SEPTEMBER 2018

M.Sc. in Civil Engineering

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INVESTIGATION OF CONCRETE SLAB CRACK WHEN PLACED DIRECTLY ON CLAY

M.Sc. THESIS
IN
CIVIL ENGINEERING

BY
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SEPTEMBER 2018

Investigation of Concrete Slab Crack When Placed Directly on Clay

M.Sc. Thesis

In

Civil Engineering

University of Gaziantep

Supervisor

Prof. Dr. Hanifi ÇANAKCI

by

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September 2018

REPUBLIC OF TURKEY
UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

Name of the thesis: Investigation of concrete slab crack when placed directly on clay

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Exam date: September 13, 2018

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This is to certify that we have read this thesis and that in our majority opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ahmed Assim ABDULLAH

ABSTRACT

INVESTIGATION OF CONCRETE SLAB CRACK WHEN PLACED DIRECTLY ON CLAY

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September 2018

52 pages

In this study, investigation of concrete slab cracks when placed directly on clay, types of cracks in seam zone, cracks depth and width, modulus of elasticity and compressive strength were studied. Also the effects of the cracks on the physical properties of concrete due to dry shrinkage. A total of eight concrete mixtures were produced with 500 kg/m^3 of total cementitious materials content and with a constant water/binder ratio of (0.55). each mixture were casted over clay layer, Each layer of clay had various water content ratio from 0% to liquid limit , concrete samples were either cured by spraying at 23℃ or maximum temperature of 28 days curing period. Test results revealed that 28-days compressive strength enhanced while leading to reduce in ultrasonic pulse velocity, it was found that the concrete mixtures that placed over high clay water content had higher compressive strength and lower dry shrinkage values compared to the samples that casted over low water content clay. However e-modulus of elasticity increased due to dry shrinkage.

Keywords: clay, ultrasonic pulse velocity, compressive strength, crack depth, dry shrinkage.

ÖZET

KİL SU MUHTEVASININ ÜZERİNE YERLEŞTİRİLEN BETONDA BLOKLARDA OLUŞAN ÇATLAKLARA ETKİSİNİN DENEYSEL İNCELENMESİ

ABDULLAH, Ahmed Assim
Yüksek Lisans, İnşaat Mühendisliği
Danışman: Prof. Dr.Hanifi ÇANAKCI
Eylül 2018
52 sayfa

Bu çalışmada, doğrudan kil üzerine serilen beton içerisinde oluşan çatlaklar incelendi. Bu kapsamda su/çimento oranı 0.55 olan beton sekiz farklı su muhtevasında (%0, %5, %10, %15, %20, % 25, 30 ve %35) hazırlana kil hazırlanılarak üzerlerine sıkıştırılarak yerleştirildi. 28 günlük kürlemenin ardında her beton numunenin içinde meydane gelen çatlakların derinlikleri ve açıklıkları incelendi. Ayrıca, kilin su muhtevasının betonun basınç dayanımı ve elestsite modülüne etkisine de bakıldı. Deneyler sonucunda kilın su muhtevasının betonda meydana gelen çatlakların derinliği ve genişliklerini etkilendiği tespit edildi. Kilin tamamen kuru olduğu durumda çatlak genişiliğin 2.8mm ve kilin su muhtevasının %35 olduğu durumda çatlak genişliğinin 0.1mm ye düştüğü görüldü. Kilin kuru olduğu durumda çatlak derinliğinin 40mm olduğu su muhtevasının likit limit değerine ulaştığında ise azalarak 0.5mm düştüğü gözlendi. Betonun mukavemetinin üzerine serilen kilin su muhtevasından etkilendiği ayrıca gözlendi.

Anhtar kelimeler: kil, çatlak derinliği, çatlak genişliği, ultrasonik ses hızı

To My

Father and mother, which they spend their life for me and give the support to reach this level from the knowledge

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

In my journey towards this degree, I have found a teacher, a friend, an inspiration, a role model and a pillar of support in my Guide, **Prof.Dr. Hanifi ÇANAKCI**. He has been there providing his heartfelt support and guidance at all times and has given me invaluable guidance, inspiration and suggestions in my quest for knowledge. He has given me all the freedom to pursue my research, while silently and non-obtrusively ensuring that I stay on course and do not deviate from the core of my research. Without his able guidance, this thesis would not have been possible and I shall eternally be grateful to him for his assistance.

My acknowledgement would be incomplete without thanking the biggest source of my strength, my parents. **Mrs. Nabila Hussien & Mr. Abdullah Assim**, and of course my prime source of ideas, my wife **Mais Abdulrazzaq** who never let things get dull or boring, have all made a tremendous contribution in helping me reach this stage in my life. I thank them for putting up with me in difficult moments where I felt stumped and for goading me on to follow my dream of getting this degree. This would not have been possible without their unwavering and unselfish love and support given to me at all times.

Finally, I wish to record my heartfelt gratitude and indebtedness to all of my friends, I appreciate them for the kind of support that they have extended to me.

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CHAPTER 1
INTRODUCTION

1.1 General

In general, all the structures and buildings strength lies in its foundation which its main purpose is to hold and keep the structure upright and safely. Oppositely, a poor constructed foundation can cause damage and dangerous to human and neighborhood.

With the development of structure building these days, it is highly important to simulate the quality of foundation. The foundations have three major roles in the construction; support and distribute the load of the building, support the building and occupants of the building from the nature calamities such as earthquake, floods, and strong winds etc., also the foundation must be built such that it keeps protected from ground moisture in order not to leak out to the structure and causing weakness to the building.

In this study, tests had been carried out on a concrete foundation placed on clay soil with various water content ratio in order to estimate the water content that can carry the foundation safely and with minimum cracks.

The clay soil has a property that makes it consider as not an ideal choice to construct above without stabilization or treatment (Coduto 1999). The clay soil takes on significantly amount of water and expands which can cause the foundation to shift upward or downward (Grim, 1953; Das and Sobhan, 2013). Over time, this shifts can lead to a serious foundation cracking. The clayey soil performance very good at the optimum water content, when the amount of water rises above the optimum point the strength and the stiffness decrease noticeability (Dhakal, 2012).Studying the early age cracking and the shrinkage behavior of concrete structure is very important, especially of that structures exposed to outdoor environmental and that that repeated heavy service load.

The soil properties is highly effected the reinforced concrete structures the random and nonlinear conduct of soil may lead to insufficient reliability levels (Kamel Bezih, 2015). The soil-structure interaction can cause reliable failure to the reinforced concrete structure especially when nonlinear conduct of soil is considered.

1.2 Objectives

The main target of this study is to determine the best ground water content to be able to build on concrete slab as well as to study the depth and thickness of cracks that occurs in the slab when place immediately on compacted clay ground after curing. Also to study the effects of clay on the slabs after curing in terms of compressive strength.

1.3 Outline

This study contains 5 chapters. Chapter 1 presents the background and the targets of this study carrying of for. Chapter 2 involves some researches histories which are relevant to current research under the name of literature review. The materials characteristics and properties and the methods that carried out during the experimental work are all included in chapter 3. Chapter 4 manages the results and discussions that acquired from the laboratory tests. Finally, chapter 5 includes the conclusions gained from the various tests on this study.

Figure 1.1 Real photoghraph of concrete slab foundation over clay

CHAPTER 2
LITERATURE REVIEW

2.1 General

The investigation of concrete slab crack when placed directly on clay were studied in few articles since this type of NDT was developed in the last few years. Limited references on the relation between UPV, shrinkage of concrete, compressive strength, and how clay water content effect on concrete foundation that related to our study are listed dawn in this chapter

2.2 Interface between Clay and Concrete

Zhu (2009) tested the simple shear of interface between clay and concrete. The samples were prepared at the same dry density and different water content ratio. They used two types of concrete, relatively smooth and relatively rough surface roughness. The results showed that the interface shear strength increases by increasing water content especially at the clay-rough concrete case. Also, two types of interface failure mechanism may change each other at different water content.

Iqnatius (2017) determined the shear properties of the soil concrete interface by using the direct shear apparatus. The results for the soil-concrete interface of the friction angles gives values between 141 and 430 kPa. This results indicated that the soil-concrete interface are very conservative for this range of normal stress as the value of normal stress under 141 kPa may not be safe because it may overestimate the friction values which such a system will develop.

Namdar (2016) studied the effects of earthquake acceleration on different settlement of soil at the base of concrete foundation. They used numerical simulation to simulate the difference of settlement due to nonlinear soil-concrete foundation interaction. They exposed the samples to similar seismic loading and therefore the seismic data were reported and used in numerical simulation.

The results showed that the differential settlement of soil based of concrete foundation depends on soil-concrete foundation interaction.

Liu (2014) studied the mechanical behavior of frozen soil-concrete interfaces by conducting a series of direct shear tests on a large-scale temperature-controlled direct Shear test system. The shear process can be explained in five stages: elastic deformation, plastic deformation, the slide part, strain hardening, and the stable residual strength part. The shear strength of the soil-concrete interface influences by normal pressure, water content, and temperature which were obtained by some sample tests by different parameters. From the fitted results it's found that the peak shear strength had linear relationship with the temperature and normal pressure, but it had a nonlinear relationship with the water content. Also, the residual shear strength had linear relationship with the temperature and normal pressure, but a nonlinear with the water content.

