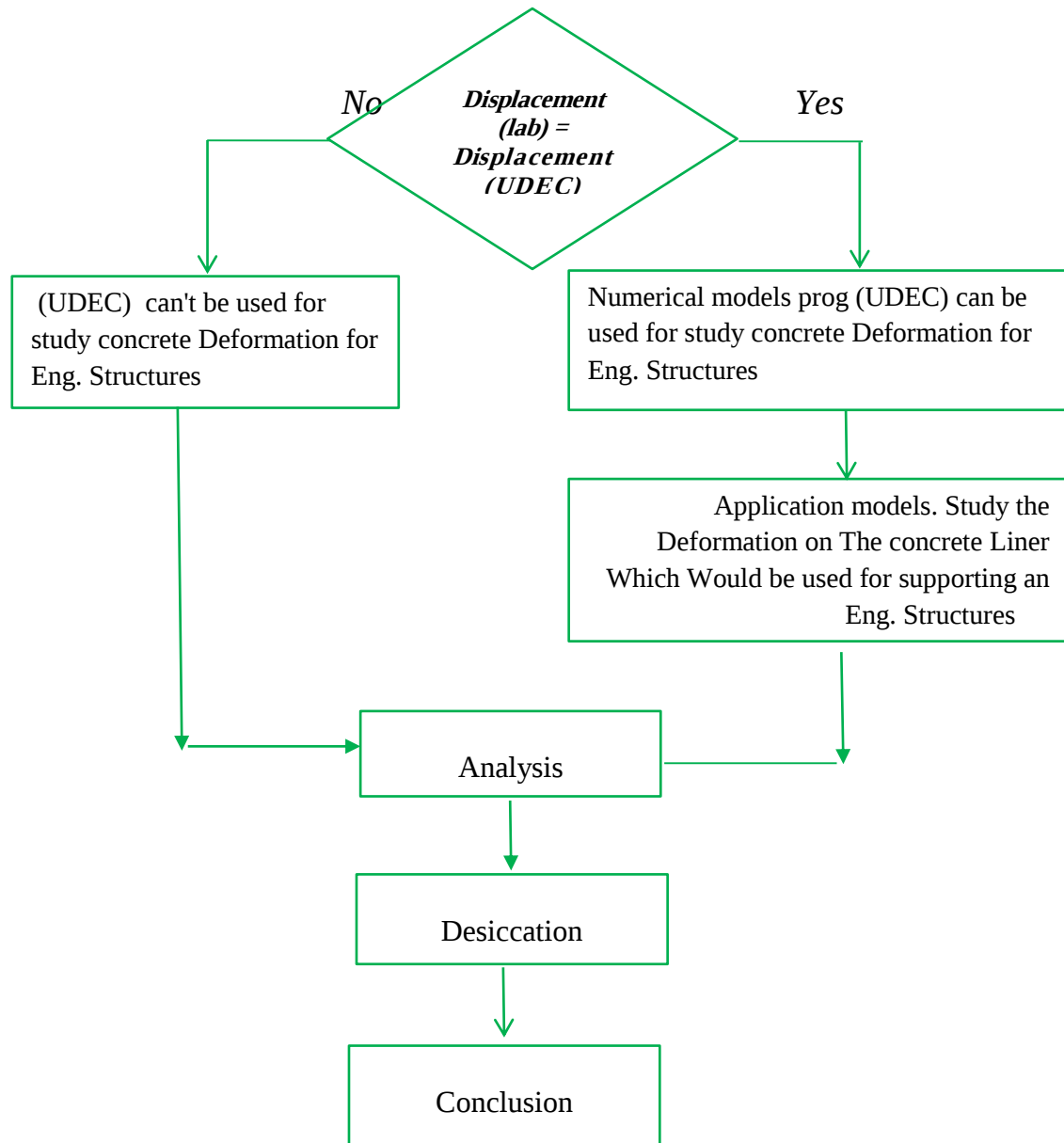


Figure 1.1 Research Methodology Flow Chart

1.5 Thesis layout

The work presented in this research consists of five chapters;

Chapter one provides introduction is including general introduction from research, objective and the reason for choosing this topic and constraints affecting the research.

Chapter two include the theoretical frame work of the components of the concrete mix and numerical methods using (UDEC) and (phase2) programs, methods and properties of each type tests.

Chapter three includes the experimental and numerical models for case study.

Chapter four provides comparison of experimental and numerical results and comparison of results and discussion.

Finally Chapter five assigned to conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction:

Concrete was made from cement, aggregates, chemical admixtures, mineral admixtures and water, comprises in quantity the largest of all man-made materials. The active constituent of concrete is cement paste and the performance of concrete is largely determined by the cement paste. Admixtures in concrete confer some beneficial effects such as acceleration, retardation, air entrainment, water reduction, plasticity, etc., and they are related to the cement-admixture interaction. Mineral admixtures such as blast furnace slag, fly ash, silica fume and others, also improve the quality of concrete. ^[1]

The performance of concrete depends on the quality of the ingredients, their proportions, placement, and exposure conditions. For example, the quality of the raw materials used for the manufacture of clinker, the claiming conditions, the fineness and particle size of the cement, the relative proportions of the phases, and the amount of the mixing water, influence the physicochemical behavior of the hardened cement paste. In the fabrication of concrete, amount and the type of cement, fine and coarse aggregate, water, temperature of mixing, admixture, and the environment to which it is exposed will determine its physical, chemical, and durability behavior. ^[1]

2.2 Previous Studies

Hasabelrsool Eltahir Abdalla Elsadig, 2012; had been working on circular Tunnel Excavation with Interior Support. This case study consists of a circular tunnel with a diameter of 2 m excavated in rock mass block of 12x12 m² with properties shown below. The model will be run till the equilibrium stage and then

the tunnel will be excavated and supported with steel sets, the history of displacements and the unbalance force will be followed in each stage of the modeling; starting from equilibrium stage, excavation stage and till supporting stage at the nodes 1, 2, 3, 4, 5, and 6. Moreover; the stress condition around the tunnel will be analyzed into the three stages too. Finally; the displacements at the nodes 1, 2, 3, and 4 as well as; the stresses around the tunnel will be obtained. The model will be run first under (stressed boundary) condition and then (Fixed velocity) boundary condition.

The conclusion can be summarized in the tables which show the displacements and stresses condition around the tunnel through all the stages of the modeling as well as; the analytical solution.

Pintea Augustin, 2012; had been working on elastic deformation of concrete. Determination of secant modulus of elasticity in compression, His case study is road structures (across the fourth Pan-European corridor, Nadlac-Arad section), namely prestressed concrete bridge beams with pre and post tensioned reinforcements, with lengths between 25 and 41 meters.

According to German standard DIN 1048-5:1991 and EN 12390 European Standard . The results of this paper, as for the other tested specimen (age 10 days), the value of Secant Modulus of Elasticity was just under the value of tested cylinder (age 28 days).

2.3. Cement

The name cement goes back to Roman times when a concrete-like masonry made of crushed stone pieces with burned lime and water as binding material was called Opus caementitium. Later the combination of brick powder and volcanic tuff with burned lime used as hydraulic binder was called cementum and cement.

[3]

The importance of clay content concerning the hydraulic properties of a naturally occurring mixture of limestone and clay was discovered by J. Smeaton of England as he was looking for a water resistant mortar for the construction of the Eddy stone light tower by Plymouth. This material would be called hydraulic lime today but was named as Roman cement at that time. The French L. J. Vicat and the German J. F. John found independently that 25 to 30% of clay addition to limestone produces the best hydraulic lime.^[2]

2.3.1. Portland cement

Portland cement concrete is composed of three basic components: Portland cement, aggregates, and water. In addition, there are a host of other materials, called additives that may be added to obtain special properties. The name Portland cement was coined in 1824 by Joseph Aspdin, a bricklayer of Leeds, England, who took out a patent for "a cement of superior quality resembling Portland stone," a natural limestone quarried on the peninsula of Portland in England Haegerman 1964. Despite the name, however, the material was probably hydraulic lime because of the apparently low burning temperature used. The production of Portland cement in the modern sense began about 20 years later by Isaac C. Johnson. Further development was influenced significantly by W. Michaels. He was the first to discuss in 1868 the most favorable composition of the raw materials for Portland cement.^[2]

The first high-early strength Portland cement was manufactured in the factory Loran's in Austria in 1912-1913; the clinker was burned at higher temperature and the fineness of the cement was also increased.^[2]

2.3.2. Tests on properties of cement

The manufacture of cement requires, and a number of tests are performed in the cement plant laboratory to ensure that the cement is of the desired quality and that it conforms to the requirements of the relevant national standards.

2.3.2.1. Fineness

On cement plant, cement fineness is normally determined with reference to surface area and 45-micro residue, while surface area is a good guide to the early rate of hydration of cement and thus early strength, it is a less reliable guide to late strength and, in particular, to 28 days strength. This is because under standard curing condition clinker particles, which are approximately 30 microns are in completely hydrated at 28 days. Since the process of rehydration begins at the surface of the particles of cement, the surface area of the total cement is representing the material available to the smoothness of granulated cement, as it is for growth of early resistance should be granulated cement with smoothness high. ^[8]

In addition to the compound composition, the fineness of cement also affects its reactivity with water. Generally the finer the cement, the more rapidly it will react. For a given compound composition the rate of reactivity and hence the strength development can be enhanced by finer grinding of cement, however, the cost of grinding and the heat evolved on hydration set some limit on the fineness. ^[8]

2.3.2.2. Soundness

Unsoundness is the harmful property that occurs when the hardened cement paste develops an undue expansion that is manifested by racking of the mass. Such expansion can be produced by several factors, for instance by misadjusted gypsum content in the cement, but the usual cause of unsoundness is the presence of free or uncombined lime. Excess quantities of crystalline magnesia, hydrated lime and hydrated magnesia occupy larger volumes than the original oxides, therefore expansion takes place during their hydration. When such hydration occurs before the final set of the cement paste, no detrimental effect results. Le chatelier accelerated test is prescribed by BS EN 196 – 3: 1995 for detecting unsoundness due to free lime only. ASTM C151 -05 specified autoclave test to both free magnesia and free lime. ^[5]

2.3.2.3. Setting time

The object of the setting time test is to determine

- (1) the time that elapses from the moment water is added until the paste ceases to be fluid and plastic (called initial set).
- (2) The time required for the paste to acquire a certain degree of hardness (called final set). To determine if a cement sets according to the time limits specified in cement specifications, tests are performed using either the Vicat apparatus (ASTM C 191 or AASHTO T 131) as shown in Figure (2.1) or the Gilmore needle (ASTM C 266 or AASHTO T 154) as in Figure (2.2). The Vicat test governs if no test method is specified by the purchaser. Initial set of cement paste must not occur too early and final set must not occur too late. The setting times indicate that a paste is or is not undergoing normal hydration reactions. Sulfate (from gypsum or other sources) in the cement regulates setting time, but setting time is also affected by cement fineness, water cement ratio and any admixtures that may be used. Setting times of concretes do not correlate directly. ^[3]

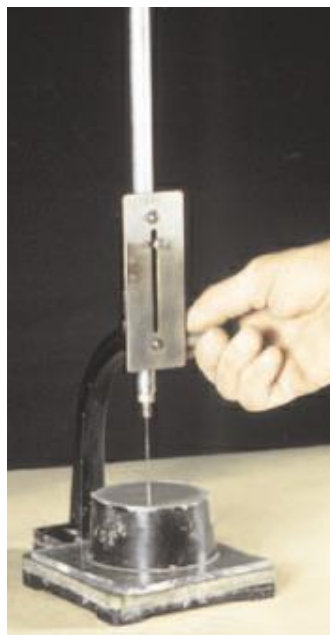


Figure (2.1): Time of set test for paste using the Vicat needle.

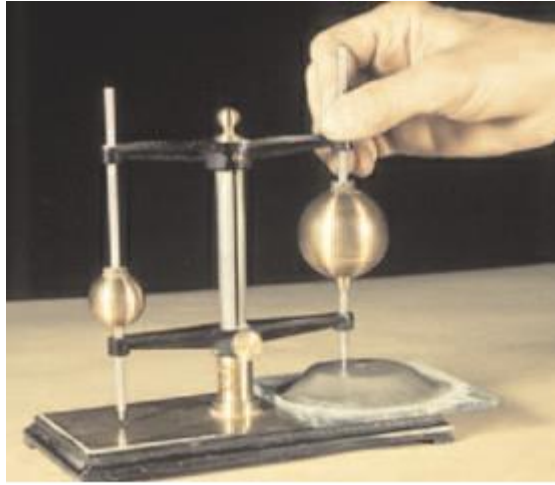


Figure (2.2): Time of set as determined by the Gillmore needle.

2.3.2.4 Consistency of Stander Paste

Consistency refers to the relative mobility of a freshly mixed cement Paste or mortar or to its ability to flow. During cement testing, pastes are mixed to normal consistency as defined by a penetration of 10 ± 1 mm of the Vicat plunger (see ASTM C187 or AASHTO T 129 and Figure (2.3)). Mortars are mixed to obtain either a fixed water/cement ratio or to yield a flow within a prescribed range. The flow is determined on a flow table as described in ASTM C 230 (AASHTO M 152) and ASTM C 1437) Figure (2.4). Both the normal consistency method and the flow test are used to regulate water contents of pastes and mortars, respectively, to be used in subsequent tests; both allow comparing dis- similar ingredients with the same penetrability or flow. ^[3]



Figure (2.3): Normal consistency test for paste using the Vicat plunger.



Figure (2.4): Consistency test for mortar using the flow table. The mortar is placed in a small brass mold centered on the table (in-set).

2.4 Aggregates for Concrete:-

The importance of using the right type and quality of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm as Figure (2.5).^[3]

Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (0.2 in.) and generally between 9.5 mm and 37.5 mm (3/8 in. and 1 1/2 in.) as shown in Figure (2.6). Some natural aggregate deposits, called pit-run gravel, consist of gravel and sand that can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Crushed air-cooled blast-furnace slag is also used as fine or coarse aggregate. ^[3]



Figure (2.5): Close-up of fine aggregate (sand).



Figure (2.6): Coarse aggregate. Rounded gravel (left) and crushed stone (right).

The aggregates are usually washed and graded at the pit or plant. Some variation in the type, quality, cleanliness, grading, moisture content, and other properties is expected. Close to half of the coarse aggregates used in Portland cement concrete in North America are gravels; most of the remainder are crushed stones.^[3]

Naturally occurring concrete aggregates are a mixture of rocks and minerals. A mineral is a naturally occurring solid substance with an orderly internal structure and a chemical composition that ranges within narrow limits. Rocks, which are classified as igneous, sedimentary, or metamorphic, depending on origin, are generally composed of several minerals. For example, granite contains quartz, feldspar, mica, and a few other minerals; most lime stones consist of calcite, dolomite, and minor amounts of quartz, feldspar, and clay. Weathering and erosion of rocks produce particles of stone, gravel, sand, Silt and clay.

Recycled concrete, or crushed waste concrete, is a feasible source of aggregates and an economic reality, especially where good aggregates are scarce. Conventional stone crushing equipment can be used, and new equipment has been developed to reduce noise and dust.^[3]

Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Aggregate particles that are friable or capable of being split are undesirable.^[3]

2.4.1. Grading

Grading is the particle-size distribution of an aggregate as determined by a sieve analysis (ASTM C 136 or AASHTOT 27). The range of particle sizes in aggregate is illustrated in Figure (2.7). The aggregate particle size is determined by using wire-mesh sieves with square openings.

The seven standard ASTM C 33 (AASHTO M 6/M 80) sieves for fine aggregate have openings ranging from 150 μm to 9.5 mm (No. 100 sieve to 3/8 in.). The 13 standard sieves for coarse aggregate have openings ranging from 1.18 mm to 100 mm (0.046 in. to 4 in.).^[3]



Figure (2.7): Range of particle sizes found in aggregate for use in concrete.

Aggregate proportions as well as cement and water requirements, workability, pump ability, porosity, shrinkage, and durability of concrete. Variations in grading can seriously affect the uniformity of concrete from batch to batch. Very fine sands are often uneconomical; very coarse sands and coarse aggregate can produce harsh, unworkable mixtures. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve will produce the most satisfactory results.^[3]

During the early years of concrete technology it was sometimes assumed that the smallest percentage of voids (greatest density of aggregates) was the most suitable for concrete. At the same time, limits were placed on the amount and size of the smallest particles. It is now known that, even on this restricted basis, this is not the best target for the mix designer. However, production of satisfactory, economical concrete requires aggregates of low void content, but not the lowest.

Sketch B represents the dispersal of aggregates in a matrix of paste. The amount of paste is necessarily greater than the void content of sketch A in order to provide workability to the concrete; the actual amount is influenced by the workability and cohesiveness of the paste. ^[3]

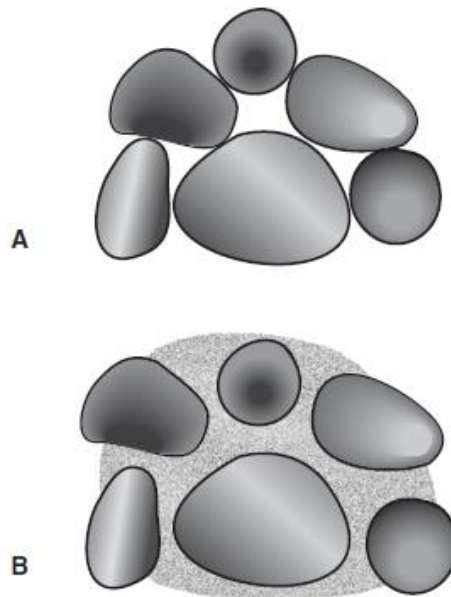


Figure (2.8): Illustration of the dispersion of aggregates in cohesive concrete mixtures.

2.5. Mixing Water for concrete

Almost any natural water that is drinkable and has no pronounced taste or odor can be used as mixing water for making concrete as shown in Figure (2.9). However, some waters that are not fit for drinking may be suitable for use in concrete. ^[3]



Figure (2.9) Water that is safe to drink is safe to use in concrete.

2.6. Mix design procedure

2.6.1. Selection of target water/cement ratio (w/c) (stage1)

If previous information concerning the variability of strength tests comprises less than 20 result the standard deviation to be adopted should be that obtained from line A in Figure (A.1).if previous information available consisting of 20 or more results, the standard deviation of such results may be used provided that this value is not less than appropriate value obtained from line B. The margin can then be derived from calculation (C1). ^[4]

$$M = K * S \quad (2.1)$$

Where M = the margin

S = the standard deviation

K= a value appropriate to the percentage defective below the characteristic strength

Calculation (C2) determines the target mean strength

$$f_m = f_c + M \quad (2.2)$$

Where f_m = the target mean strength

f_c = the specified characteristic strength

M = the margin

Next, a value is obtained from Table (A.1) for the strength of a mix made with a free-water /cement ratio of 0.5 according to the specific age, the type of cement and the aggregate to be used. This strength value is then plotted on Figure (A.2) and a curve is drawn from this point and parallel to the printed curves until it intersects a horizontal line passing through the ordinate representing the target mean strength. The corresponding value for the water/cement ratio (w/c) can then be read from the abscissa. ^[4]

2.6.2. Selection of free- water content (stage 2)

In this stage consists simply of determining the free- water content from Table (A.2) depending upon the type and maximum size aggregate to give a concrete of the specified slump (mm). ^[4]

2.6.3. Determination of cement content (stage 3)

The cement content is Determined from calculation (C3)

$$\text{cement content} = \frac{\text{free – water content}}{\text{free water/cement ratio}} \quad (2.3)$$

The resulting value should be checked against any maximum or minimum value that may any be specified. If the calculated cement content from (C3) is below a specified minimum, this minimum value must be adopted and a modified water/cement ratio (w/c) from stage1. ^[4]

2.6.4. Determination of cement content (stage 4)

Stage4 requires an estimate of the density of the fully compacted concrete, which is obtained from figure (A.3) for depending upon the free- water content and the relative density of the combined aggregate in the saturated surface-dry condition

(SSD). If no information is available regarding the relative density of the aggregate an approximate can be made by assuming a value of 2.6 for uncrushed aggregate and 2.7 for crushed aggregate. From this estimated density of the concrete the total aggregate content is determined from calculation (C4).^[4]

$$\text{Total aggregate content} = D - C - W \quad (2.4)$$

Where D = the wet density of concrete (kg/m^3)

C = the cement content (kg/m^3)

W = the free- water content (kg/m^3)

2.6.5. Selection of fine and coarse aggregate content (stage 5)

5stage involves deciding how much of the total aggregate should consist of material than 5mm.the sand or fine aggregate content Figure (A.4) shows recommended values for the proportion of fine aggregate depending on the maximum size of aggregate, the workability level , the grading of the fine aggregate (defined by its percentage passing a 600 μm sieve) and the free water/cement ratio. The best proportion of fine to use in a given mix will depend on the shape of the particular aggregate, the actual grading of the fine aggregate and the used to which the concrete is to be put. However, adoption of proportion obtained from Figure (A.4) will generally give a satisfactory concrete be adjusted as required for the exact conditions prevailing

The final calculation (C5) to determine the fine and coarse aggregate content, is made using the proportion of fine aggregate obtained from Figure (A.4) and the total aggregate content derived in stage4.^[4]

$$\text{Fine aggregate content} = \text{total aggregate content} \times \text{proportion of fine}$$

$$\text{Coarse aggregate content} = \text{aggregate content} - \text{fine aggregate content}$$

2.7. Concrete Tests

Interest of testing of fresh concrete and hardened concrete has increased considerably, and significant advances have been made in techniques, equipment, and methods of application. ^[5]

Change in cement manufacture, increased use of cement replacement and decline in standards of workmanship and construction supervision have all been blamed. Particular attention has thus been paid to development of test methods which are related to durability performance and integrity. There is also an increasing awareness of the shortcomings of control or compliance tests which require a 28-days wait before results are available. The tests should be performed and interpreted by experienced specialists, many difficulties arise both at the planning and interpretation stage because of a lack of common understanding. ^[5]

A great deal of time, effort and money can be wasted on unsuitable or badly planned testing, leading to inconclusive results which then become the subject of heated debate. ^[5]

2.7.1. Fresh concrete

2.7.1.1. Slump test

This test is carried out by filling the slump cone with freshly mixed concrete which is tamped with a steel rod in three layers; the concrete is leveled off with the top of the slump cone. The slump test in Figure (2.10), which is simple, quick and cheap, is almost universally used for nearly all types of medium and high workability concrete. There are also some differences in practice with its use in different countries. The mould for the slump test is a frustum of 305mm (12in) high. The base of 203mm (8in) diameter is placed on a smooth surface with the smaller opening of 102mm (4in) diameter at the top, and the container is filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm (5/8 in) diameter steel rod, rounded at the end, and the top surface is struck off by

means of rolling motion of the tamping rod. The mould must be firmly held against its base during the entire operation. This is facilitated by handles or foot-rests brazed to the mould. Immediately after filling, the cone is slowly lifted, and the unsupported concrete will now slump-hence the name of the test. The decrease in the height of the center of the slumped concrete is called slump and is measured to the nearest 5mm (1/4 in).^[8]

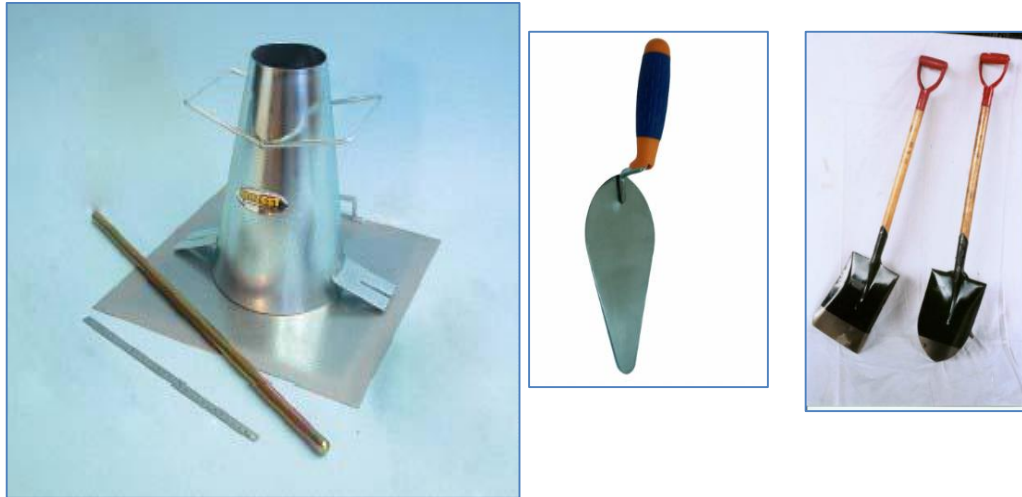


Figure (2.10): Slump test devices.

Mixes of stiff consistence have a zero slump, so that in the rather dry range no variation can be detected between mixes of different workability. There is no problem with rich mixes, their slump being sensitive to variation in workability.^[5]

2.7.1.2. Compacting Factor test

The test was developed in the UK and described in BS 1881: part 103:1993 and ACI standard. The apparatus consists essentially of two hoppers, each in the shape of a frustum cone, and one cylinder, the three being above one other. The hoppers have hinged doors at the bottom, as shown in Figure (2.11).

All inside surfaces are polished to reduce friction. The upper hopper is filled with concrete, this being placed gently so that, at this stage, no work is done on the concrete to produce compaction. The bottom door of the hopper is then released

and the concrete fall into the lower hopper. This hopper is smaller than the upper one and is, therefore, filled to overflowing and thus always contains approximately the same amount of concrete in a standard state; this reduces the influence of the personal factor in filling the top hopper. [5]



Figure (2.11): Compacting Factor apparatus.

2.7.1.3. Compressive Strength test

The most common of all tests on hardened concrete is the compressive strength test, partly because it is an easy test to perform, and partly because many, though not all, of the desirable characteristics of concrete are qualitatively related to its strength; but mainly because of the intrinsic importance of the compressive strength of concrete in structural design.

The strength test results may be affected by variation in:

1. Type of test specimen
2. Specimen size.
3. Curing
4. Preparation of the end surface
5. Rigidity of the testing machine

The age at which service specimens are tested is governed by information required. On the other hand, standard specimens are tested at prescribed ages, generally 28 days, with additional tests often made at 3 and 7 days.

Two type of compression test specimens are used:

1. Cubes : used in Great Britain, Germany and many other countries in Europe
1. Cylinders: are the standard specimens in the United State, France, Canada, Australia, and New Zealand.

Universal ball seated upper platen. 10*10*10 cm, 15*15*15 cm, 20*20*20 cm cube, and 75*150cm 15*30 cm standard cylinder samples can be tested. Distant pieces are supplied according to sample size as shown in Figure (2.12). Upper and lower platens are hardened. After samples tested, the results are compressive strength.



Figure (2.12): Compressive Strength test devices.

2.8. Universal Distinct Element Code program

The Universal Distinct Element Code (UDEC) is a two-dimensional numerical program based on the distinct element method for discontinuous modeling. UDEC simulates the response of discontinuous media subjected to either static dynamic loading. The discontinuous medium is represented as an assemblage of discrete blocks. The discontinuities are treated as boundary conditions between blocks; large displacements along discontinuities and rotations of blocks are allowed. Individual blocks behave as either rigid or deformable material. Deformable blocks are subdivided into a mesh of finite-difference elements, and each element responds according to a rescribed linear or nonlinear stress-strain law. The relative motion of the discontinuities is also governed by linear or nonlinear force-displacement relations for movement in both the normal and shear directions. UDEC has several built-in material behavior models, for both the intact blocks and the discontinuities, which permit the simulation of response representative of discontinuous geologic (or similar) materials. UDEC is based on a “Lagrangian” calculation scheme that is well-suited to model the large movements and deformations of a blocky system.[7]

2. 8.1. History of Universal Distinct Element Code Program

UDEC (Universal Distinct Element Code) is a two-dimensional computer program based on the distinct element method. The program, originally written by P. A. Condell (Condell 1980), has been under active development for over 10 years. The distinct element method is a recognized discontinuum modeling approach for simulating the behavior of jointed media subjected to quasi-static or dynamic boundary conditions.

The distinct element method was originally created as a two-dimensional representation of a jointed-rock mass, but the method has also been extended to applications in particle flow research (Walton 1980), studies on microscopic mechanisms in granular material (Condell and Strack 1983), and crack

development in rocks and concrete (Plesha and Aifantis 1983, and Lorig and Condell 1987). The method has three distinguishing features which make it well suited for discontinuum modeling.

1. The medium is simulated as an assemblage of blocks which interact through corner and edge contacts.
2. Discontinuities are regarded as boundary interactions between these blocks; discontinuity behavior is prescribed for these interactions.
3. The method utilizes an explicit' time stepping (dynamic) algorithm which allows large displacements.^[6]

2.8.2. Analytical Solution for the Axial Deformation of the Concrete Model

The model consists of a cubes concrete with a diameter of (0.15 x 0.15m) block of with properties shown below. The model will be run till the equilibrium stage and the concrete models and supported in one direction, the history of displacements and the unbalance force will be followed in each stage of the modeling, starting from equilibrium stage, equilibrium in this stage and supporting at the nodes 6. The model elastic medium subjected to hydrostatic stress in Mpa (N/mm^2).

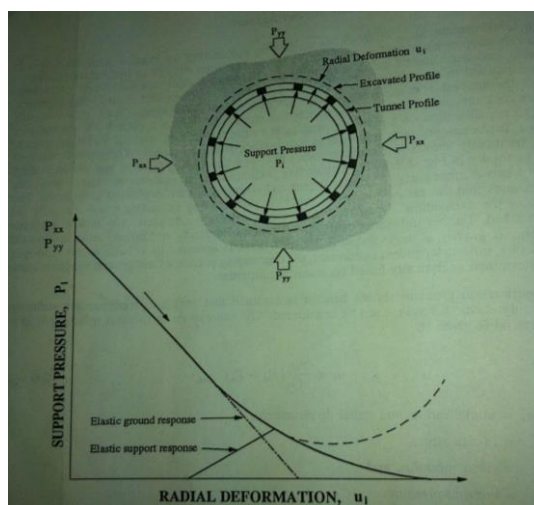


Figure (2.13): Conceptual Representation of Support Reaction and Ground Reaction curves.

The expression for axial deformation is by:

$$u_i = \frac{r_i}{2G} \{P_o - P_i\} \quad (2.5)$$

where: r_i , u_i : tunnel radius and displacement

P_o : In – situ stress

G : shear modulus and

P_i : Internal pressure

2.8.2.1. Concrete Properties

The Bulk modulus, (K) and shear modulus, (G), are related to young's modulus, (E) and Poisson ratio, ν , given by

$$K = \frac{E}{3(1 - 2\nu)} \quad (2.6)$$

$$G = \frac{E}{2(1 + \nu)} \quad (2.7)$$

$$E = \frac{9KG}{3K + G} \quad (2.8)$$

$$\nu = \frac{3k - 2G}{2(3K + G)} \quad (2.9)$$

2.8.2.2. Poisson's Ratio, ν

Where linear elastic analysis is appropriate and Poisson's ratio may be taken as 0.2 according to (BSI 8110 2.4.2.4 Poisson's ratio for concrete), Density for concrete 2400 kg/m³.

2.8.2.3. Mechanics of Using UDEC

UDEC is based on a command-driven format. Word commands control the operation of the program. This section provides an introduction to the basic commands a new user needs to perform simple UDEC calculations. Alternatively, the project files (with extension “.PRJ”) corresponding to these data files can be called into the GIIC using the File / Open Project menu item. ^[6]

In order to set up a model to run a simulation with UDEC, three fundamental components of a problem must be specified. ^[6]

- (1) a distinct-element model block with cuts to create problem geometry;
- (2) Constitutive behavior and material properties; and
- (3) Boundary and initial conditions.