Zong-Ze (1995) were performed a large size direct shear test of the soil-concrete interface. The results of the relative slip displacement of the interface showed that the relative displacement distribution is uneven. Also, the rigid-plastic sample was suggested for interface deformation. And a new kind of thickness interface element was developed, which can explain the deformation behavior of the interface more realistically.

Shakir (2008) investigated the behavior of soil-concrete interface by using simple shear test apparatus. They used five types of concrete to study the effect of surface shape on the stress displacement relationship. They used compacted clay and sandy clay which was made by mixing 75% sand and 25% clay. The results showed that the failure line of the interface of clay concrete is linear but the interface of sandy clay concrete can be presented by log function.

Canakci (2011) investigated the interface frictional resistance between organic soil and construction materials (concrete, wood, and metal). Direct shear test was performed to the samples of three fixed water content of the organic soil (0%, 25%, 50%, and 75%). Three different normal forces were used and maximum shear stress at 10% strain rate. The results indicated that the organic soil water content, surface roughness, and type of the material should be studied while investigation of interface friction angle of the organic soil-construction materials.

Cheng (2013) studied the interface between the pile foundation and the soil that embedded in. they used a large direct test apparatus to study the interface between the clay and concrete. It can be found that the shear behavior of the interface influences significantly by the normal stress history.

2.3 Effects of Soil Water Content on Concrete Foundation

Al-Shayea (2001) investigated the effects of water content on the stress-strain relationship and also on the strength parameters (cohesion and friction angle). Also they had studied the effects of clay content on hydraulic conductivity and swelling potential. It was found that the cohesion of clay increased with increasing water content to a certain level. The strength parameters were found to be decreased with increasing water content. Also the hydraulic conductivity noticeably decreased with increased the clay content to up 40%.

Ohdaira (2000) studied the relationship between the water content and ultrasonic dissemination in concrete. The test samples were prepared with 10cm in diameter and 20 cm in length. The samples were been cured in water for 50 days to saturate them. In order to study the effect of different water content, the samples were dried in a drying chamber until the samples dried and its weight changed and the water content changed from 8% to 0%.

By using the pulse transmission method Figure 2.1, ultrasonic dissemination with a frequency between 20 to 100 kHz was determined as a function of water content. The results of sound velocity changed from 3000 m/s to 4500 m/s depending on water content. The maximum transmission frequency is also depend on water content. It can be concluded that the ultrasonic nondestructive evaluating of concrete strength is possible. It can be seen from Figure 2.2 and Figure 2.3 that the propagation velocity of ultrasonic pulse and the transmission of frequency of concrete decreases linearly by decreasing water content this is because that when the water content is great enough in the concrete it fills the concrete so that the velocity of ultrasonic pulse will be quicker and with high frequency. Also when the concrete dried after the water evaporated from concrete and replaced with air voids, the velocity became slower and the frequency became difficult to transmit through concrete.

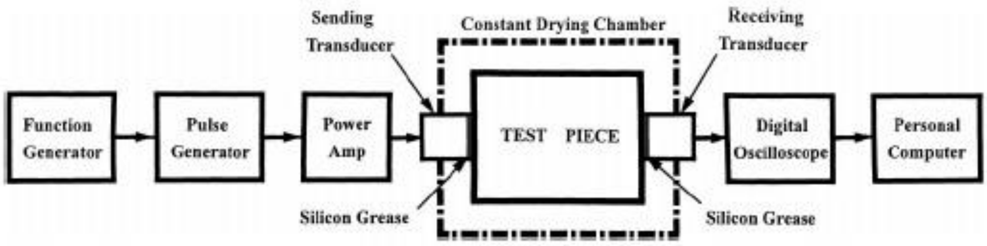

Figure 2.1 Block Diagram of the Mechanical Assembly for Pulse Velocity Estimation.

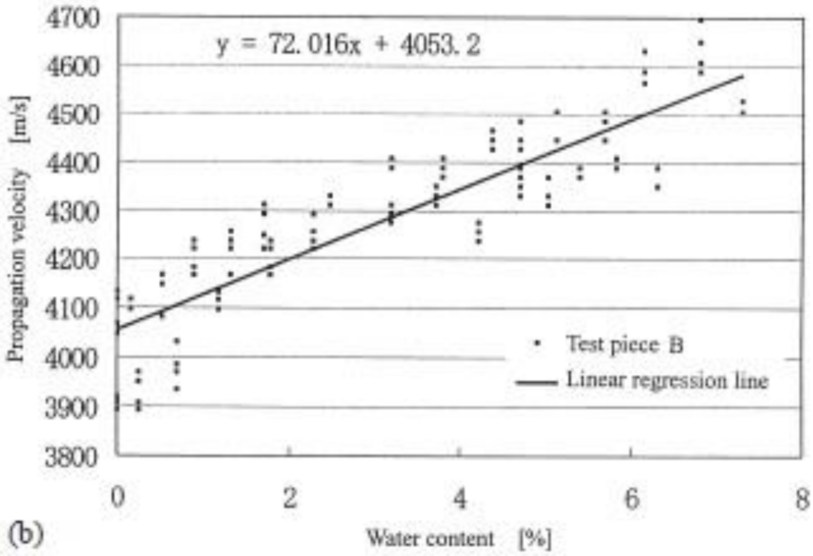

Figure 2.2 Relationship between the Propagation Velocity of Ultrasonic Pulses and Water Content

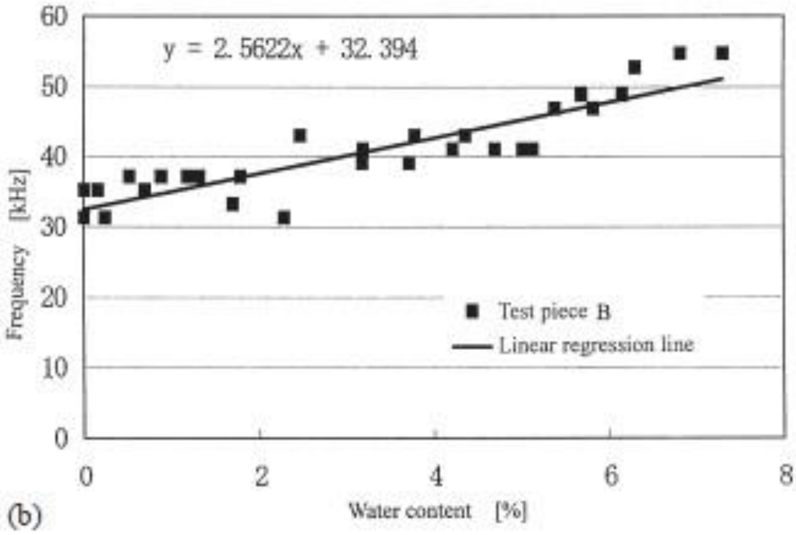

Figure 2.3 Relationship between Frequency and Water Content.

2.4 Shrinkage of Concrete

Ramseyer (2015) studied behavior of concrete slab placed on ground at controlled environmental to understand the performance of the slab which is exposed to environment at the top and moisture ground at the bottom. They used different types of concrete (normal strength concrete, high strength concrete, concrete with shrinkage reducing, and concrete with calcium sulfoaluminate cement). Tests carried out to examine the join movement, the effects and difference of temperature and humidity over the slab depth, and also the material characteristic tests. The results indicated that the normal strength concrete and high strength concrete show crack and continued with crack growth at over the age of 600 days. While the behavior of concrete using calcium sulfoaluminate cement was very stable and showed no long term shrinkage, wrapping or cracking. The concrete with shrinkage reducing in its mixtures show minor impact at early age and limited effect on long term sectional stability.

Marc (2017) investigated about the shrinkage of the concrete foundation in the earth. They made their study on four samples of concrete that contain four different contents of soil and various water/cement ratios. After the sample had been curried at normal temperature, tests of tensile strength, modulus elasticity, one directional shrinkage, and X-ray diffraction were carried on all the samples. The results show that the soil content in the earth concrete effects the mechanical behavior and shrinkage.

Demir (2018) studied the effects of using the shrinkage-reducing admixtures in concrete in terms of strength, workability, and durability. The results indicated that the addition of the shrinkage reducing has negative effects on the mechanical properties of concrete as well as the workability of the normal concrete and concrete with shrinkage reducing found to be the same.

Roberto (2015) estimated the depth of surface opening cracks by using the ultrasound with the time-of-flight diffraction technique. They developed two graphically-based method to estimate crack depth penetration. The results indicated that the method developed can improve the overall estimation with at least four readings with an error near 10% which is smaller than the errors of other methods.

Goueygou (2008) tested the surface breaking cracks of the concrete by using two non-destructive testing methods: the measurement of electrical resistivity and the transmission of ultrasonic surface waves. They obtained the depth and width of the cracks of the concrete from each method.