The model block defines the geometry of the problem. The constitutive behavior and associated material properties dictate the type of response the model will display upon disturbance (e.g. deformational response due to loading). Boundary and initial conditions define the in-situ state (i.e., the condition before a change or disturbance in problem state is introduced).

After these conditions are defined in UDEC, an alteration is made (e.g., change boundary conditions), and the resulting response of the model is calculated. The actual solution of the problem is different for an explicit-solution program like UDEC than it is for conventional implicit-solution programs. ^[6]

The solution is reached after a series of computational steps. In UDEC, the number of steps required to reach a solution is controlled manually by the user. The user ultimately must determine whether the number of steps is sufficient to reach the solved state. ^[6]

2.9. Numerical Modeling

The general solution procedure for an explicit static analysis with UDEC. This procedure is convenient because it represents the sequence of processes that occur in the physical environment. The basic UDEC commands needed to perform simple analyses with this solution procedure are described in the following pages. [6]

2.9.1. Block Cutting

The UDEC model is created by cutting the original UDEC block into smaller blocks that represent boundaries of physical features in the problem. The model block is made with the command `Block (x1,y1), (x2,y2), (x3,y3) ...` where (x₁,y₁), (x₂,y₂), (x₃,y₃) ... are coordinate pairs that define the corners of the block. The pairs, Must be entered in a clockwise order. The corners should be located to coincide with the boundary of the physical problem. The block can have many corners, but it is usually easiest to start with a four-corner block. [6]

The overall view of program is shown in Figure (2.14)

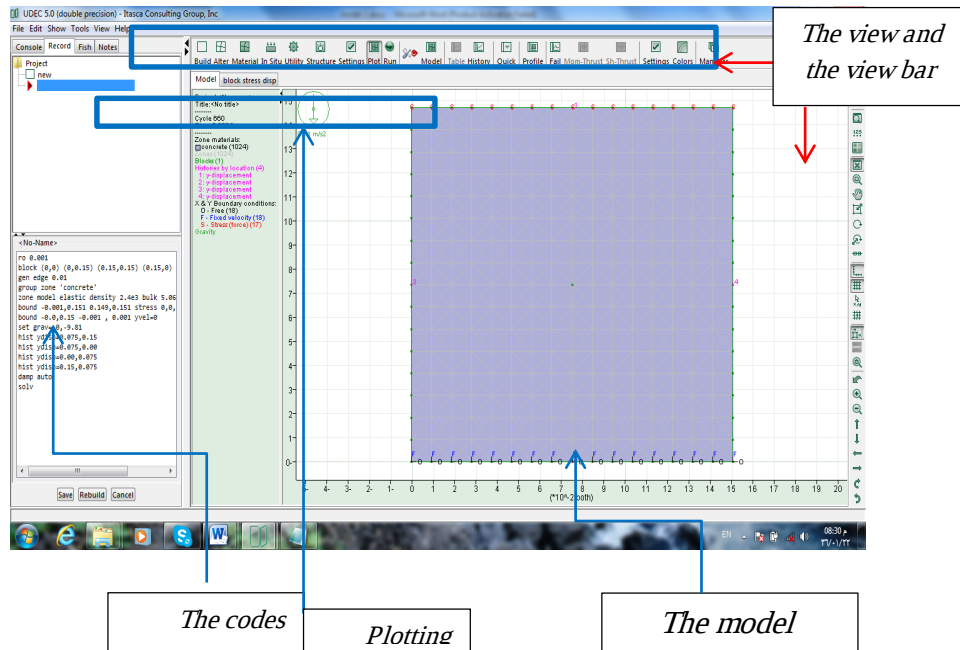


Figure (2.14): The Overall View of the Model.

2.9.2. Round (d)

The rounding distance or length is the same for all blocks in a model.

It is recommended that the rounding length be specified before the BLOCK command. The effect of corner rounding can be seen by typing plot block after the BLOCK command is given.

There are several commands available to cut the UDEC block in order to create geometries in the model. Two primary commands are used to create geologic structure (e.g., joints):

2.9.3 Crack:

The CRACK command creates a single straight-line fracture in the block. The crack is defined by its endpoints (x_1, y_1) and (x_2, y_2) .

2.9.4. Applying Boundary and Initial Conditions

Boundary and initial conditions must not be applied until after all block cutting is complete and the mesh for deformable blocks is generated. Mechanical boundary conditions are generally applied with the Boundary command. This command is used to specify force, stress and velocity (displacement) boundary conditions. [6]

The general solution procedure for an explicit static analysis with UDEC is illustrated in Figure 2.48. This procedure is convenient because it represents the sequence of processes that occur in the physical environment. The basic UDEC commands needed to perform simple analyses with this solution procedure are described in the following pages. [6]

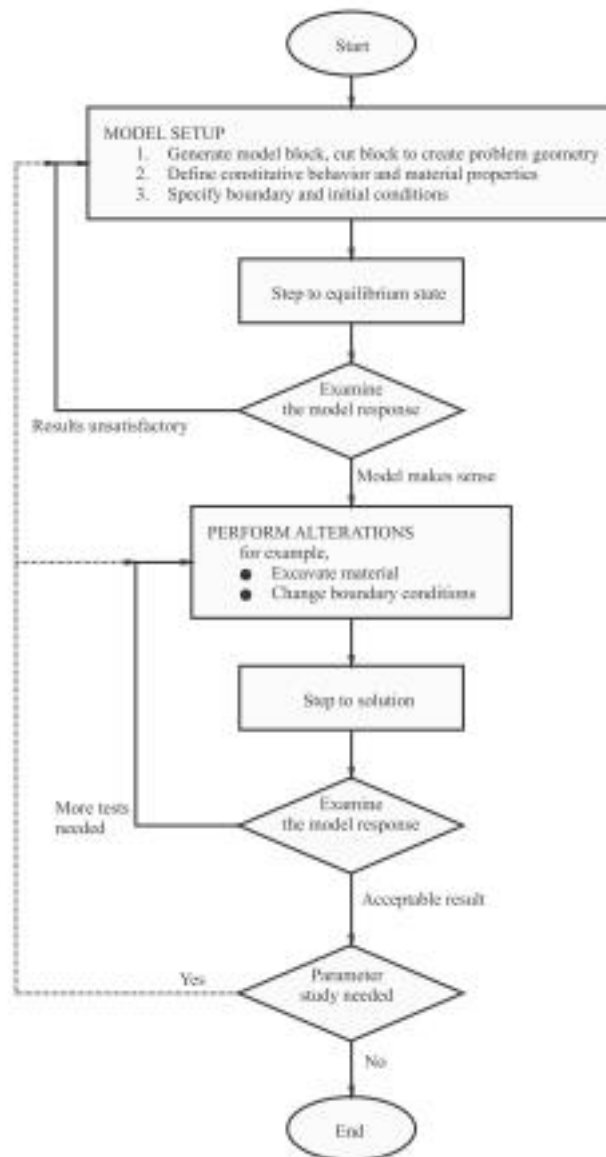


Figure (2.15): General solution procedure for static analysis.

2.10. Computer Software Phase 2

2.10.1. Introduction

Phase2 is a tow-dimensional elastic -plastic finite element program for calculating stresses and displacements, and can be used to solve a wide range of mining, geotechnical and civil engineering problems.

Bolt models have been implemented in various numerical methods such as the Finite Element Method (FEM), the Boundary Element Method (BEM) and block methods .This document outlines the background theories of the bolt

support models used in Phase 2 Let us consider the generic element shown in Figure (2.15).

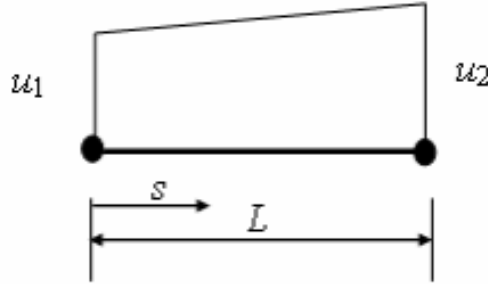


Figure (2.16): Linear displacement variation.

2.10.2. Mechanics of Using Phase2 program

The displacements u are to be linear in axial coordinates (Cook, 1981). The Displacement field equals u_1 at one end and u_2 at the other. Then, the displacement at any point along the element can be given as:

$$u = \frac{L-s}{L}u_1 + \frac{s}{L}u_2 \quad \text{or} \quad u = [N]\{d\}$$

$$\text{where } [N] = \begin{bmatrix} \frac{L-s}{L} & \frac{s}{L} \end{bmatrix} \text{ and } \{d\} = \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix} \quad (2.10)$$

$$u = \begin{Bmatrix} u_x \\ u_r \end{Bmatrix} = \begin{bmatrix} N_1 & N_2 & 0 & 0 \\ 0 & 0 & N_1 & N_2 \end{bmatrix} \begin{Bmatrix} u_{x1} \\ u_{x2} \\ u_{r1} \\ u_{r2} \end{Bmatrix} \quad (2.11)$$

$$-\int \left(AE_b \frac{du_x}{dx} \frac{d\delta u}{dx} + ku_x \delta u \right) dx + \int (ku_r \delta u) dx = - \begin{bmatrix} u_{x1} & u_{x2} & u_{r1} & u_{r2} \end{bmatrix} \begin{bmatrix} K_b & 0 \\ 0 & -K_r \end{bmatrix} \delta \begin{Bmatrix} u_{x1} \\ u_{x2} \\ u_{r1} \\ u_{r2} \end{Bmatrix}$$

and let us introduce the notation $[B] = [N_{,x}]$

$$\text{then } u_{,x} = \frac{du}{dx} = [B] \{d\} = \begin{bmatrix} -\frac{1}{L} & \frac{1}{L} \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix}$$

(2.12)

Hence,

$$[K_b] = \int_0^L \left\{ AE_b \begin{bmatrix} N_{1,x} N_{1,x} & N_{1,x} N_{2,x} \\ N_{2,x} N_{1,x} & N_{2,x} N_{2,x} \end{bmatrix} + k \begin{bmatrix} N_1 N_1 & N_1 N_2 \\ N_2 N_1 & N_2 N_2 \end{bmatrix} \right\} dx$$

$$[K_b] = \frac{AE_b}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} + k \int_0^L \begin{bmatrix} \left(1 - \frac{x}{L}\right)^2 & \left(1 - \frac{x}{L}\right) \frac{x}{L} \\ \left(1 - \frac{x}{L}\right) \frac{x}{L} & \left(\frac{x}{L}\right)^2 \end{bmatrix} dx$$

$$[K_b] = \frac{AE_b}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} + \frac{kL}{3} \begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix}$$

and

$$[K_r] = k \begin{bmatrix} N_1 N_1 & N_1 N_2 \\ N_2 N_1 & N_2 N_2 \end{bmatrix} = \frac{kL}{3} \begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix}$$

(2.13)

The Equations are used to assemble the stiffness for the nodal. Phase2 uses Bolts that are not necessarily connected to the element vertices, therefore a mapping procedure is carried out to transfer the effect to the element vertices. This procedure is done for each bolt segment by mapping the stiffness by the shape function depends on the intersected side of the elements. [7]

The Following Steps were Performed to obtain axial deformations and compressive stresses.

1. Geometric

The Phase2 model is created by cutting the original Phase2block into smaller blocks that represent boundaries of physical features in the problem. The model block is made with the command Block (x_1, y_1) , (x_2, y_2) , (x_3, y_3) ...

where (x_1, y_1) , (x_2, y_2) , (x_3, y_3) ... are coordinate pairs that define the corners of the block.

The block can have many corners, but it is usually easiest to start with a four-corner block.

2. Concrete Properties

- i. Modulus of Elasticity, E_c
- ii. Poisson's Ratio, ν
- iii. Unit weight of Concrete

3. Discretization

Before the mesh is generated the boundaries must first be discretized. This process subdivides the boundary line segments into discretization which will form the framework of the finite element mesh. ^[7]

4. Meshing

After discretizing, the finite element mesh can be generated. The mesh is based on the discretization of the boundaries, and the mesh and element types selected in the Mesh Setup dialog

5. Making discretize and mesh

Discretize manufacture external boundary that divides into segments as connective point mesh. Mesh made in this work is graded by type of tile elements 8 noded quadrilaterals see Figure (2.16)

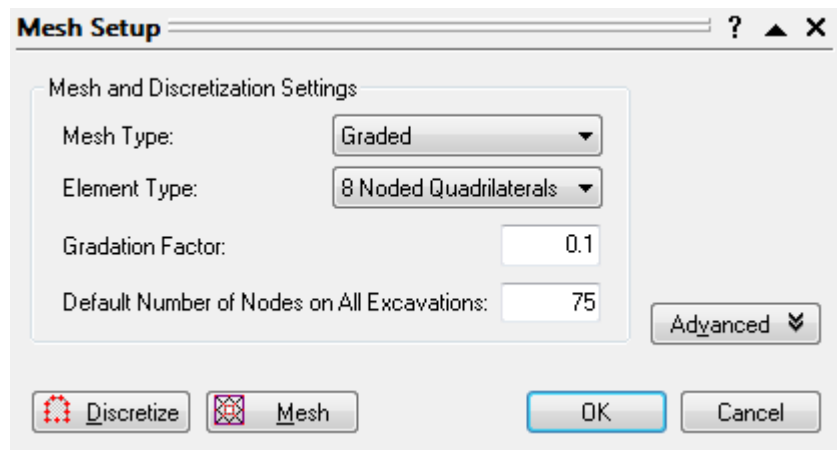


Figure (2.17) Determination of element types (mesh) to be used.

6. Calculation

The calculation is performed by iterating 500 times with a maximum tolerance of 0001 . To perform the calculation press toolbar as shown in Figure (2.17) . ^[7]

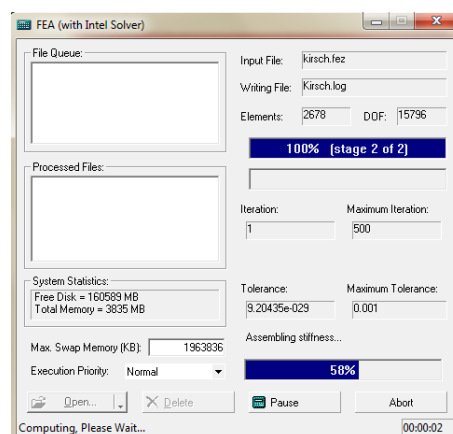


Figure (2.18): The calculation process

7. Display the results to stresses and deformations

The calculation result can be seen on the menu interpret. On the menu this can be seen interpret stress distribution and displacement distribution on each node (a node between the mesh). Distribution that can be seen in Figures (2.18)

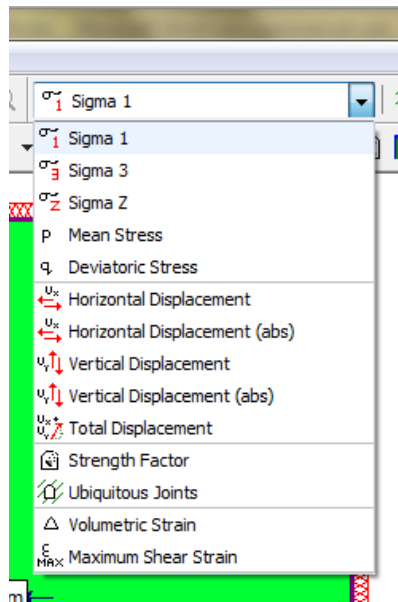


Figure (2.19): Display of stresses and deformations

CHAPTER THREE

EXPERIMENTAL AND NUMERICAL OF CONCRETE CUBES

3.1 Introduction:

In this chapter Experimental Work has been presented which estimate the compressive strength of 12 concrete cubes, and other related properties of concrete such as slump, density, elastic modulus and axial deformation it was also done, the numerical analysis for cubes using two computer software programs (UDEC and phase2) to obtain compressive strength and axial deformation.

The 12 concrete cubes were tested by crushing machine at different ages such as 7, 14, 21 and 28 days respectively. The concrete mix design was prepared according British standard to make concrete cubes and the results of cement, fresh and hardened concrete tests were presented.