Lencis (2013) tested the effects of moisture of concrete on the ultrasonic pulse velocity. The tests carried out on concrete under standard conditions and elevated temperature. The results indicated that the ultrasonic pulse velocity when concrete in its saturated condition is higher than that of dry concrete as shown in Figure 2.4

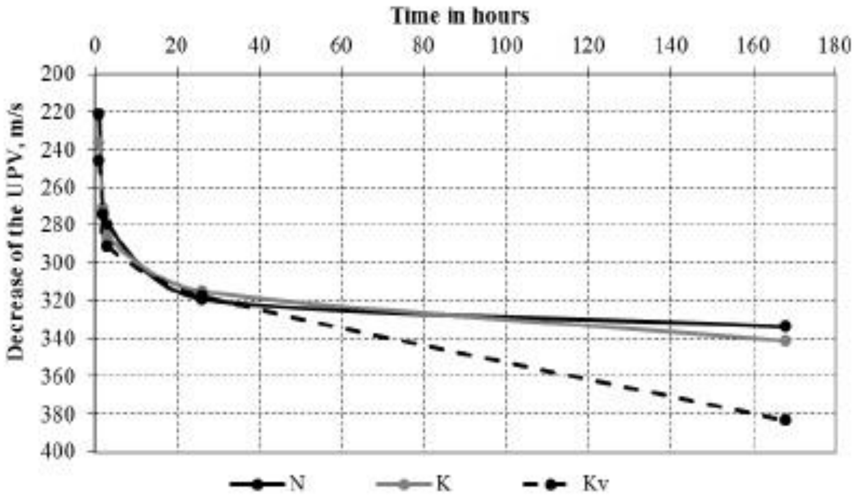

Figure 2.4 Decrease in the upv in concrete after the concrete are taken out from water.

Kaplan (1959) studied the effects of variation of aggregate/cement, water/cement, and age of concrete on the relation between compressive strength and ultrasonic pulse velocity. The results show that the changes in water/cement ratio was not generally the same as the change in age on the pulse velocity and compressive strength. So that, the relation between pulse velocity and compressive strength is not independent of water/cement ratio and age. In case of concrete with the same aggregate/cement ratio, low pulse velocity was recorded at early age and low strength at later age.

The relationship between pulse velocity and compressive strength appears to be less independent on water/cement ratio and age at strength less than 4000 lb/in^2 than at higher strength, Figure 2.5.

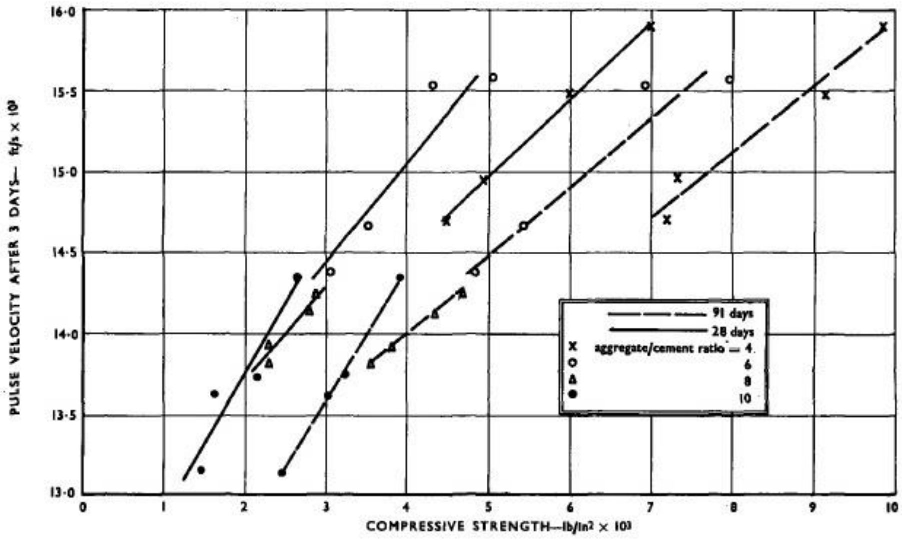

Figure 2.5 Relation between upv after 3 days and compressive strength after 28 days and 91 days.

Djamila (2018) investigated the effect of adding admixtures like limestone powder, granulated slag, natural pozzolana on the correlation factor (R^2) between compressive strength and pulse velocity of the self-compacted concrete (SCC) which is cured at 3, 7, 28, and 90 days. The results demonstrated that it is possible to develop a good correlation factor for the relation between compressive strength and pulse velocity such as (R^2 = 0.85) in case of adding granulated slag and (R^2 = 0.72) by adding stone powder but lowest correlation (R^2 = 0.69) in case of adding pozzolana as shown in Figures 2.6, 2.7, and 2.8.

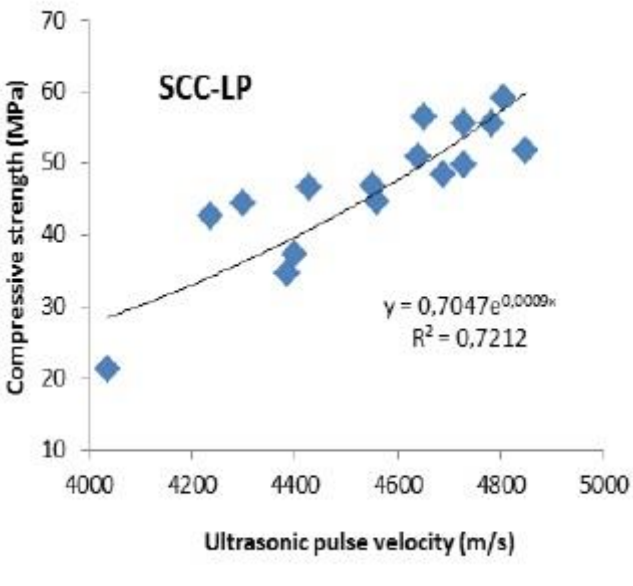

Figure 2.6 Relationship between compressive strength and upv for concrete with limestone powder.

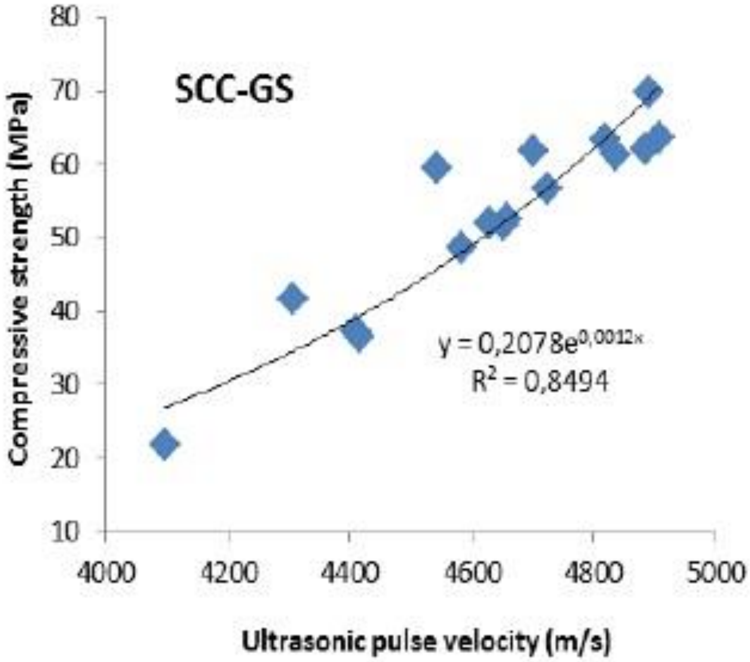

Figure 2.7 Relationship between compressive strength and upv for concrete with granulated slag.

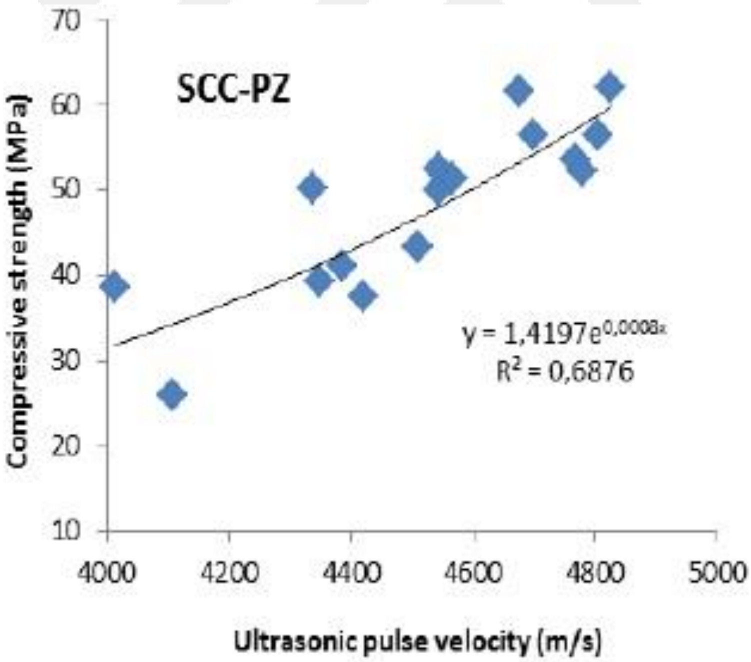

Figure 2.8 Relationship between compressive strength and UPV for concrete with natural pozzolana.

Guneyli (2017) investigated the effects of water content and temperature on the ultrasonic pulse velocity of concrete mixed with water/cement ratio of 0.5. Tests were carried out on cubic samples of concrete that cured in water for 90 days to saturate them. Tests results indicated that the increasing in both water content and temperature leads to increase in the ultrasonic pulse velocity of concrete, Figure 2.9 and 2.10.

Also the relationship between the compressive strength and the ultrasonic pulse velocity was contemplated. Figure 2.11 shows that the UPV varied with the compressive strength and the relation has a strong correlation factor (R=0.8739).

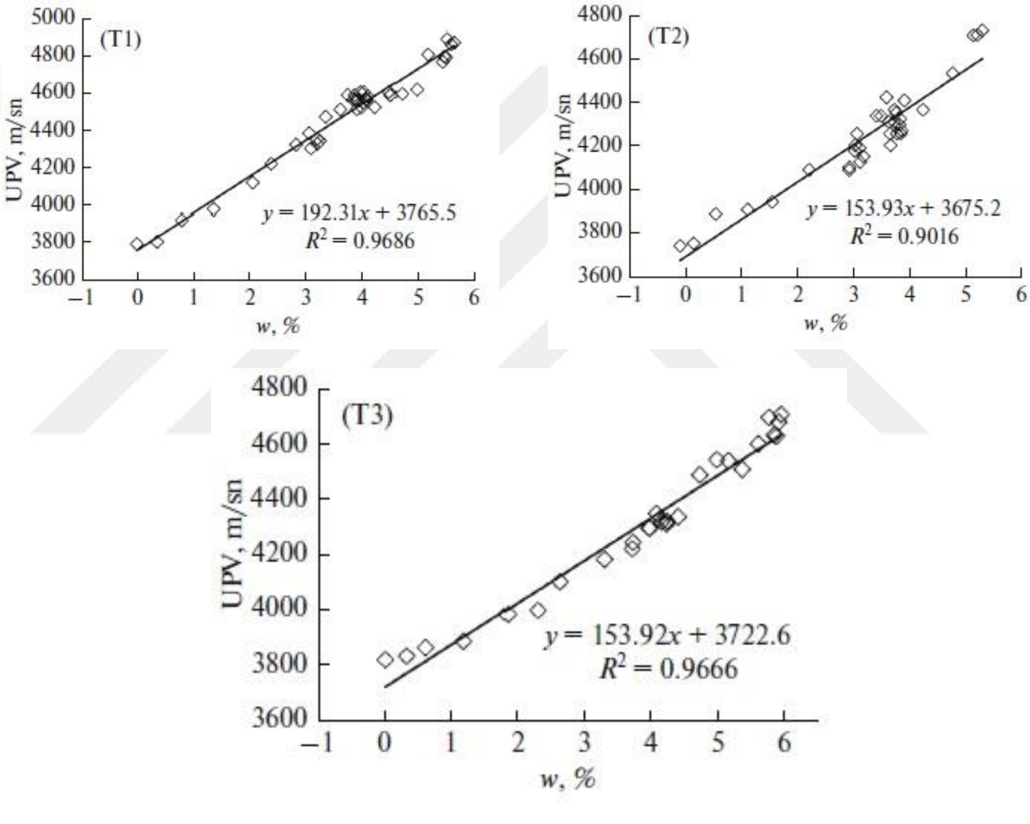

Figure 2.9 Ultrasonic pulse velocity vs. water content for 3 Samples (T1, T2, T3).

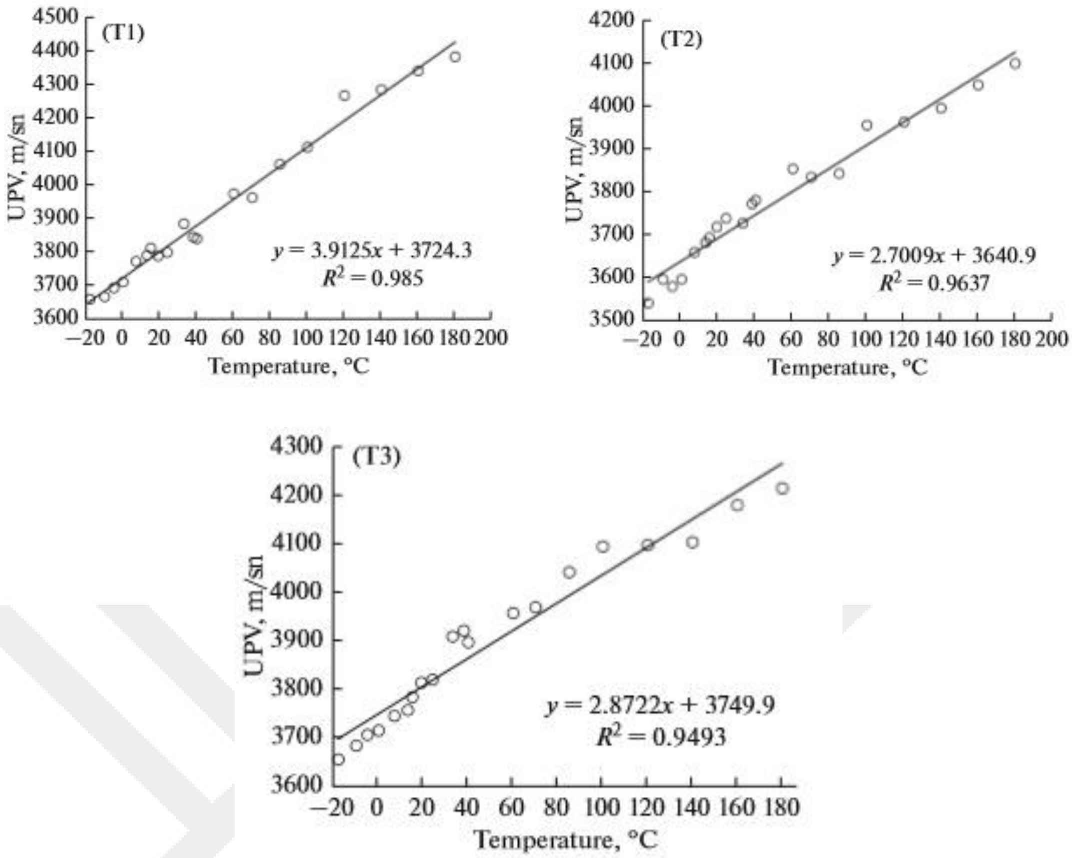

Figure 2.10 Ultrasonic pulse velocity vs. temperature for 3 Samples (T1, T2, T3).

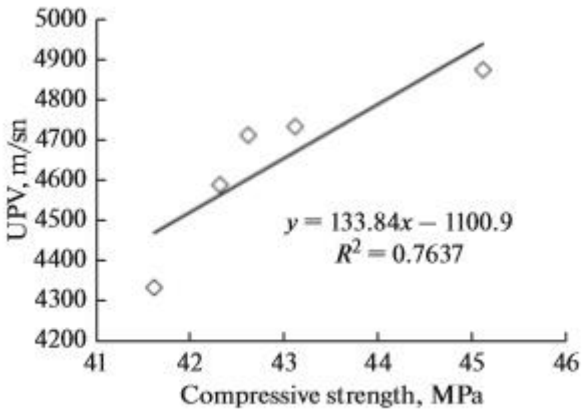

Figure 2.11 Compressive strength vs. ultrasonic pulse velocity

CHAPTER 3
MATERIALS AND EXPERIMENTAL METHODOLOGY

3.1 Introduction

This chapter represents all the laboratory tests which carried out to achieve the objectives of this study. All the samples had been prepared in accordance with the standards of the American Society of Testing and Materials (ASTM). During the laboratory tests, the clayey soil had been compacted at different water content (0%, 5%, 10%, 15%, 20%, 25%, 30%, and 35%). Two samples were prepared for each water content mix ratio. The concrete mixture that placed directly on the compacted clay had been mixed at the ration 1:1.5:1.5. The mold dimensions are 50*25*30 cm as shown in Figure 3.1 below.

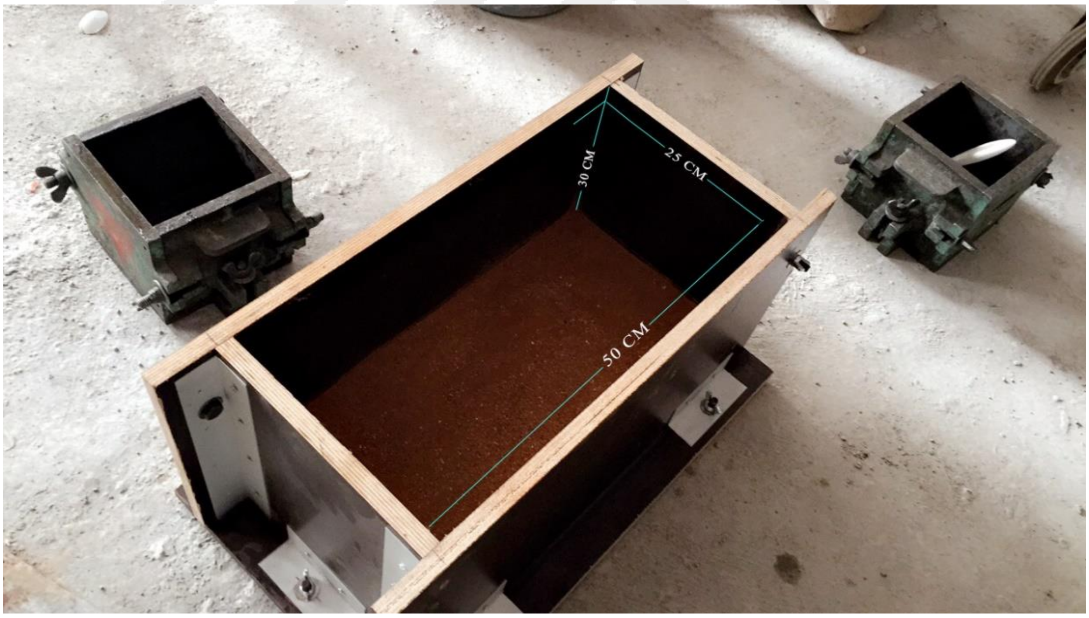

Figure 3.1 The mold used during the experimental work.