3.2 Material used in Experimental model

Materials used in Experimental model were as follows:

- 1- The cement used was ordinary Portland cement type of cement (O.P.C) fineness and setting time had been tested;
- 2- The aggregate used with maximum size 20mm and relative density 2.6
- 3- The water used in concrete mix was natural water and drinkable

3.3 Equipments used in tests

Equipments used in test were as follows:

- 1- 12 concrete cubes
- 2- Slump test set.
- 3- Strain gauges to measure axial deformation.

- 4- British standard for was used for concrete mix design form as shown in appendix A
- 5- Compressive machine device.

3.4. Experimental work

Experimental work in includes Fineness test, Setting time, fresh and hardened concrete tests.

3.4.1 Fineness test

Dry cement of 100g by sieve index 0.09 ml for 15 minutes, then sieving process conducted by hand. The weight of the cement has been retained on a sieve to the nearest 10g and fineness was the percentage of the wright to the retained sieve , noted that the sieve of the test was based upon a pot lid tightly , and taking into account the cleanliness of the sieve before testing .

Setting time test

A cement of 400 g was added to water to form a standard paste with stop watch running while adding water to cement. Cement mixed with water for four minutes and then placed cement past in Vicat device and adjustment surface of paste. Vicat device puttred over metal plate, which was under cylindrical side. The surface of the needle drooping even touched the surface of the paste slowly, then descended to fall under the influence of the total weight cylindrical tip and took a reading gradient in front of the mark on the drum and drooping after the needle tip from the bottom. The process of entry needle into cement past was repeated more than once. The process was repeated several times until the needle far from the bottom of the mold about 604 mm. The time recorded and it was initial setting time. The results of initial and final setting time ware presented as shown in Figure (3.1).



Figure (3.1): Setting time test.

Table (3.1): Setting time results:

Initial Setting time (min)	90
Final Setting time (min)	185

3.4.2 Fresh and hardened test:

First step was to determine concrete quantities and then to choose trial mixes, so modify quantities before mix it. The workability test was set by using slump test and the result was determined (20mm).

Secondary, fresh concrete was tested in cubes moulds as shown in Figure (3.2) and the curing of 12 concrete cubes was done using water path. Each 3 cubes were tested by compressive machine at 7, 14, 21 and 28 days. To determine the axial deformation and compressive strength of concrete as shown in Figure (3.3).



Figure (3.2): Slump test.



Figure (3.3): Axial deformation test.

3.5 Mechanical properties of Concrete cubes

The mechanical properties include axial deformation and compressive strength and modulus elasticity of concrete.

3.5.1 The models Geometry

The models geometries dimension are 15cm in length and 15cm in width and 15 cm in height as shown in Figure (3.4).



Figure (3.4): Typical concrete cubes.

3.5.2.1 Compressive Strength of the models

The 12 concrete models were tests by compression machines to obtain the axial deformation and compressive strength as shown in table (3.2).

Table (3.2): Result of Experimental Compressive strength and axial deformation for 12 concrete cubes.

<i>Model No.</i>	<i>Age</i>	<i>Compressive strength (N/mm²)</i>	<i>Axial deformation (mm)</i>
1	7days	13.22	3.5
2		14.73	3.2
3		15.11	3.0
4	14 days	18.89	2.8
5		19.27	2.6
6		20.78	2.3
7	21days	22.29	2.2
8		23.04	2
9		23.42	1.9
10	28 days	24.56	2.2
11		25.88	2
12		26.44	1.9

3.6 Simulation of Concrete cube by software (UDEC)

3.6.1 The Problem description:

- In this model, concrete cubes. The axial deformations will be used as a criterion to show the stability.
- The code of the shown into the Table (3.3).

- The axial deformations in one model as shown in Table (3.4)
- The compressive strength in the model as shown Table (3.5)
- The model 0.15X 0.15 m block, Displacement history at six Node coordinate

- 1) 0.075,0.15
- 2) 0.15,0.1125
- 3) 0.15,0.075
- 4) 0.00,0.0375
- 5) 0.075,0.01875
- 6) 0.075,0.0

Table (3 .3): The program code.

ro 0.001	
block (0,0) (0,0.15) (0.15,0.15) (0.15,0)	<u>Model Geometry</u>
gen edge 0.04	<u>Model Discretization</u>
group zone 'concrete'	
zone model elastic density 2.4e3	<u>Model martial</u>
<u>properties</u>	
bulk 3.15e8 shear 2.369e8	
bound stress 0,0,-13.22e6	<u>Apply Stress</u>
bound 0.0,0.15 0.001 , 0.001 yvel=0	<u>Fix the bottom of the model</u>
set grav= 0, 9.81	
hist ydisp=0.075,0.15	
hist ydisp=0.15,0.1125	
hist ydisp=0.15,0.075	<u>According Deformation</u>
hist ydisp=0.00,0.0375	
hist ydisp=0.075,0.01875	
hist ydisp=0.075,0.0	
damp auto	
Solv	<u>lay data and model deformation</u>
pri hist 1 2 3 4 5 6	
plot hold block stress disp	

**Table (3.4): Result of axial deformations using numerical models
by software (UDEC).**

<i>Model No.</i>	<i>Compressive strength (N/mm^2)</i>	<i>Axial deformation (mm)</i>
1	13.22	3.29
2	14.73	2.84
3	15.11	3.02
4	18.89	2.65
5	19.27	2.47
6	20.78	2.18
7	22.29	2.09
8	23.04	1.90
9	23.42	1.81
10	24.56	1.52
11	25.88	1.43
12	26.44	0.96

Table (3.5): Result of Compressive strength using numerical models by software (UDEC).

<i>Model No.</i>	<i>Axial deformation (Experimental)</i>	<i>Compressive strength (N/mm²)</i>
1	3.5	14.09
2	3	15.6
3	3.2	16.05
4	2.8	20.01
5	2.6	20.35
6	2.3	21.95
7	2.2	23.48
8	2	24.25
9	1.9	24.67
10	1.6	25.75s
11	1.5	27.37
12	1	28

3.7 Application of bending test using program (phase2).

In order to validate the numerical programs, the bending test for beam was modeled. Using program (phase2).

The has cross section area (0.2*0.2)m and span 0.6m .the properties of concrete obtained from Experimental model was done in program.

The incremental Load (4, 6, 8, 10, 12 KN) were applied until the collapse. The span to deflection for each in incremental is presented in Figure (3.6)

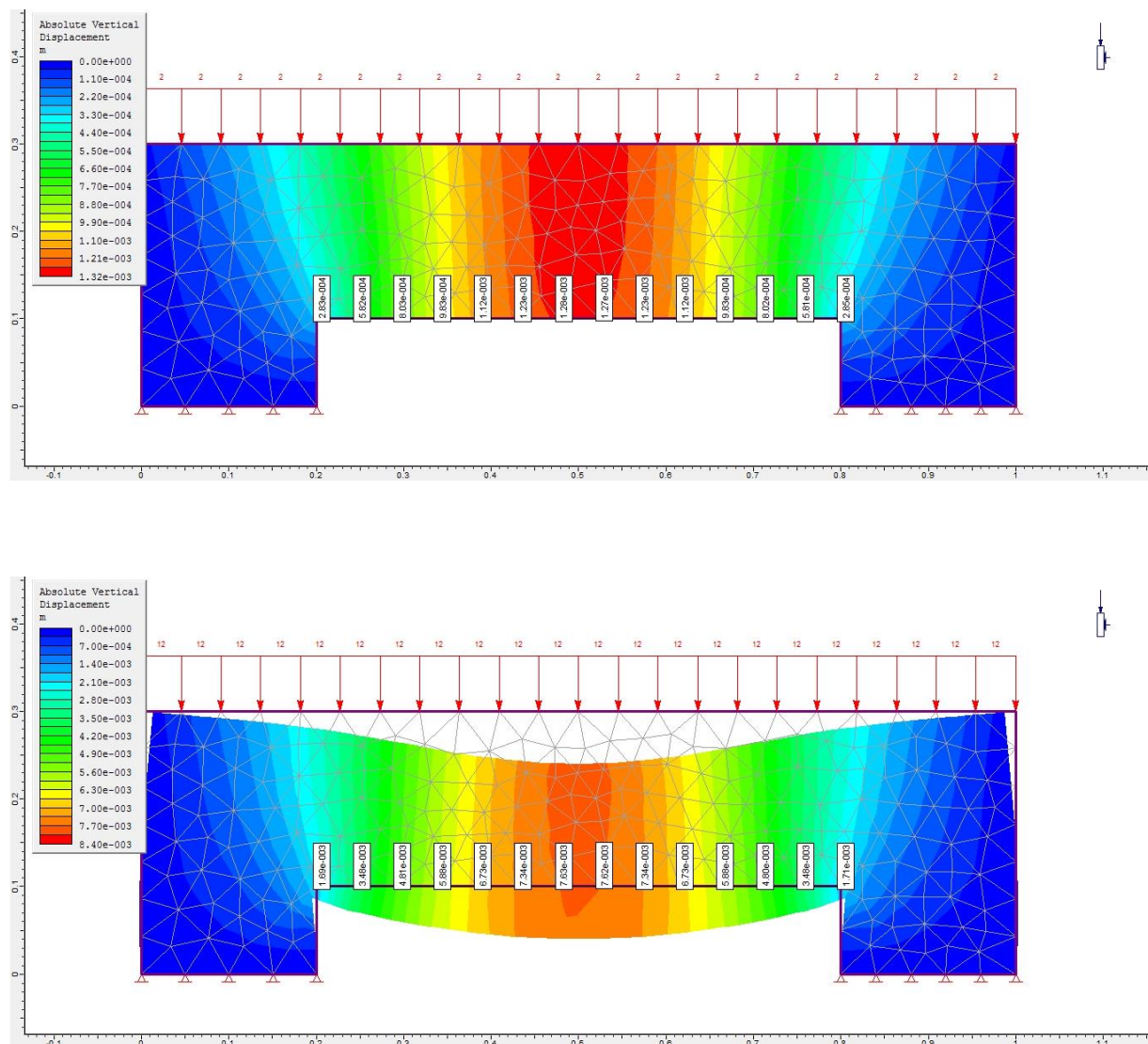


Figure (3.6): The Overall View of the Model.

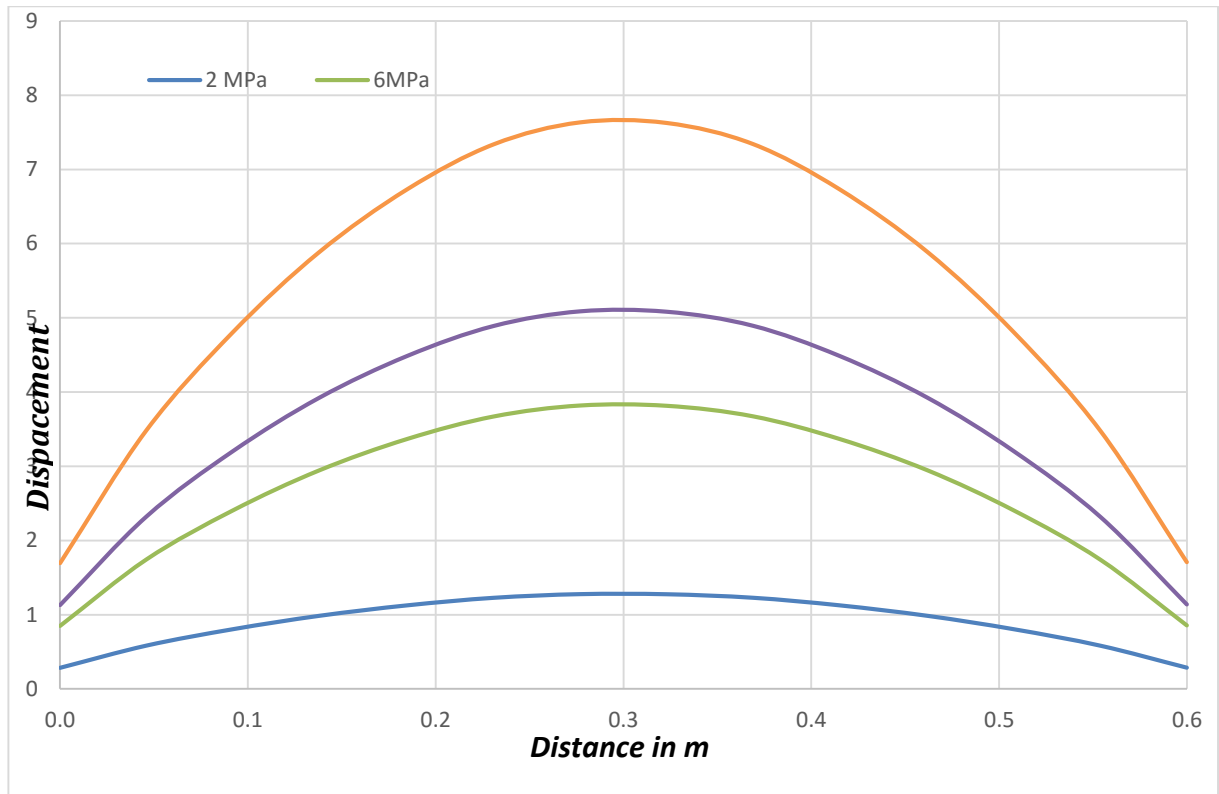


Figure (3.7): Numerical Axial Deformations for bending test for beam.

CHAPTER FOUR

RESULTS OF EXPERIMENTAL AND NUMERICAL WORK

4.1 Comparison of Results

Comparison of results between experimental and numerical axial deformations of concrete cubes were summarized on Tables (4.1) - (4.4). Comparison of compressive strength between experimental and numerical using computer software (UDEC) were summarized on Table (4.5) - (4.8) Comparison between the maximum stresses in the experimental and numerical at (7, 14, 21, 28 days).were also presented

Table (4.1): Comparison of Axial Deformations between Experimental and Computer Program (UDEC) at age (7days).

<i>Model No.</i>	<i>Compressive strength (N/mm²)</i>	<i>Experimental axial deformation (mm)</i>	<i>Numerical axial deformation (mm)</i>	<i>Difference (%)</i>
1	13.22	3.5	3.29	-6.00
2	14.73	3.2	2.84	-5.63
3	15.11	3.0	3.02	-5.67

Table (4.2): Comparison of Axial Deformations between Experimental and Computer Program (UDEC) at age (14days).

<i>Model No.</i>	<i>Compressive strength (N/mm²)</i>	<i>Experimental axial deformation (mm)</i>	<i>Numerical axial deformation (mm)</i>	<i>Difference (%)</i>
4	18.89	2.8	2.65	-5.36
5	19.27	2.6	2.47	-5.00
6	20.78	2.3	2.18	-5.22

Table (4.3): Comparison of Axial Deformations between Experimental and Computer Program (UDEC) at age (21days).

<i>Model No.</i>	<i>Compressive strength (N/mm²)</i>	<i>Experimental axial deformation (mm)</i>	<i>Numerical axial deformation (mm)</i>	<i>Difference (%)</i>
7	22.29	2.2	2.09	-5.00
8	23.04	2	1.90	-5.00
9	23.42	1.9	1.81	-4.74

Table (4.4): Comparison of Axial Deformations between Experimental and Computer Program (UDEC) at age (28days).

<i>Model No.</i>	<i>Compressive strength (N/mm²)</i>	<i>Experimental axial deformation (mm)</i>	<i>Numerical axial deformation (mm)</i>	<i>Difference (%)</i>
10	24.56	1.6	1.52	-5.00
11	25.88	1.5	1.43	-4.67
12	26.44	1	0.96	-4.00

Table (4.5): Comparison of Compressive Strength between Experimental and Computer Program (UDEC) at age (7days).

<i>Model No.</i>	<i>Axial deformation (mm)</i>	<i>Experimental compressive strength (N/mm²)</i>	<i>Numerical compressive strength (N/mm²)</i>	<i>Difference (%)</i>
1	3.5	13.22	14.09	6.58
2	3.2	14.73	15.63	6.11
3	3.0	15.11	16.10	6.55

Table (4.6): Comparison of Compressive Strength between Experimental and Computer Program (UDEC) at age (14days).

<i>Model No.</i>	<i>Axial deformation (mm)</i>	<i>Experimental compressive strength (N/mm²)</i>	<i>Numerical compressive strength (N/mm²)</i>	<i>Difference (%)</i>
4	2.8	18.89	20.01	5.93
5	2.6	19.27	20.35	5.60
6	2.3	20.78	21.95	5.63

Table (4.7): Comparison of Compressive Strength between Experimental and Computer Program (UDEC) at age (21days).

<i>Model No.</i>	<i>Axial deformation (mm)</i>	<i>Experimental compressive strength (N/mm²)</i>	<i>Numerical compressive strength (N/mm²)</i>	<i>Difference (%)</i>
7	2.2	22.29	23.48	5.34
8	2	23.04	24.25	5.25
9	1.9	23.42	24.67	5.34

Table (4.8): Comparison of Compressive Strength between Experimental and Computer Program (UDEC) at age (28days)

<i>Model No.</i>	<i>Axial deformation (mm)</i>	<i>Experimental compressive strength (N/mm²)</i>	<i>Numerical compressive strength (N/mm²)</i>	<i>Difference (%)</i>
10	1.6	24.56	25.75	4.85
11	1.5	25.88	27.37	5.76
12	1	26.44	28	5.90

4.2 Summary of Results

Summary of axial deformation of 12 concrete cubes of experimental and numerical models using computer programs (UDEC) and Phase2 are shown in Table (4.9).

Table (4.9): Summary of Axial Deformations between Experimental and Numerical concrete Models by Computer Programs (UDEC) and (Phase2) at 7, 14, 21and 28 days respectively.

<i>Model No.</i>	<i>Axial compressive strength (N/mm²) Experimental</i>	<i>Axial deformation by Experimental (mm)</i>	<i>Axial deformation by UDEC (mm)</i>	<i>Axial deformation by Phase2 (mm)</i>
1	13.22	3.5	3.29	3.45
2	14.73	3.2	3.02	3.15
3	15.11	3.0	2.83	3.0
4	18.89	2.8	2.65	2.7
5	19.27	2.6	2.47	2.55
6	20.78	2.3	2.18	2.28
7	22.29	2.2	2.09	2.16
8	23.04	2	1.90	1.92
9	23.42	1.9	1.81	1.84
10	24.56	1.6	1.52	1.5
11	25.88	1.5	1.43	1.44
12	26.44	1	0.96	0.96

The comparison of axial deformation and compressive strength by experimental and numerical models were drawn by graphical presentation as shown in figure (4.1) – (4.2). It was also done linear approximation between experimental and numerical models by straight line using program origin lab.

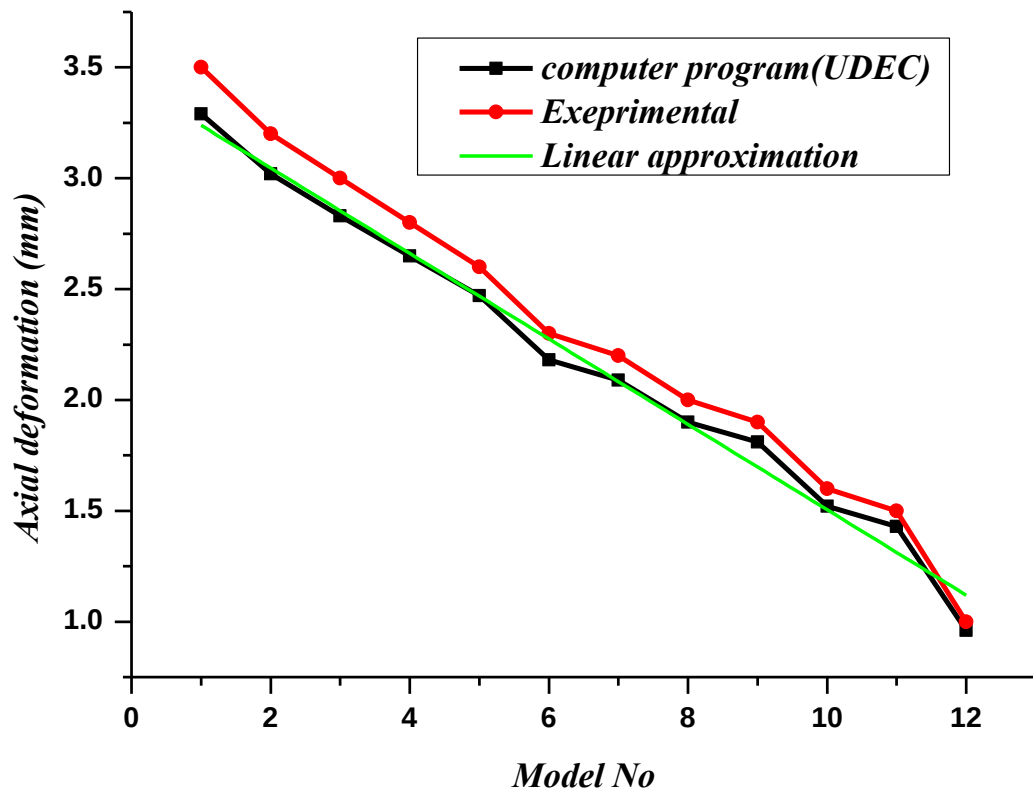


Figure (4.1): Comparison between Experimental and Numerical Axial Deformations for 12 Concrete Cubes.

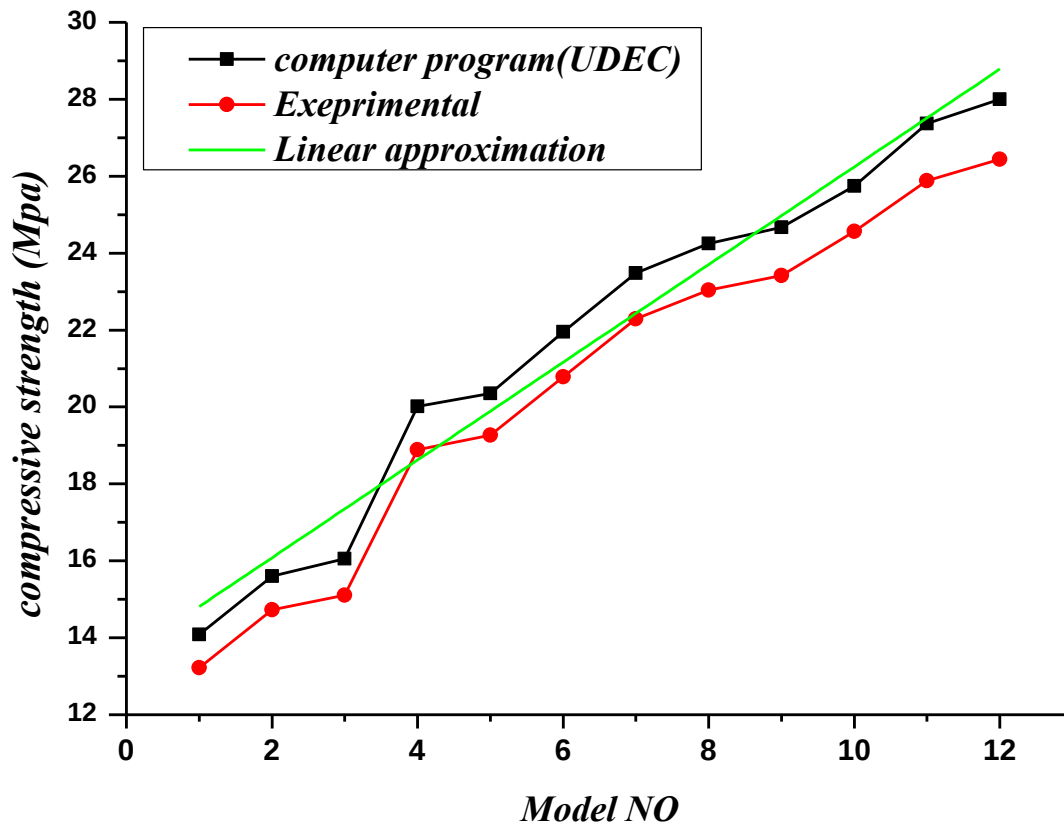


Figure (4.2): Comparison between Experimental and Numerical Axial Compressive Strength for 12 Concrete Cubes.

The comparison of experimental and numerical axial deformation by computer programs (UDEC) and (Phase2) was presented in Figure (4.3)

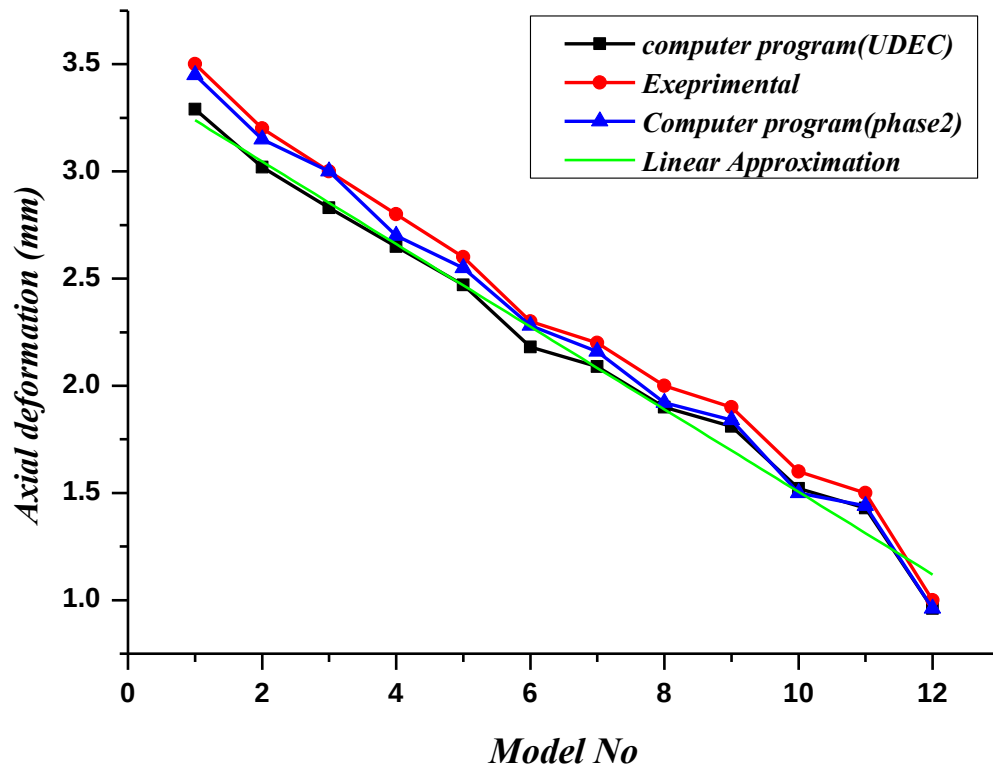


Figure (4.3): Comparison between Experimental and Numerical Axial Compressive

4.3 Discussion of Results

The discussion of results of 12 concrete cubes were summarized as follows:

1. Compressive strength of concrete cubes at 14 days increased by 36.93 %, and axial deformation decreases by 20.7 %, in comparison with concrete cubes at 7 days
2. Compressive strength of concrete cubes at 21 days increased amounts to the ratio of 59.4 %, and decreases the axial deformation to the ratio of 37.4 %.
3. Compressive strength of concrete cubes at 28 days increased by 78.6 %, and axial deformation decreases by 57.72 %.in comparison with concrete cubes at 7 days
4. Compressive strength of concrete cubes at 7, 14,21and 28 days respectively increased with decreases of the difference of axial deformation to the ratio 25 %.
5. The difference between experimental and numerical calculation is slightly small for axial deformation and Compressive strength

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

In this study the comparison between Experimental and numerical modeling using computer programs (UDEC+Phase2) in two-dimensional computer program , compressive strength for hardened concrete in 7,14,21,and 28 days. Based on the results, it can be concluded:

1. Physical and Numerical modeling of the concrete cubes can be used to estimate the axial deformation and axial compressive strength using programs (UDEC and Phase2).
2. The software UDEC and Phase2 have a high ability to simulate the concrete models.
3. The axial Compressive strength increased the decreases the axial deformations decrease as shown in graphical presentation as shown Figures (4.1) – (4.3).

5.2 Recommendations

Recommendations of this study were summarized as follows:

1. Ability of computer programs (UDEC) to simulate different concrete models to obtain another mechanical properties of concrete such as: bending, Fatigue, modulus of elasticity, etc.
2. Program UDEC has ability to solve nonlinear problem of deep beams.
3. Program UDEC has ability to solve linear problem in structure machines

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Appendix A: Concrete Mix Design

Table (A.1): concrete mix design form (British stander)

Stage item	Reference or calculation		Values
1.1 Characteristic strength	specified	25 N/mm^2 at 28 days	Proportion defection 5.0 percent
1.2 Standard deviation	Figure (A.1)	8 N/mm^2 or no data	
1.3 Margin	Eq (2.1)	$(k=1.64 \times 8 = 13.12 \text{ N/mm}^2)$	
1.4 Target mean strength	Eq (2.1)	$25 + 13.12 = 38 \text{ N/mm}^2$	
1.5 Cement type	specified	OPC/SRPC/RHPC	
1.6 aggregate type: Course		Crushed	
Aggregate type: fine		Uncrushed	
1.7 free water/cement ratio	Table (A.1), Figure (A.2)		0.5
1.8 Maximum free water/ cement ratio specified		0.55	Use the lower value
2.1 Slump	specified	Slump 10-30 mm	
2.2 Maximum aggregate size	specified	20 mm	
2.3 Free-water content	Table (A.2)	190 kg/m^3	
3.1 Cement content	Eq (2.3)	$190 \div 0.5 = 380 \text{ kg/m}^3$	
3.2 Minimum cement content	specified	320 kg/m^3	
4.1 Relative density of aggregate (SSD)		2.6 Known/ assumed	
4.2 Concrete density	Figure (A.3)	2400 kg/m^3	
4.3 Total aggregate content	Eq (2.4)	$2400 - 190 - 380 = 1830 \text{ kg/m}^3$	
5.1 grading of fine aggregate	Percentage passing 600 an sieve		70%
5.2 Proportion of fine aggregate	Figure (A.4)		27%
5.3 fine aggregate content		$0.27 \times 1830 = 494.1 \text{ kg/m}^3$	
5.4 Coarse aggregate content		$1830 - 494.1 = 1336 \text{ kg/m}^3$	

Quantities	Cement (kg)	Water (kg or L)	Fine aggregate (kg)	Coarse aggregate (kg)
Per m^3 (to nearest 5 kg)	380	190	494	1336
Per trial mix of 0.021 m^3	7.98	3.99	10.4	28.10

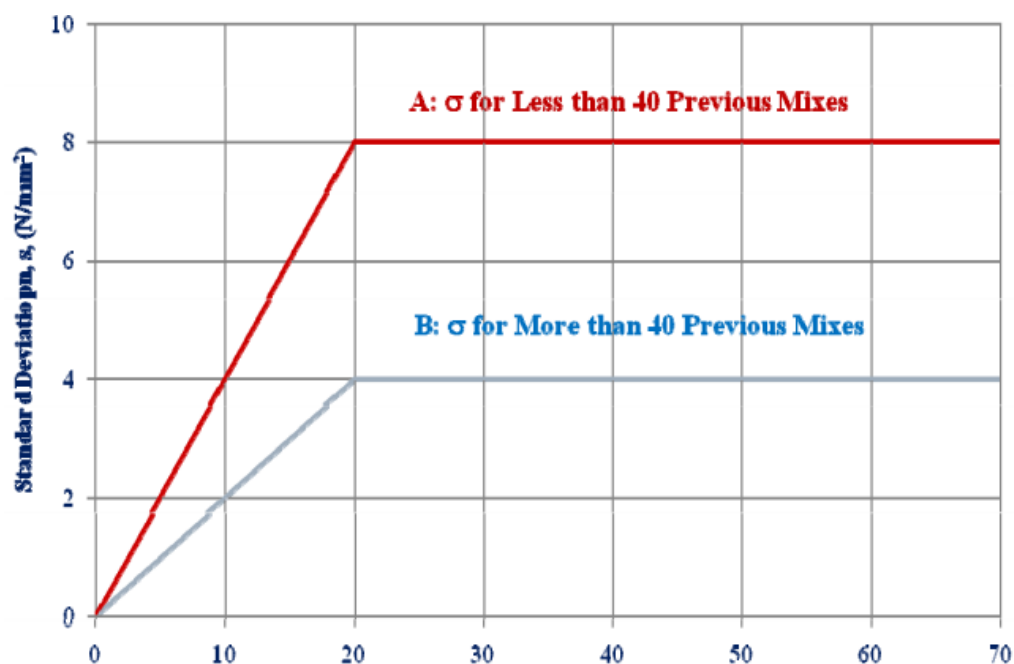


Figure (A.1): Relationship between Standard Deviation and Characteristic Strength

Table (A.1): Approximate Compressive Strengths (N/mm²) of Concrete Mixes made with a free-water /cement ratio of 0.5.