3.2 Purpose

The concrete foundation is highly influenced by the ground material and especially the moisture content. The clayey soil has very high ability to absorb water which then lead to expand the soil particles and therefore effect the foundation by shifting upward or downward also cause cracks. The main objective of this study is to investigate the effects of clay on concrete by changing the water content of compacted clay from 0% to liquid limit. Tests of ultrasonic had been carried out to investigate the depth of the cracks, as well as the compressive strength test to test the strength of cubic and cylindrical samples of concrete.

3.3 Materials

In this section, the properties and characteristics of the untreated soil and the concrete contents were studied and analyzed.

3.3.1 Clayey Soil

The soil used to treat in this study was gathered from Gaziantep University campus (TURKEY). Its color was observed to be dim dark as shown in Figure 3.2 Table 3.1 showing some engineering properties that were earned during the laboratory tests accomplished to the soil. The Atterberg limit test was carried out in accordance with ASTM D4318-2000 standards in order to estimate the liquid limit (LL), plastic limit (PL), and the plasticity index (PI). The soil classified according to ASTM D2487-2000 as CL. The particle size distribution of the soil is showing in Figure 3.3 The amend compaction test was performed to calculate the optimum moisture content (OMC) and the maximum dry density (γ_{dmax}) in accordance with ASTM D1557-98-2000.

Figure 3.2 The soil used during the experimental work

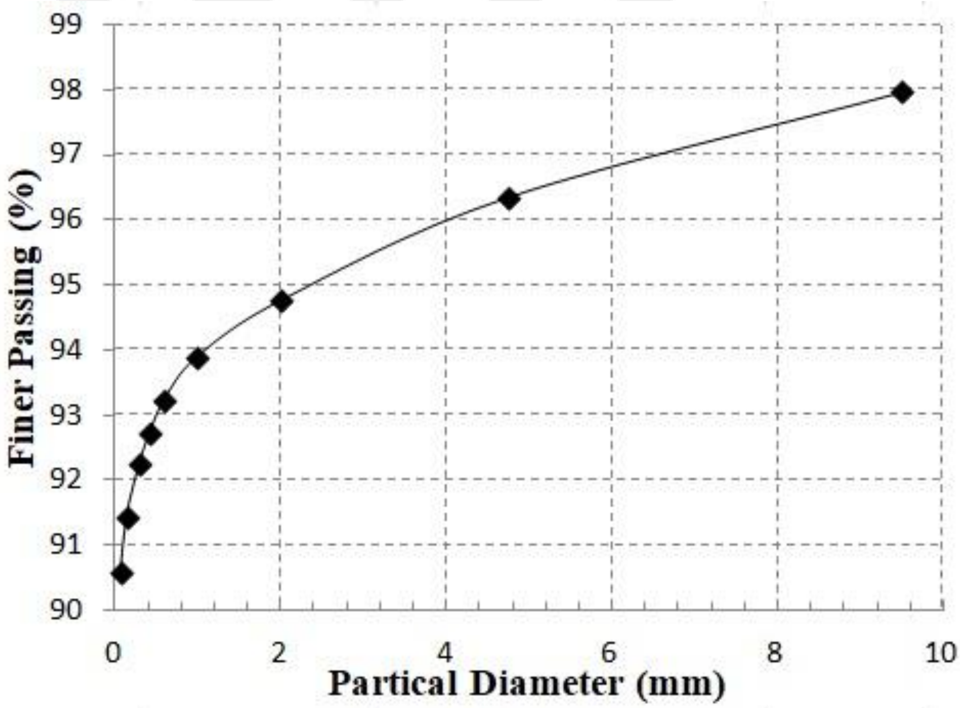

Figure 3.3 Particle size distribution of soil

Table 3.1 Some Engineering Propertied of the Untreated Soil.

Properties of untreated soil	Results
Liquid limit (LL) %	41
Plastic limit (PL) %	25
Plasticity index (PI) %	16
Specific gravity, GS	2.77
Classification (USCS)	CL
Swelling potential %	3.58

3.3.2 Cement

Ordinary Portland cement (PC CEM, I 42.5R) matching to the TS EN 197-1, which mainly depending on the European EN 197-1, used in this study. It had a specific gravity of 3.15 g/cm^3 and specific surface area of 326 m^2/kg. It was used in the production of concrete. Physical and chemical properties of the cement are given in Table 3.2.

3.3.3 Aggregate

River gravel with a greatest size of 16 mm was used as a coarse aggregate while the mixture of nature sand with a maximum size of 4 mm was as a fine aggregate. Nature sand and river gravel had the specific gravity of 2.66 and 2.72 and the fineness modulus of 2.79 and 5.68, respectively. The sieve analysis results of nature aggregates are presented in Figure 3.4 and Table 3.3.

Table 3.2 Properties of plain Portland cement (CEM I 42.5R).

Composition	Percentage (%)
SiO2	19.79
Al2O3	3.85
Fe2O3	4.15
CaO	63.84
MgO	3.22
SO3	2.755
Na2O	-
K2O	-
Cl	0.0063
Insoluble residue	0.34
Loss on ignition	0.87
Free lime	1.28
Specific gravity (gr/cm^3)	3.12
Specific surface (cm^2/gr)	3349

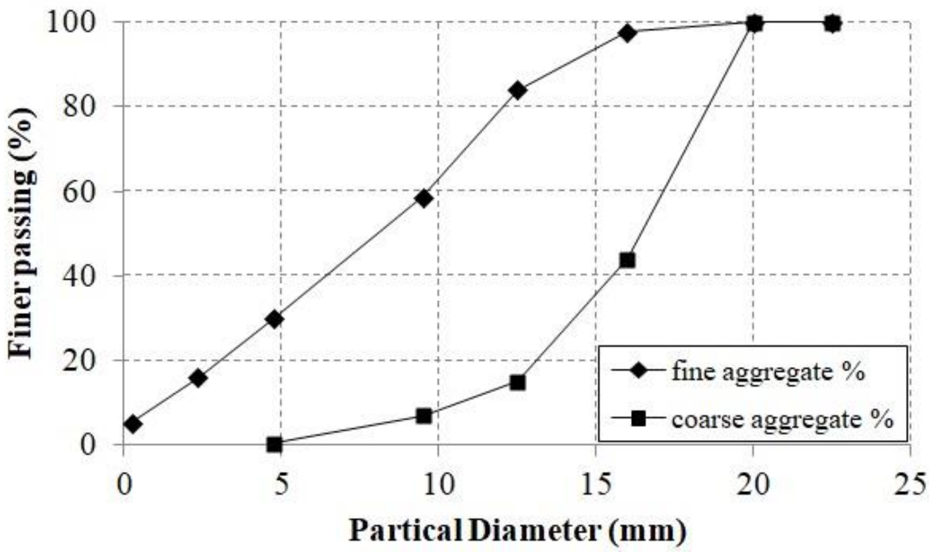

Figure 3.4 Particle Size Appropriation of Aggregate

Table 3.3 Physical Properties and Sieve Analysis of the Aggregate

Sieve size	Fine aggregate %	Coarse aggregate %
16	100	100
8	99.7	31.5
4	94.5	0.4
2	58.7	0
1	38.2	0
0.5	24.9	0
0.25	5.4	0
Fineness modulus	2.79	5.68
Specific gravity	2.66	2.72

3.4 Grain Size distribution of Soil

Contingent upon ASTM C325-2007 standards, the sieve analysis had been carried out using 1 kg dry soil. The sieves were arranged in a set according to the sieve opening diameter from top to bottom; 19, 12.5, 9.5, 8, 0.300, 0.150, and 4.75 mm; respectively. The dried soil was then placed in the first top sieve and shacked for 10 minutes. The remained soil in each sieve has then been weighted.

3.5 Mold Manufacturing

In this study ply-wood boxes were used as a mold with (50x25x30) cm dimensions, eight molds have been manufactured in Gaziantep university workshop. Two ply-wood sheets were used for manufacturing Figure 3.5

Figure 3.5 Mold manufacturing.

Then, all pieces were linked by a hex-bolts with wing nuts for hand tightening as shown in Figure 3.6 , silicone caulking had been used to close gaps in molds in order to support stability of water content during cast and curing period see Figure 3.7.

Figure 3.6 Hex-bolts with wing were used for tightening.

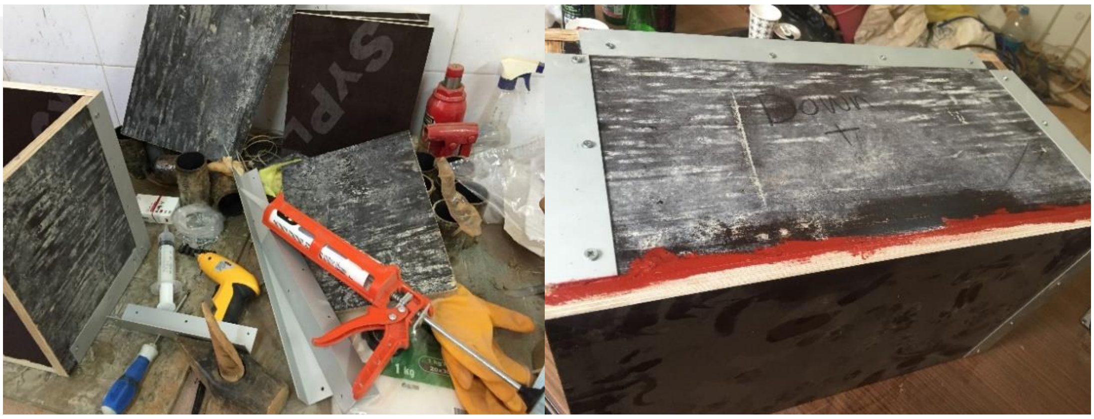

Figure 3.7 Applying silicone caulking to close gaps in mold.

3.6 Clay Preparation

The procedure for preparing clay was performed in accordance with (Japanese Geotechnical Society, JGS 0821-2000 and section 7.2) laboratory slandered for laboratory sample preparation. To prepare samples, the soft soil initially was sieved using sieve (4.75mm) Figure 3.8. amount of needed clay were dried in oven for 24 hr. ensure having zero initial water content, after that the dry clay were packed in plastic bags until time of preparing samples Figure 3.9

Figure 3.8 Sieve analysis.

Figure 3.9 The plastic bags that used in sample preparation.

3.7 Sample Preparation

All the laboratory samples were prepared by compacted the clay in the wooden mold 50*25*30 cm for three to five equal layers each layers received 25 strikes of a hammer of standard weight to increase the stability and supporting capacity of soil (improving the physical properties of soil) until we reached 10 cm from the mold height as shown in Figure 3.10. Then, anti-adhesion sheet were added over compacted clay in order to prevent oil from going throw or over clay while oiling the mold this lead to change in clay moisture as show in Figure 3.11. After these steps the mold is ready for casting Figure 3.12.

Figure 3.10 Fully compacted layer of clay.

Figure 3.11 Anti-adhesion sheet added before oiling the mold.

Figure 3.12 Photographic view for molds before casting.

Eight series of ctrl mixtures with same w/c ratios 0.5 with 500 kg/m^2 were designed. The concrete was then mixed in a power-driven revolving pan mixer at the ratio 1:1.5:1.5, Figure 3.13 and then placed directly on the compacted clay with compaction Figure 3.14. The process had been repeated for 16 samples, each two samples had a fixed clay water content ratio. All the samples were then cured for the age of 28 days spray curing method were used in this study, Figure 3.15.

Figure 3.13 Power-driven revolving pan mixer used in this study.

Figure 3.14 During the casting process.

Figure 3.15 The Curing method that used in this study.

3.8 Concrete Mix Details

To reach the same homogeneity and uniformity in all mixtures, a special batching and mixing procedure was followed since mixing sequence and duration are very vital in concrete production . Regarding to this procedure, the fine and coarse aggregates were spilled in a power-driven revolving pan mixer and let to mix homogeneously for one minute. After that about quarter of the mixing water was added into the mixer and it was allowed to proceed the mixing for one more minute. The aggregates, then were left to uptake water for one minute. Thereafter, cement material were added to the wetted aggregate mixture for mixing extra 2 min. the remainder of the mixing water was added into the mixer. Finally, the concrete was mixed for additional 2 min. to complete the production. Same sequence was followed for all mixtures. Concrete were mixed for a total time of 7 min. finally, the fresh tests were applied on concrete mixtures.

3.9 Experimental Methodology

3.9.1 Atterberg Limits Test

This test was performed to estimate the liquid limit (LL), plastic limit (PL), and the plasticity index (PI) for each soil admixture ratio in accordance with ASTM D4318 test specifications;

1) Liquid limit (LL): a sample of about 100 gm. dried soil with different amounts of the stabilizers were prepared to test the liquid limit by Casagrande device shown in Figure 3.16. The sample first mixed with water to obtain a uniform paste. Each sample was repeated 4 times at 4 different water contents. At the first trial, the paste should have a consistency that makes it needs 35 to 40 drops of cup to cause closed of standard groove for sufficient length. The sample replaced in the marked brass with a flat surface by using knife-edge. A groove will then make in the specimen by using a special grooving tool. The test must be repeated to get a groove closing between 10 and 40 blows. When the groove closed at a distant of 12mm, number of blows that achieved this groove closing recorded and a wet sample must be taken from the closing area and placed in a pre-weighted cup to be balanced and dried for 24 hours. The water content will then calculated after 24 hours, the number of blows was drawn against the

water content. The liquid limit is the water content at the 25 blows gained from the graph.

2) Plastic limit (PL): the same mixed soil-admixture that prepared for the liquid limit finding had been taken and placed on a flat plate then rolled by hand fingers at a rate of 80-90 strokes per minute to make a thread of about 3mm in diameter. The plastic limit is the water content at which the soil threads cracks at 3mm in diameter. If the thread diameter becomes less than 3mm without cracks, its mean that the water content is larger than the plastic limit. Reduce the water content by repeating the kneading of soil and rolling it again into thread. When the soil threads cracked into several pieces, these pieces had been collected into a ball and re-rolled again into a thread. These steps were repeated until the soil could no longer roll into a thread. The cracked pieces were placed into pre-weighted containers and its weight was recorded before it was placed in oven for 24 hours to calculate the water content. The average of two water contents was calculated as the plastic limit of the mixture.

3) Plasticity index (PI): is the difference between the liquid limit and the plastic limit, it is the state in which the soil still has a plastic behavior between the non-plastic and viscous fluid states.

Figure 3.16 Casagrande device used during the experimental study.

3.9.2 Compaction (modified proctor) Test

The compaction method defined as the method of re-arranging the soil particle by reducing the internal air void by impacting an external energy. The modified proctor test was carried out on the all previously mentioned proportions in accordance with ASTM D1557-2000 standards, as shown in Figure 3.17. The dry soil with the admixture was first mixed in a large pan, the weight of soil mix with the compaction mould and its base were weighted with an electronic balance. The water then added to the dry mix gradually with an interval of 3% by the dry weight and blended carefully until the mix became uniform in color and texture. The mix placed in the compaction mould with five equal layers, each layer compacted with 31 blows by the special designed proctor hammer; as described by (Cabalar et al., 2014) at a rate not exceed 1.5 seconds per blow, it was ensured that the hammer covered all the surface during the impacting. It was also ensured that the last layer thickness must be above the top end of the mould and extended through the collar. After finishing the compaction of five layers, the collar carefully separated from the mould and the extended layer trimmed off by a spatula. The weight of the mould with still the soil inside was then recorded. To measure the water content, specimen from top, middle, and bottom of the compacted soil was then placed in the oven containers to be dried for 24 hours.

The dry density can be calculated by:

$$\gamma_d = \frac{\gamma_m}{1 + \left(\frac{w_c}{100}\right)} \tag{3.1}$$

Where;

γ_d is the dry density (gm/cm^3);

γ_m is the moist density (gm/cm^3); and

w_c is the water content (%).

Figure 3.17 Compaction apparatus used during the experimental study.

3.9.3 Slump Test

Concrete slump is to decide the workability or consistency of concrete blend arranged at the research facility or the building site amid the advancement of the work. Concrete slump test had been done from cluster to bunch to check the uniform nature of concrete. The slump test is the most straightforward workability test for concrete, includes minimal effort and gives quick results. Because of this reality, it has been generally utilized for workability tests since 1922. The slump had been done as pre systems specified in AST C143 in the United States, IS: 1199_1959 in India and EN 12350-2 in Europe. Generally concrete slump value is utilized to find the workability, which demonstrates water/cement ratio, yet there are different variables including properties of materials, mixing method, dosage, admixtures etc. also affect the concrete slump value.

A concrete of 1:1.5:1.5 mixture samples with 0.5 water/cement ratio were prepared at the laboratory within a period of 2 min after sampling to test the workability as in Figure 3.18 The difference in length between the mold and the sample length after removal of the cone mold is 3 mm which means that the concrete have high workability, Figure 3.19.

Figure 3.18 Slump test method procedure.

Figure 3.19 Result of slump test.

3.9.4 Ultrasonic Pulse Velocity (UPV)

Non-destructive test has been implemented to measure damage in structures. Common structures are assessed with the use of operational and easy application of ultrasonic pulse velocity (UPV). This study discusses the use of ultrasound with the time of flight to estimate the depth of surface opening cracks and S-P- waves Transducers. This technique is a very useful tool for practical applications Figure 3.20. It is inexpensive, simple and easy to preform, giving a rapid indication of the extension of cracking.

Figure 3.20 The ultrasonic device that used in this study.

3.9.4.1 Surface Opening Cracks by Ultrasonic Method

Surface opening cracks often occurs in concrete they may appear as a consequence of several degradation mechanisms such as repeated loading, differential settlement and drying shrinkage Figure 3.21. While in some cases, surface cracks may only affect the aesthetics of the concrete surface, in most cases they are an indication of structural distress or decreased durability.

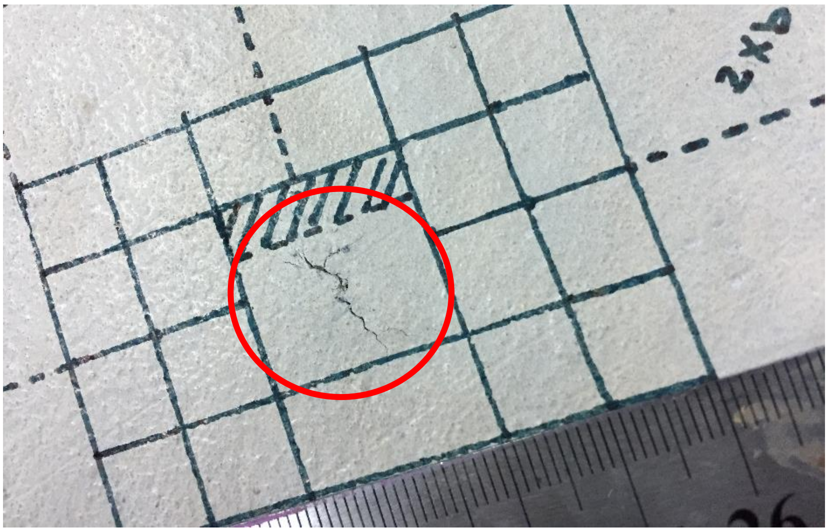

Figure 3.21 Open surface cracks that appeared after 28 days of curing.