Type of cement	Type of coarse aggregate	Compressive strengths (N/mm ²)			
		Age (days)			
		3	7	28	91
Ordinary Portland (OPC) or sulphate-resisting Portland (SRPC)	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
Rapid-hardening Portland (RHPC)	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

1 N/mm² = 1 MN/m² = 1 MPa (see footnote on earlier page).

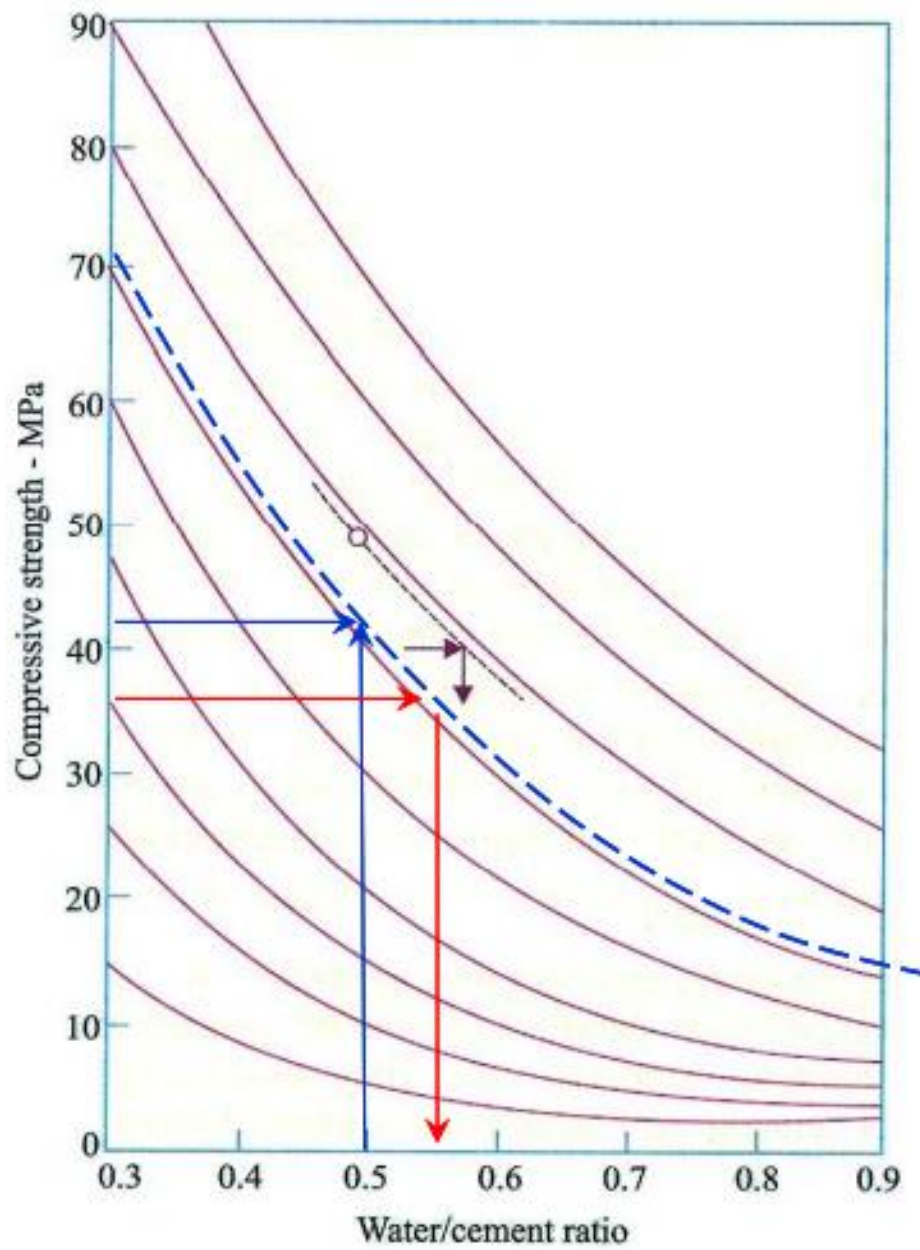


Figure (A.2): Relationship between Compressive Strength and water/cement ratio.

Table (A.2): Approximate Free- water Content Required to give Various Levels of Workability.

Slump (mm) Vebe time(s)		0-10 > 12	10-30 6-12	30-60 3-6	60-180 0-3
Maximum size aggregate (mm)	Type of aggregate				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

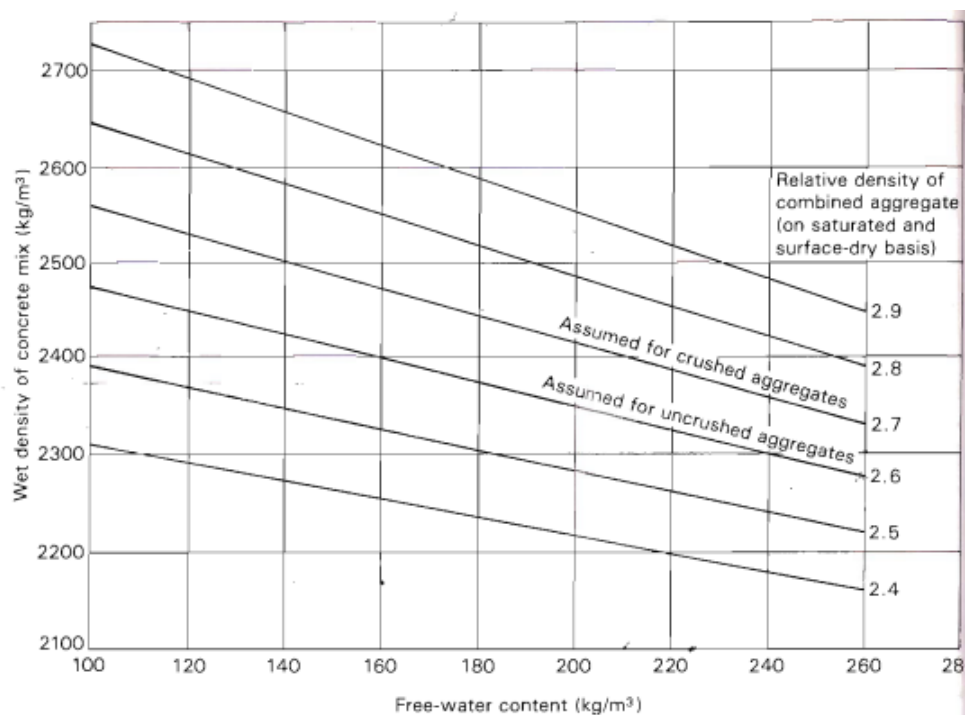
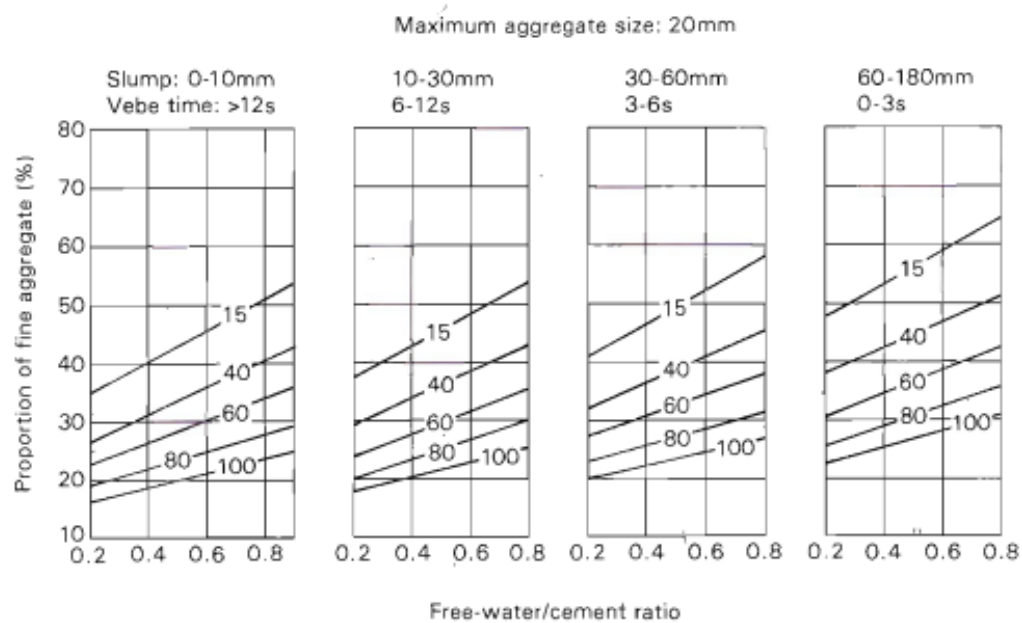
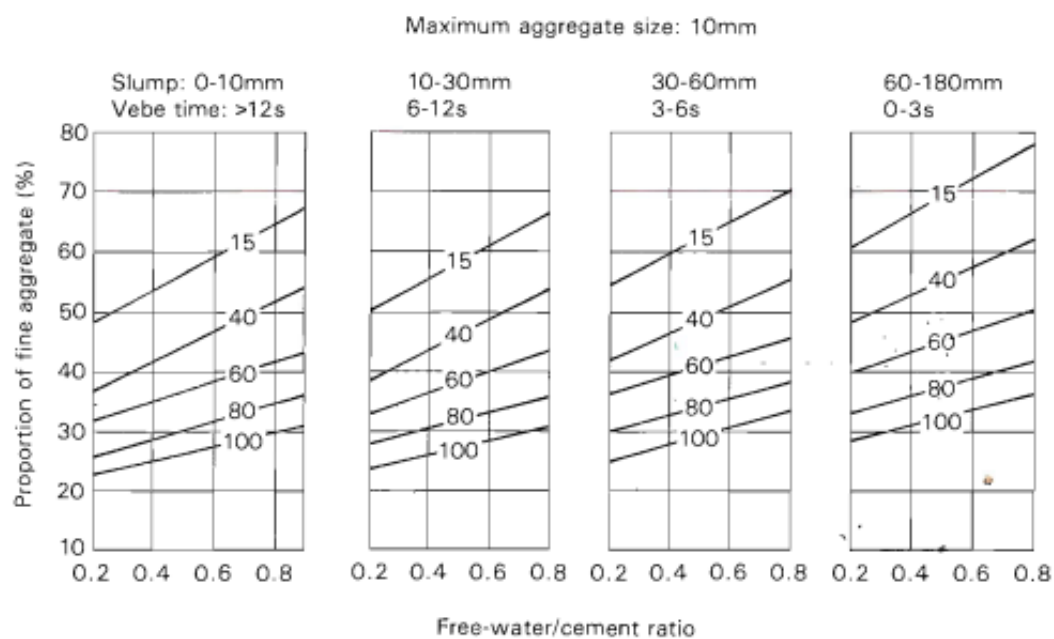


Figure (A.3): Estimated Wet Density of Fully Compacted Concrete.



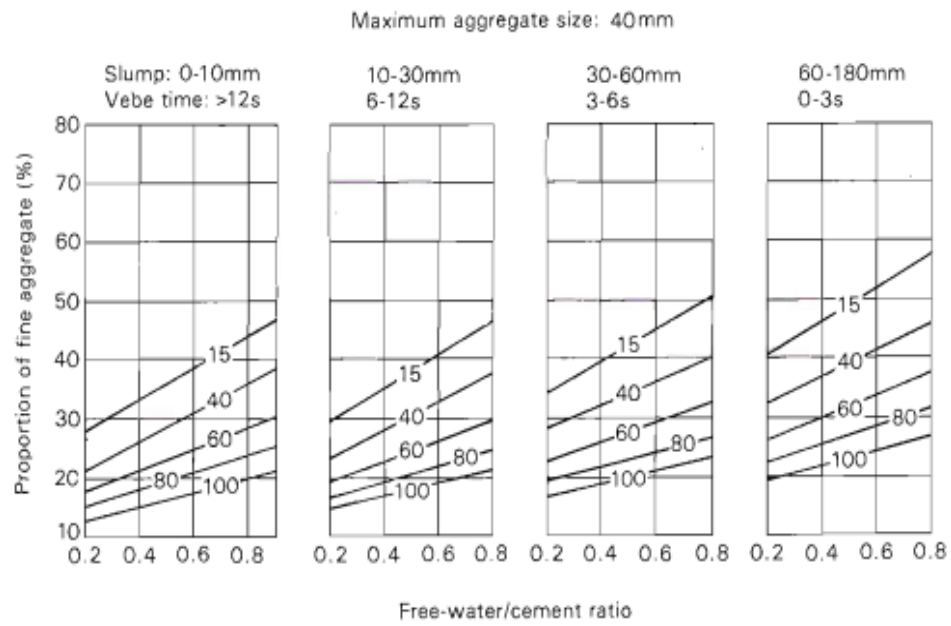


Figure (A.4): recommended of fine aggregate according to percentage passing a 600 μm sieve

Appendix B: Result of Axial Deformation a of Concrete Cubes

Using UDEC

Table (B.1): UDEC code of modeling.

```
ro 0.001
block (0,0) (0,0.15) (0.15,0.15) (0.15,0(
gen edge 0.04
group zone 'concrete '
zone model elastic density 2.4e3 bulk 3.15e8 shear 2.369e8
bound stress 0,0,-13.22e6
bound -0.0,0.15 -0.001 , 0.001 yvel=0
set grav= 0,-9.81
hist ydisp=0.075,0.15
hist ydisp=0.15,0.1125
hist ydisp=0.15,0.075
hist ydisp=0.00,0.0375
hist ydisp=0.075,0.01875
hist ydisp=0.075,0.0
pri hist 1 2 3 4 5 6
plot hold block stress disp
```