In this study crack depth non-destructively determined by the time of flight diffraction technique BS 1881: Part 203. In this technique, stress waves are generated on one side of the crack, with wave arrival times monitored by a transducer placed on the opposite side of the crack Figure 3.22 Stress waves can be generated by a mechanical pulse, such as given by ultrasound equipment’s.

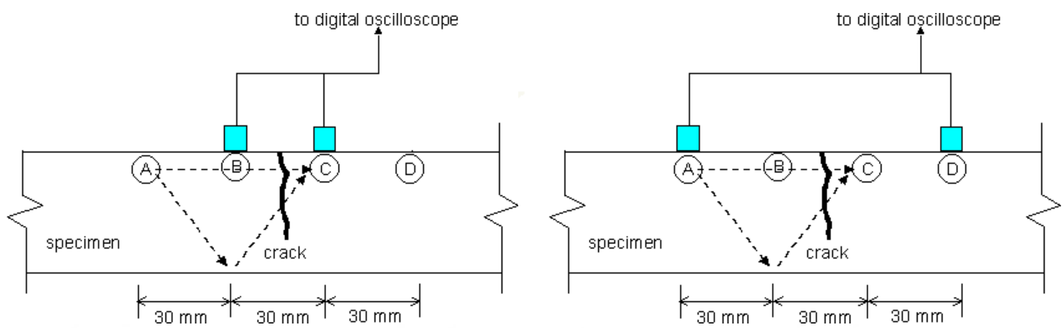

Figure 3.22 Crack depth measurement by ultra-sonic method.

3.9.4.2 S-P wave’s Measurement

We measured the P-wave velocity of concrete, *V*P, according to BS 1881 using a pair of P-wave transducers (MK-954 transmitters and receivers) connected to a pulse-receiver (Ultrasonic-Pundit lab).The transmitter was driven by a 200V square pulse, generating a transverse (transmitter and receiver), and cross marks indicate the average P-wave velocity between two transducers. We gained the transmitter and conditioned receiver signals using a high-speed (1MHz sampling rate) analog to digital data procurement board. We developed a computer algorithm based on a fixed threshold level to determine the time of flight using the digitally gained waveforms. Figure 3.23 presents a typical signal of the transmitter and receiver transducers.

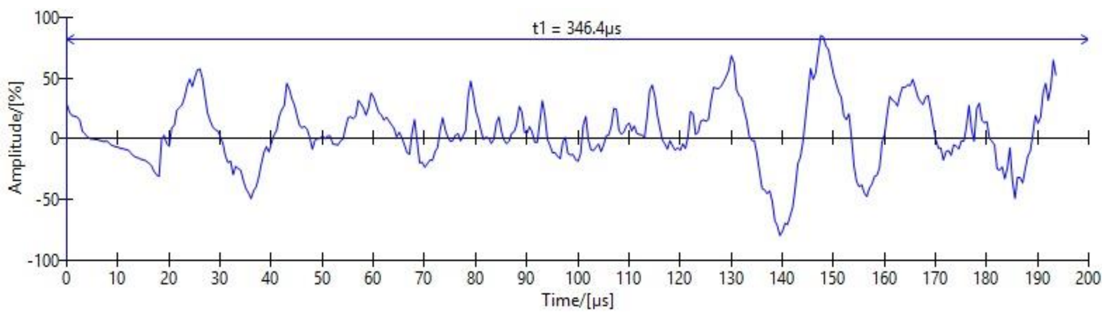

Figure 3.23 Typical signal of the transmitter and receiver transducers on computer.

For effective S-wave measurement we made a total of 20 direct S-wave measurements on each concrete slab using the same coordinate system as for the P-wave measurement. we labeled the gridlines along the width of the specimens as axes AB, CD, EF, and GH and those along the length of the specimens as axes I, II, III, IV, and V. We carried out direct measurements at a single position because we used the pulse-echo method see Figure 3.24

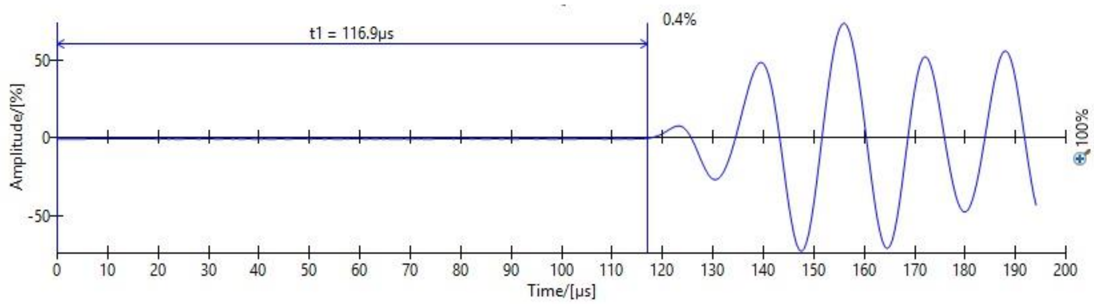

Figure3.24 S-wave signal of the transmitter and receiver transducers on computer.

By measuring P-wave transmission time and as S-wave transmission time with Ultrasonic device we able to determine the P-wave modulus (M) and the shear modulus (G).

P-wave modulus (M):

$$\boldsymbol{M = \rho V_p^2}$$

Where:

ρ = density of concrete

V_p = pulse velocity of the P-wave

Shear modulus (G):

$$\boldsymbol{G = \rho V_s^2}$$

Where:

ρ = density of concrete

V_s = pulse velocity of the S-wave

3.9.4.3 Poison's Ratio and E-modulus by Measuring S-P waves

Poison ratio can be determined simply by measuring the P- wave and Shear wave velocity and it is not necessary to know the density of the concrete, by using the following equation we can determine poison's ratio (v):

$$V = \frac{M - 2G}{2M - 2G} = \frac{\rho V_P^2 - 2\rho V_S^2}{2\rho V_P^2 - 2\rho V_S^2} = \frac{V_P^2 - 2V_S^2}{2V_P^2 - 2V_S^2} = \frac{\boldsymbol{V_P^2 - 2V_S^2}}{\boldsymbol{2(V_P^2 - V_S^2}}$$

Once poison’s ratio is known, the elastic modulus can be calculated from the equation:

$$E = 2G(1 + V)$$

Where: G = shear modulus

V = poison’s ratio

For the modulus of elasticity it is necessary to know the density of concrete.

3.9.5 Compressive Strength

For compressive strength measurement of SCCs, 150x150 mm cubes, 100x50 mm cylinders were tested according to ASTM C 39 by means of a 3000 KN capacity testing machine see Figure 3.25. The test was conducted on two 150x150 mm cubes, 100x50 mm cylinders for each mixture at the ages of 28 days. The compressive strength was computed from average of two cubes, cylinders at each testing age Figure 3.26.

Figure 3.25 Photographic view of compressive strength machine.

Figure 3.26 Samples before applying compressive strength test.

All selected samples were painted white to ensure that the amount of surface cracks is detected. As for the samples that were taken by the core cutting was covered with sulfur to ensure that the compression is properly distributed as shown in Figure 3.27. All results were recorded by computer plugged with the machine, then, the average for each mix has been taken at the same water content of clay. Figure 3.28 shows the samples after the test.

Figure 3.27 Samples after applying compressive strength.

3.9.6 Core-drilling

An experimental method known as the concrete core-drilling technique for the determination of stresses in concrete structures under uniaxial stress condition were used in this study. Figure 3.28. The core drill is a highly efficient and powerful tool for boring holes through reinforced non-reinforced concrete, block, brick, masonry, and stone see Figure 3.29. The typical core bits are made of hollow steel cylinders that are fitted with segmented diamond teeth. The teeth grind away the concrete surface for creating a hole of any coveted size. The reliability of this technique was established in the laboratory, by conducting experimental investigations on concrete specimens with known stress strain conditions, two cores were extracted for each concrete specimen by using 50mm core bits, extracted samples used for compressive strength test.

Figure 3.28 Standard concrete core cutting machine.

Figure 3.29 Machine while cutting.

3.9.7 Crack Width by Microscope

A portable Microscope were used in this study for measuring open surface cracks width in concrete slabs after 28 days of curing Figure 3.30. Specification of device listed in Table 3.4.

Figure 3.30 Portable microscope device used in this study.

Table 3.4 Specification of the microscope device.