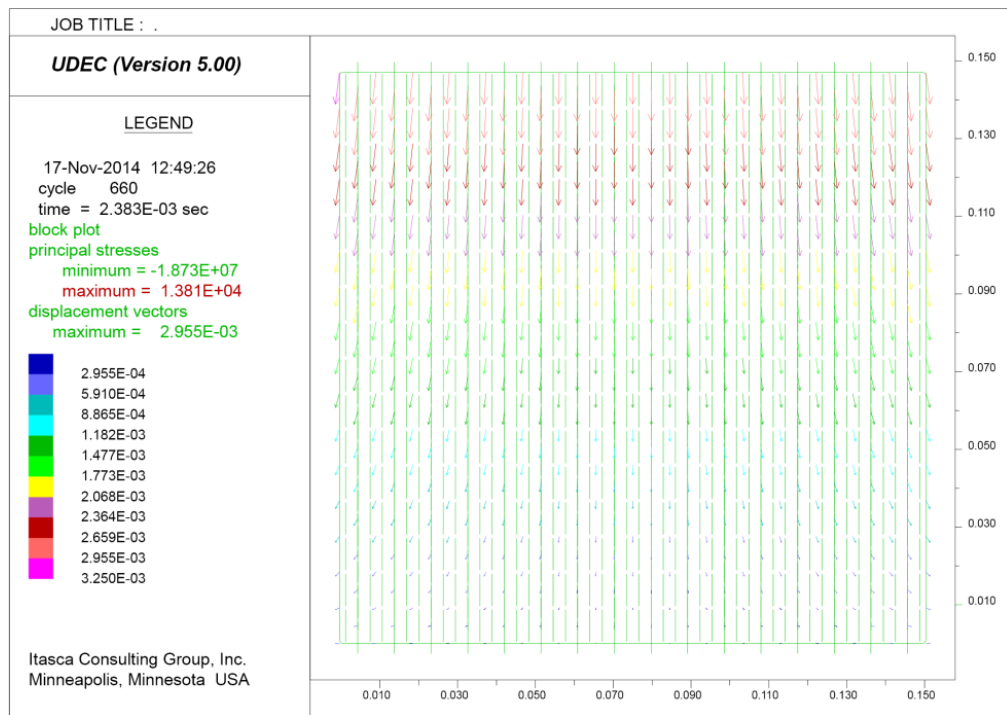


Figure (B.1) internal displacement the of the Model

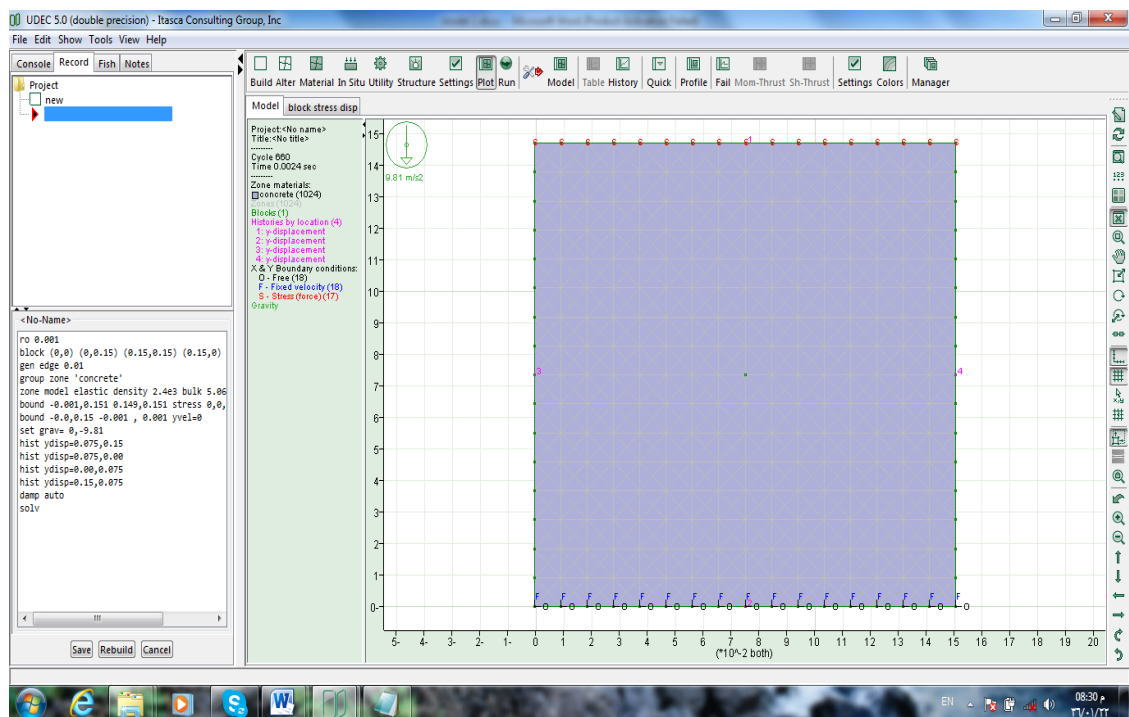


Figure (B.2): Discretization of Numerical modeling

Table (B.1): Result of deformation for numerical models (UDEEC)

Model 1					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -1.228E-03	20 -1.945E-03			
30 -2.521E-03	40 -2.899E-03	50 -3.112E-03			
60 -3.221E-03	70 -3.268E-03	80 -3.282E-03			
90 -3.286E-03	100 -3.288E-03	110 -3.290E-03			
120 -3.290E-03	130 -3.291E-03	140 -3.292E-03			
150 -3.292E-03	160 -3.292E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -5.931E-04	20 -1.351E-03			
30 -1.875E-03	40 -2.160E-03	50 -2.322E-03			
60 -2.411E-03	70 -2.451E-03	80 -2.463E-03			
90 -2.466E-03	100 -2.468E-03	110 -2.469E-03			
120 -2.469E-03	130 -2.470E-03	140 -2.470E-03			
150 -2.471E-03	160 -2.471E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -9.305E-05	20 -7.948E-04			
30 -1.194E-03	40 -1.402E-03	50 -1.537E-03			
60 -1.602E-03	70 -1.633E-03	80 -1.641E-03			
90 -1.644E-03	100 -1.645E-03	110 -1.646E-03			
120 -1.646E-03	130 -1.647E-03	140 -1.647E-03			
150 -1.647E-03	160 -1.647E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -4.752E-06	20 -3.781E-04			
30 -5.735E-04	40 -6.884E-04	50 -7.656E-04			
60 -7.976E-04	70 -8.160E-04	80 -8.205E-04			
90 -8.219E-04	100 -8.225E-04	110 -8.229E-04			
120 -8.232E-04	130 -8.234E-04	140 -8.236E-04			
150 -8.237E-04	160 -8.238E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -4.677E-06	20 -3.291E-04			
30 -5.173E-04	40 -6.748E-04	50 -7.559E-04			
60 -7.960E-04	70 -8.146E-04	80 -8.200E-04			
90 -8.216E-04	100 -8.223E-04	110 -8.228E-04			
120 -8.232E-04	130 -8.234E-04	140 -8.236E-04			
150 -8.237E-04	160 -8.238E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 2					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -1.056E-03	20 -1.673E-03			
30 -2.168E-03	40 -2.494E-03	50 -2.679E-03			
60 -2.773E-03	70 -2.815E-03	80 -2.829E-03			
90 -2.832E-03	100 -2.833E-03	110 -2.834E-03			
120 -2.835E-03	130 -2.835E-03	140 -2.836E-03			
150 -2.836E-03	160 -2.836E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -5.089E-04	20 -1.161E-03			
30 -1.611E-03	40 -1.858E-03	50 -1.997E-03			
60 -2.076E-03	70 -2.111E-03	80 -2.123E-03			
90 -2.125E-03	100 -2.126E-03	110 -2.127E-03			
120 -2.127E-03	130 -2.128E-03	140 -2.128E-03			
150 -2.128E-03	160 -2.128E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -7.971E-05	20 -6.825E-04			
30 -1.026E-03	40 -1.205E-03	50 -1.322E-03			
60 -1.378E-03	70 -1.406E-03	80 -1.415E-03			
90 -1.417E-03	100 -1.417E-03	110 -1.418E-03			
120 -1.418E-03	130 -1.419E-03	140 -1.419E-03			
150 -1.419E-03	160 -1.419E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -4.070E-06	20 -3.242E-04			
30 -4.927E-04	40 -5.916E-04	50 -6.585E-04			
60 -6.864E-04	70 -7.029E-04	80 -7.071E-04			
90 -7.083E-04	100 -7.087E-04	110 -7.090E-04			
120 -7.092E-04	130 -7.093E-04	140 -7.094E-04			
150 -7.095E-04	160 -7.095E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -4.005E-06	20 -2.822E-04			
30 -4.442E-04	40 -5.800E-04	50 -6.501E-04			
60 -6.849E-04	70 -7.016E-04	80 -7.067E-04			
90 -7.081E-04	100 -7.086E-04	110 -7.089E-04			
120 -7.091E-04	130 -7.093E-04	140 -7.094E-04			
150 -7.095E-04	160 -7.095E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 3					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -1.126E-03	20 -1.783E-03			
30 -2.311E-03	40 -2.658E-03	50 -2.855E-03			
60 -2.956E-03	70 -3.000E-03	80 -3.014E-03			
90 -3.018E-03	100 -3.019E-03	110 -3.020E-03			
120 -3.021E-03	130 -3.021E-03	140 -3.022E-03			
150 -3.022E-03	160 -3.022E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -5.428E-04	20 -1.238E-03			
30 -1.718E-03	40 -1.981E-03	50 -2.129E-03			
60 -2.212E-03	70 -2.250E-03	80 -2.262E-03			
90 -2.265E-03	100 -2.266E-03	110 -2.266E-03			
120 -2.267E-03	130 -2.267E-03	140 -2.268E-03			
150 -2.268E-03	160 -2.268E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -8.508E-05	20 -7.279E-04			
30 -1.094E-03	40 -1.285E-03	50 -1.409E-03			
60 -1.469E-03	70 -1.499E-03	80 -1.508E-03			
90 -1.510E-03	100 -1.511E-03	110 -1.511E-03			
120 -1.512E-03	130 -1.512E-03	140 -1.512E-03			
150 -1.512E-03	160 -1.512E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -4.345E-06	20 -3.459E-04			
30 -5.255E-04	40 -6.308E-04	50 -7.020E-04			
60 -7.316E-04	70 -7.491E-04	80 -7.536E-04			
90 -7.548E-04	100 -7.553E-04	110 -7.555E-04			
120 -7.558E-04	130 -7.559E-04	140 -7.560E-04			
150 -7.561E-04	160 -7.561E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -4.275E-06	20 -3.010E-04			
30 -4.735E-04	40 -6.183E-04	50 -6.930E-04			
60 -7.301E-04	70 -7.478E-04	80 -7.532E-04			
90 -7.546E-04	100 -7.551E-04	110 -7.555E-04			
120 -7.557E-04	130 -7.559E-04	140 -7.560E-04			
150 -7.561E-04	160 -7.561E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 4					
history 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -9.857E-04	20 -1.562E-03			
30 -2.024E-03	40 -2.328E-03	50 -2.501E-03			
60 -2.590E-03	70 -2.629E-03	80 -2.642E-03			
90 -2.645E-03	100 -2.646E-03	110 -2.647E-03			
120 -2.648E-03	130 -2.648E-03	140 -2.648E-03			
150 -2.649E-03	160 -2.649E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -4.747E-04	20 -1.083E-03			
30 -1.504E-03	40 -1.734E-03	50 -1.865E-03			
60 -1.938E-03	70 -1.972E-03	80 -1.982E-03			
90 -1.985E-03	100 -1.986E-03	110 -1.986E-03			
120 -1.987E-03	130 -1.987E-03	140 -1.987E-03			
150 -1.987E-03	160 -1.988E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -7.429E-05	20 -6.367E-04			
30 -9.570E-04	40 -1.124E-03	50 -1.234E-03			
60 -1.287E-03	70 -1.313E-03	80 -1.321E-03			
90 -1.323E-03	100 -1.324E-03	110 -1.324E-03			
120 -1.325E-03	130 -1.325E-03	140 -1.325E-03			
150 -1.325E-03	160 -1.325E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -3.785E-06	20 -3.023E-04			
30 -4.597E-04	40 -5.521E-04	50 -6.147E-04			
60 -6.408E-04	70 -6.563E-04	80 -6.603E-04			
90 -6.614E-04	100 -6.618E-04	110 -6.621E-04			
120 -6.623E-04	130 -6.624E-04	140 -6.625E-04			
150 -6.626E-04	160 -6.626E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -3.725E-06	20 -2.632E-04			
30 -4.145E-04	40 -5.413E-04	50 -6.068E-04			
60 -6.395E-04	70 -6.552E-04	80 -6.600E-04			
90 -6.612E-04	100 -6.617E-04	110 -6.620E-04			
120 -6.623E-04	130 -6.624E-04	140 -6.625E-04			
150 -6.626E-04	160 -6.626E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 5					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -9.158E-04	20 -1.451E-03			
30 -1.881E-03	40 -2.164E-03	50 -2.325E-03			
60 -2.408E-03	70 -2.445E-03	80 -2.457E-03			
90 -2.460E-03	100 -2.461E-03	110 -2.462E-03			
120 -2.462E-03	130 -2.463E-03	140 -2.463E-03			
150 -2.463E-03	160 -2.463E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -4.407E-04	20 -1.006E-03			
30 -1.397E-03	40 -1.611E-03	50 -1.733E-03			
60 -1.802E-03	70 -1.833E-03	80 -1.843E-03			
90 -1.846E-03	100 -1.847E-03	110 -1.847E-03			
120 -1.848E-03	130 -1.848E-03	140 -1.848E-03			
150 -1.848E-03	160 -1.849E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -6.892E-05	20 -5.913E-04			
30 -8.890E-04	40 -1.045E-03	50 -1.147E-03			
60 -1.196E-03	70 -1.221E-03	80 -1.228E-03			
90 -1.230E-03	100 -1.231E-03	110 -1.232E-03			
120 -1.232E-03	130 -1.232E-03	140 -1.232E-03			
150 -1.232E-03	160 -1.232E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -3.514E-06	20 -2.805E-04			
30 -4.270E-04	40 -5.129E-04	50 -5.712E-04			
60 -5.958E-04	70 -6.103E-04	80 -6.140E-04			
90 -6.151E-04	100 -6.155E-04	110 -6.157E-04			
120 -6.159E-04	130 -6.161E-04	140 -6.162E-04			
150 -6.162E-04	160 -6.163E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -3.457E-06	20 -2.442E-04			
30 -3.848E-04	40 -5.029E-04	50 -5.640E-04			
60 -5.944E-04	70 -6.092E-04	80 -6.137E-04			
90 -6.149E-04	100 -6.154E-04	110 -6.157E-04			
120 -6.159E-04	130 -6.161E-04	140 -6.162E-04			
150 -6.162E-04	160 -6.163E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 6					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -8.103E-04	20 -1.284E-03			
30 -1.665E-03	40 -1.915E-03	50 -2.058E-03			
60 -2.131E-03	70 -2.164E-03	80 -2.175E-03			
90 -2.178E-03	100 -2.179E-03	110 -2.180E-03			
120 -2.180E-03	130 -2.181E-03	140 -2.181E-03			
150 -2.181E-03	160 -2.181E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -3.894E-04	20 -8.896E-04			
30 -1.235E-03	40 -1.425E-03	50 -1.533E-03			
60 -1.595E-03	70 -1.623E-03	80 -1.632E-03			
90 -1.634E-03	100 -1.635E-03	110 -1.635E-03			
120 -1.636E-03	130 -1.636E-03	140 -1.636E-03			
150 -1.636E-03	160 -1.636E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -6.082E-05	20 -5.226E-04			
30 -7.860E-04	40 -9.239E-04	50 -1.015E-03			
60 -1.059E-03	70 -1.081E-03	80 -1.087E-03			
90 -1.089E-03	100 -1.090E-03	110 -1.090E-03			
120 -1.091E-03	130 -1.091E-03	140 -1.091E-03			
150 -1.091E-03	160 -1.091E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -3.075E-06	20 -2.478E-04			
30 -3.775E-04	40 -4.535E-04	50 -5.053E-04			
60 -5.272E-04	70 -5.401E-04	80 -5.435E-04			
90 -5.444E-04	100 -5.448E-04	110 -5.451E-04			
120 -5.452E-04	130 -5.454E-04	140 -5.455E-04			
150 -5.455E-04	160 -5.456E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -3.026E-06	20 -2.158E-04			
30 -3.403E-04	40 -4.447E-04	50 -4.989E-04			
60 -5.260E-04	70 -5.391E-04	80 -5.432E-04			
90 -5.443E-04	100 -5.447E-04	110 -5.450E-04			
120 -5.452E-04	130 -5.453E-04	140 -5.454E-04			
150 -5.455E-04	160 -5.456E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 7					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -7.758E-04	20 -1.230E-03			
30 -1.594E-03	40 -1.834E-03	50 -1.971E-03			
60 -2.041E-03	70 -2.073E-03	80 -2.083E-03			
90 -2.086E-03	100 -2.087E-03	110 -2.088E-03			
120 -2.088E-03	130 -2.089E-03	140 -2.089E-03			
150 -2.089E-03	160 -2.089E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -3.727E-04	20 -8.517E-04			
30 -1.183E-03	40 -1.364E-03	50 -1.469E-03			
60 -1.527E-03	70 -1.554E-03	80 -1.563E-03			
90 -1.565E-03	100 -1.566E-03	110 -1.566E-03			
120 -1.567E-03	130 -1.567E-03	140 -1.567E-03			
150 -1.567E-03	160 -1.568E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -5.822E-05	20 -5.003E-04			
30 -7.525E-04	40 -8.847E-04	50 -9.716E-04			
60 -1.014E-03	70 -1.035E-03	80 -1.041E-03			
90 -1.043E-03	100 -1.044E-03	110 -1.044E-03			
120 -1.045E-03	130 -1.045E-03	140 -1.045E-03			
150 -1.045E-03	160 -1.045E-03				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -2.965E-06	20 -2.372E-04			
30 -3.614E-04	40 -4.342E-04	50 -4.839E-04			
60 -5.049E-04	70 -5.173E-04	80 -5.206E-04			
90 -5.215E-04	100 -5.219E-04	110 -5.221E-04			
120 -5.223E-04	130 -5.224E-04	140 -5.225E-04			
150 -5.225E-04	160 -5.226E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -2.918E-06	20 -2.065E-04			
30 -3.257E-04	40 -4.258E-04	50 -4.778E-04			
60 -5.037E-04	70 -5.164E-04	80 -5.203E-04			
90 -5.214E-04	100 -5.218E-04	110 -5.220E-04			
120 -5.222E-04	130 -5.224E-04	140 -5.225E-04			
150 -5.225E-04	160 -5.226E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 8					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -7.053E-04	20 -1.118E-03			
30 -1.449E-03	40 -1.668E-03	50 -1.792E-03			
60 -1.856E-03	70 -1.885E-03	80 -1.895E-03			
90 -1.897E-03	100 -1.898E-03	110 -1.899E-03			
120 -1.900E-03	130 -1.900E-03	140 -1.900E-03			
150 -1.900E-03	160 -1.900E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -3.385E-04	20 -7.740E-04			
30 -1.075E-03	40 -1.240E-03	50 -1.335E-03			
60 -1.389E-03	70 -1.414E-03	80 -1.422E-03			
90 -1.423E-03	100 -1.424E-03	110 -1.425E-03			
120 -1.425E-03	130 -1.425E-03	140 -1.426E-03			
150 -1.426E-03	160 -1.426E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -5.285E-05	20 -4.546E-04			
30 -6.839E-04	40 -8.041E-04	50 -8.833E-04			
60 -9.220E-04	70 -9.415E-04	80 -9.473E-04			
90 -9.488E-04	100 -9.494E-04	110 -9.499E-04			
120 -9.502E-04	130 -9.504E-04	140 -9.505E-04			
150 -9.506E-04	160 -9.507E-04				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -2.691E-06	20 -2.154E-04			
30 -3.285E-04	40 -3.947E-04	50 -4.399E-04			
60 -4.591E-04	70 -4.705E-04	80 -4.735E-04			
90 -4.743E-04	100 -4.747E-04	110 -4.749E-04			
120 -4.751E-04	130 -4.752E-04	140 -4.753E-04			
150 -4.753E-04	160 -4.754E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -2.649E-06	20 -1.876E-04			
30 -2.960E-04	40 -3.871E-04	50 -4.344E-04			
60 -4.581E-04	70 -4.696E-04	80 -4.732E-04			
90 -4.742E-04	100 -4.746E-04	110 -4.749E-04			
120 -4.750E-04	130 -4.752E-04	140 -4.753E-04			
150 -4.753E-04	160 -4.754E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 9					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -6.694E-04	20 -1.061E-03			
30 -1.376E-03	40 -1.584E-03	50 -1.702E-03			
60 -1.763E-03	70 -1.791E-03	80 -1.800E-03			
90 -1.803E-03	100 -1.804E-03	110 -1.804E-03			
120 -1.805E-03	130 -1.805E-03	140 -1.805E-03			
150 -1.805E-03	160 -1.805E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -3.212E-04	20 -7.348E-04			
30 -1.020E-03	40 -1.178E-03	50 -1.268E-03			
60 -1.319E-03	70 -1.343E-03	80 -1.350E-03			
90 -1.352E-03	100 -1.353E-03	110 -1.354E-03			
120 -1.354E-03	130 -1.354E-03	140 -1.354E-03			
150 -1.355E-03	160 -1.355E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -5.013E-05	20 -4.314E-04			
30 -6.492E-04	40 -7.634E-04	50 -8.388E-04			
60 -8.757E-04	70 -8.943E-04	80 -8.998E-04			
90 -9.014E-04	100 -9.020E-04	110 -9.024E-04			
120 -9.026E-04	130 -9.029E-04	140 -9.030E-04			
150 -9.031E-04	160 -9.032E-04				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -2.555E-06	20 -2.043E-04			
30 -3.118E-04	40 -3.747E-04	50 -4.177E-04			
60 -4.360E-04	70 -4.469E-04	80 -4.498E-04			
90 -4.506E-04	100 -4.509E-04	110 -4.512E-04			
120 -4.513E-04	130 -4.514E-04	140 -4.515E-04			
150 -4.516E-04	160 -4.516E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -2.514E-06	20 -1.779E-04			
30 -2.808E-04	40 -3.674E-04	50 -4.124E-04			
60 -4.350E-04	70 -4.460E-04	80 -4.495E-04			
90 -4.505E-04	100 -4.508E-04	110 -4.511E-04			
120 -4.513E-04	130 -4.514E-04	140 -4.515E-04			
150 -4.516E-04	160 -4.516E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model10					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -5.645E-04	20 -8.953E-04			
30 -1.160E-03	40 -1.336E-03	50 -1.436E-03			
60 -1.488E-03	70 -1.511E-03	80 -1.519E-03			
90 -1.521E-03	100 -1.522E-03	110 -1.522E-03			
120 -1.523E-03	130 -1.523E-03	140 -1.523E-03			
150 -1.523E-03	160 -1.524E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -2.706E-04	20 -6.192E-04			
30 -8.600E-04	40 -9.929E-04	50 -1.069E-03			
60 -1.113E-03	70 -1.133E-03	80 -1.139E-03			
90 -1.141E-03	100 -1.142E-03	110 -1.142E-03			
120 -1.142E-03	130 -1.143E-03	140 -1.143E-03			
150 -1.143E-03	160 -1.143E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -4.219E-05	20 -3.635E-04			
30 -5.471E-04	40 -6.435E-04	50 -7.073E-04			
60 -7.386E-04	70 -7.545E-04	80 -7.592E-04			
90 -7.605E-04	100 -7.610E-04	110 -7.614E-04			
120 -7.616E-04	130 -7.618E-04	140 -7.619E-04			
150 -7.620E-04	160 -7.621E-04				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -2.148E-06	20 -1.720E-04			
30 -2.628E-04	40 -3.158E-04	50 -3.522E-04			
60 -3.678E-04	70 -3.770E-04	80 -3.795E-04			
90 -3.802E-04	100 -3.805E-04	110 -3.807E-04			
120 -3.808E-04	130 -3.809E-04	140 -3.810E-04			
150 -3.810E-04	160 -3.810E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -2.115E-06	20 -1.499E-04			
30 -2.367E-04	40 -3.098E-04	50 -3.478E-04			
60 -3.669E-04	70 -3.763E-04	80 -3.792E-04			
90 -3.801E-04	100 -3.804E-04	110 -3.806E-04			
120 -3.808E-04	130 -3.809E-04	140 -3.810E-04			
150 -3.810E-04	160 -3.810E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 11					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -5.287E-04	20 -8.386E-04			
30 -1.087E-03	40 -1.251E-03	50 -1.345E-03			
60 -1.393E-03	70 -1.415E-03	80 -1.423E-03			
90 -1.425E-03	100 -1.425E-03	110 -1.426E-03			
120 -1.426E-03	130 -1.427E-03	140 -1.427E-03			
150 -1.427E-03	160 -1.427E-03				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -2.533E-04	20 -5.798E-04			
30 -8.053E-04	40 -9.298E-04	50 -1.001E-03			
60 -1.042E-03	70 -1.061E-03	80 -1.067E-03			
90 -1.069E-03	100 -1.069E-03	110 -1.070E-03			
120 -1.070E-03	130 -1.070E-03	140 -1.070E-03			
150 -1.071E-03	160 -1.071E-03				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -3.948E-05	20 -3.403E-04			
30 -5.122E-04	40 -6.026E-04	50 -6.624E-04			
60 -6.918E-04	70 -7.066E-04	80 -7.111E-04			
90 -7.123E-04	100 -7.128E-04	110 -7.131E-04			
120 -7.134E-04	130 -7.136E-04	140 -7.137E-04			
150 -7.138E-04	160 -7.138E-04				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -2.010E-06	20 -1.610E-04			
30 -2.460E-04	40 -2.957E-04	50 -3.299E-04			
60 -3.444E-04	70 -3.531E-04	80 -3.554E-04			
90 -3.561E-04	100 -3.564E-04	110 -3.565E-04			
120 -3.567E-04	130 -3.568E-04	140 -3.568E-04			
150 -3.569E-04	160 -3.569E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -1.978E-06	20 -1.403E-04			
30 -2.217E-04	40 -2.901E-04	50 -3.257E-04			
60 -3.436E-04	70 -3.524E-04	80 -3.552E-04			
90 -3.560E-04	100 -3.563E-04	110 -3.565E-04			
120 -3.566E-04	130 -3.568E-04	140 -3.568E-04			
150 -3.569E-04	160 -3.569E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Model 12					
History 1					
y-displacement	7.500E-02 1.500E-01				
17 history records					
0 0.000E+00	10 -3.538E-04	20 -5.613E-04			
30 -7.275E-04	40 -8.376E-04	50 -9.004E-04			
60 -9.333E-04	70 -9.483E-04	80 -9.534E-04			
90 -9.548E-04	100 -9.554E-04	110 -9.558E-04			
120 -9.561E-04	130 -9.563E-04	140 -9.564E-04			
150 -9.565E-04	160 -9.565E-04				
History 2					
y-displacement	1.500E-01 1.125E-01				
17 history records					
0 0.000E+00	10 -1.692E-04	20 -3.876E-04			
30 -5.385E-04	40 -6.221E-04	50 -6.704E-04			
60 -6.979E-04	70 -7.108E-04	80 -7.150E-04			
90 -7.161E-04	100 -7.166E-04	110 -7.169E-04			
120 -7.172E-04	130 -7.173E-04	140 -7.174E-04			
150 -7.175E-04	160 -7.175E-04				
History 3					
y-displacement	1.500E-01 7.500E-02				
17 history records					
0 0.000E+00	10 -2.633E-05	20 -2.274E-04			
30 -3.425E-04	40 -4.031E-04	50 -4.434E-04			
60 -4.633E-04	70 -4.734E-04	80 -4.764E-04			
90 -4.773E-04	100 -4.777E-04	110 -4.779E-04			
120 -4.781E-04	130 -4.782E-04	140 -4.783E-04			
150 -4.784E-04	160 -4.784E-04				
History 4					
y-displacement	0.000E+00 3.750E-02				
17 history records					
0 0.000E+00	10 -1.340E-06	20 -1.075E-04			
30 -1.645E-04	40 -1.978E-04	50 -2.208E-04			
60 -2.306E-04	70 -2.365E-04	80 -2.381E-04			
90 -2.386E-04	100 -2.388E-04	110 -2.389E-04			
120 -2.390E-04	130 -2.391E-04	140 -2.391E-04			
150 -2.392E-04	160 -2.392E-04				
History 5					
y-displacement	7.500E-02 3.750E-02				
17 history records					
0 0.000E+00	10 -1.319E-06	20 -9.366E-05			
30 -1.482E-04	40 -1.940E-04	50 -2.180E-04			
60 -2.301E-04	70 -2.361E-04	80 -2.380E-04			
90 -2.385E-04	100 -2.388E-04	110 -2.389E-04			
120 -2.390E-04	130 -2.391E-04	140 -2.391E-04			
150 -2.392E-04	160 -2.392E-04				
History 6					
y-displacement	7.500E-02 0.000E+00				
17 history records					
0 0.000E+00	10 0.000E+00	20 0.000E+00			
30 0.000E+00	40 0.000E+00	50 0.000E+00			
60 0.000E+00	70 0.000E+00	80 0.000E+00			
90 0.000E+00	100 0.000E+00	110 0.000E+00			
120 0.000E+00	130 0.000E+00	140 0.000E+00			
150 0.000E+00	160 0.000E+00				

Appendix C: Result of Axial Deformation of Concrete Cubes Using Phase 2

Table (C.1): Result of deformation by (Phase 2)

Model 1					
y-displacement					
1.50E-04		2.10E+04		5.70E+04	
9.30E+04		1.29E+03		1.65E+03	
2.01E+03		2.37E+03		2.73E+03	
3.09E+03		3.45E+03			
Model 2					
y-displacement					
0.00E+00		0.00E+00		2.70E+04	
6.60E+04		9.90E+04		1.35E+03	
1.71E+03		2.07E+03		2.43E+03	
2.79E+03		3.15E+03			
Model 3					
y-displacement					
0.00E+00		0.00E+00		1.20E+04	
4.80E+04		8.40E+04		1.20E+03	
1.56E+03		1.92E+03		2.28E+03	
2.64E+03		3.00E+03			
Model 4					
y-displacement					
0.00E+00		0.00E+00		0.00E+00	
1.80E+04		5.40E+04		9.00E+04	
1.25E+03		1.62E+03		1.98E+03	
2.34E+03		2.70E+03			

Model 5					
y-displacement					
0.00E+00		0.00E+00		0.00E+00	
3.00E+05		3.90E+04		7.50E+04	
1.11E+03		1.47E+03		1.83E+03	
2.19E+03		2.55E+03			
Model 6					
y-displacement					
0.00E+00		2.28E+04		4.56E+04	
6.84E+04		9.12E+04		1.14E+03	
1.37E+03		1.60E+03		1.82E+03	
2.05E+03		2.28E+03			
Model 7					
y-displacement					
0.00E+00		2.16E+04		4.32E+04	
6.48E+04		8.64E+04		1.08E+03	
1.30E+03		1.51E+03		1.73E+03	
1.94E+03		2.16E+03			
Model 8					
y-displacement					
0.00E+00		1.92E+04		3.84E+04	
5.76E+04		7.68E+04		9.60E+04	
1.15E+03		1.34E+03		1.54E+03	
1.73E+03		1.92E+03			

Model 9					
y-displacement					
0.00E+00		1.12E+04		3.04E+04	
4.96E+04		6.88E+04		8.80E+04	
1.07E+03		1.26E+03		1.46E+03	
1.65E+03		1.84E+03			
Model 10					
y-displacement					
0.00E+00		1.50E+04		3.12E+04	
4.68E+04		6.24E+04		7.80E+04	
9.36E+04		1.09E+03		1.25E+03	
1.40E+03		1.56E+03			
Model 11					
y-displacement					
0.00E+00		1.44E+04		2.88E+04	
4.32E+04		5.76E+04		7.20E+04	
6.84E+04		1.01E+03		1.15E+03	
1.30E+03		1.44E+03			
Model 12					
y-displacement					
0.00E+00		9.60E+05		1.92E+04	
2.88E+04		3.88E+04		4.80E+04	
5.76E+04		6.72E+04		7.68E+04	
8.64E+04		9.60E+04			

Appendix D: Results from tests in document paper of laboratory

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بسم الله الرحمن الرحيم



Omdurman Islamic university
Faculty of engineering sciences
Civil engineering department
Material lab



Project name: Experimental work For 12 Cubes

Location: Khartoum

Date report: 21/8/2014

Client: sust

Model No.	Age	Compressive strength (N/mm ²)	Axial deformation (mm)
1	7 days	13.22	3.5
2		14.73	3
3		15.11	3.2
4	14 days	18.89	2.8
5		19.27	2.6
6		20.78	2.3
7	21 days	22.29	2.2
8		23.04	2
9		23.42	1.9
10	28 days	24.56	1.6
11		25.88	1.5
12		26.44	1

Tested by: Ali Yahiya

Checked by: Abdel Hameed Hamed

Head of department