Amplification	X 40
Power	1.5v battery light source
Dimensions	130mm x 80mm x35mm
Weight	659g including case

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Compressive Strength

Variations in the compressive strength of cubes and cylinder core samples of concretes measured at 28 days, Figure 4.1, are tabulated Table 4.1 and presented in Figure 4.2 and 4.3. Two series of concrete having initial compressive strengths of about 22 and 30 MPa were achieved for 0% and 35% clay water content, respectively. It was noticed that compressive strength decreased when concrete were placed over clay with low water content percentage this was due to loss of capillary water (Drying shrinkage). Contracting of hardened concrete mixture due to loss of capillary water is called Drying Shrinkage Figure 4.4. This shrinkage causes an increase in the tensile stress which is mean decease in compressive strength. A few studies and investigations have exhibited that adequate and proper curing of concrete is the most appropriate step to prevent shrinkages and developing a high degree of the attractive properties of concrete.

Table 4.1 Results of compressive strength for cylindrical and cubic concrete samples at 28 days.

Sample code	Compressive strength (MPa)	
	Cubes (150X150)	Cylinder (100X50)
0WC:S12D28	22	10
5WC:S12D28	23	12
10WC:S12D28	25.5	13
15WC:S12D28	26.75	13.8
20WC:S12D28	27	15
25WC:S12D28	28	15.5
30WC:S12D28	28.72	17.2
35WC:S12D28	30	18.7

Figure 4.1 Samples during compressive strength test.

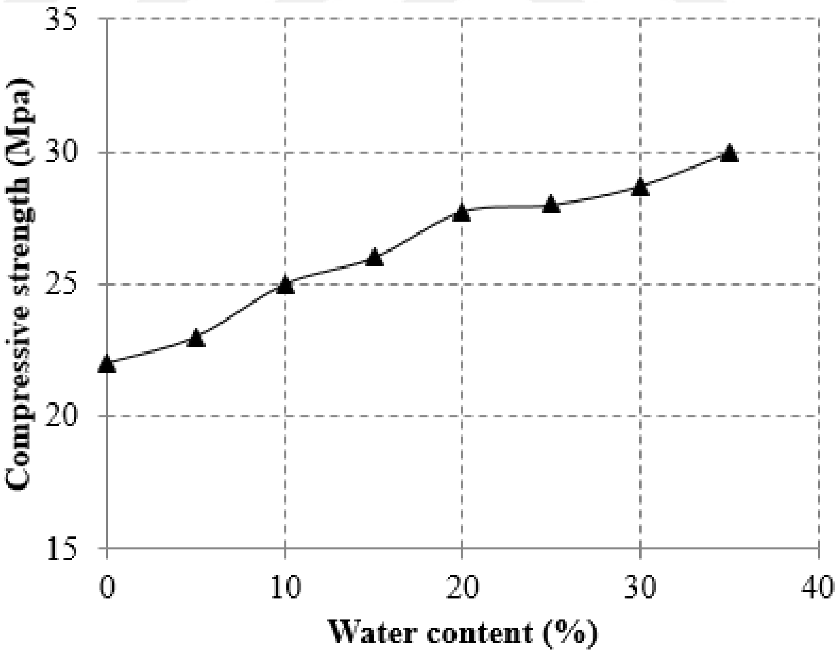

Figure 4.2 Relationship between compressive strength and water content for the cubic samples.

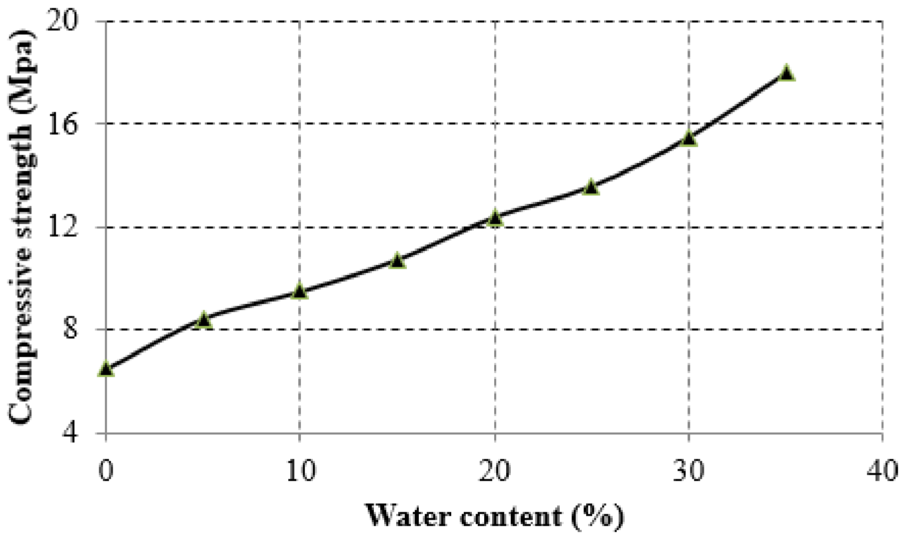

Figure 4.3 Relationship between compressive strength and water content for the cylinderical samples.

Figure 4.4 Samples after test.

4.2 Ultrasonic Pulse Velocity (UPV)

Table 4.2 and Figure 4.5 shows the UPV values of the concrete specimens cured for 28 days. As expected, the Figure 4.6 shows that the UPV increasingly with specimens had low clay water content, (*Ultrasonics* 38, no. 1-8 (2000): 546-552). Used in this study. The relations between UPV and water content was obtained using:

$$c = 0.2/(T_d - 0.6) \times 10^{-6}$$

Table 4.2 Results of UPV for each water content ratio.

Mix	UPV m/s
M1 0% CWC	8787
M2 5% CWC	8489
M3 10% CWC	6219
M4 15% CWC	5928
M5 20% CWC	4277
M6 25% CWC	4068
M7 30% CWC	3925
M8 35% CWC	3666

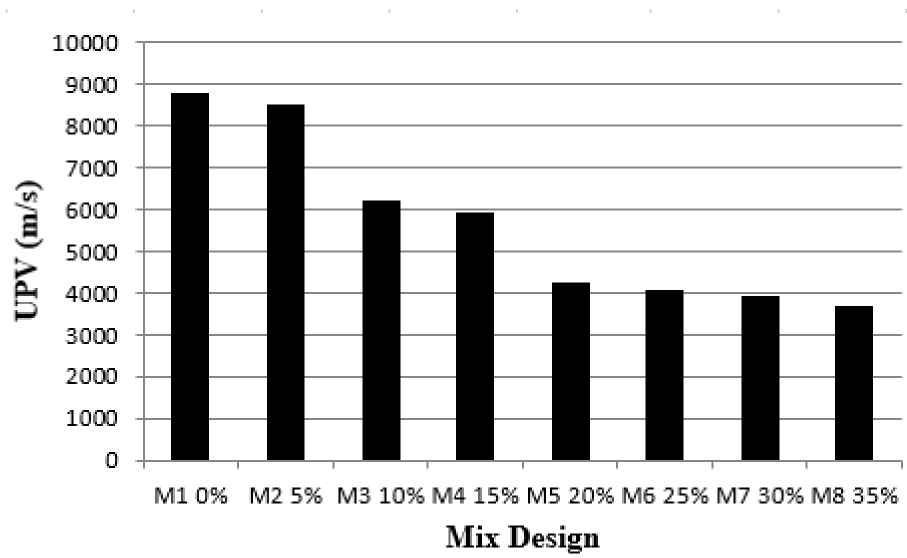

Figure 4.5 UPV values for concrete specimens cured for 28 days

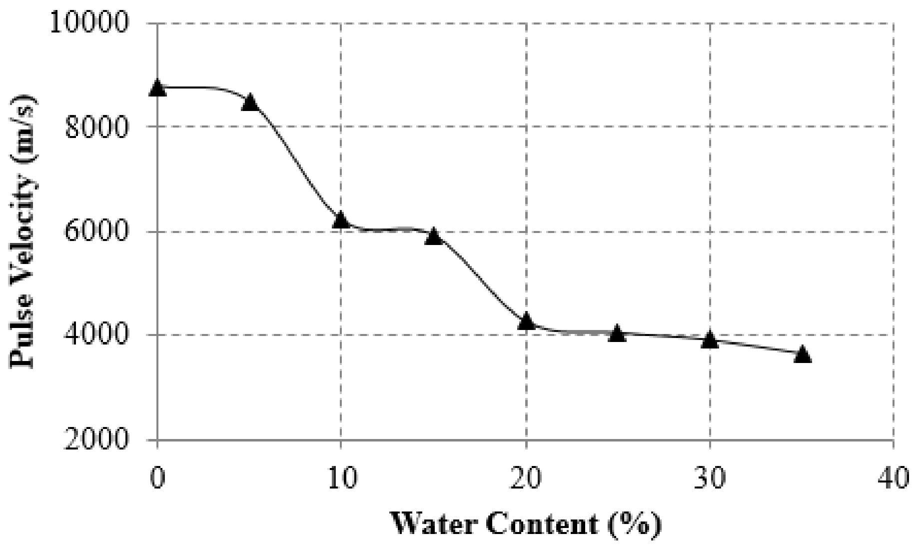

Figure 4.6 Relationship between UPV and water content of clay

4.2.1 Crack Depth

In this study cracks depth were measured by ultrasonic British standards method (BS 4408) and tabulated Table 4.3. Results shows that there was an inverse relationship between the clay water content and the depth of the cracks in the concrete, see Figure 4.7.

Table 4.3 Results of UPV crack depth for each water content ratio.

Mix	Crack depth (cm)
M1 0% CWC	4
M2 5% CWC	3.15
M3 10% CWC	3.05
M4 15% CWC	2.15
M5 20% CWC	2.1
M6 25% CWC	1.25
M7 30% CWC	0.35
M8 35% CWC	0.05

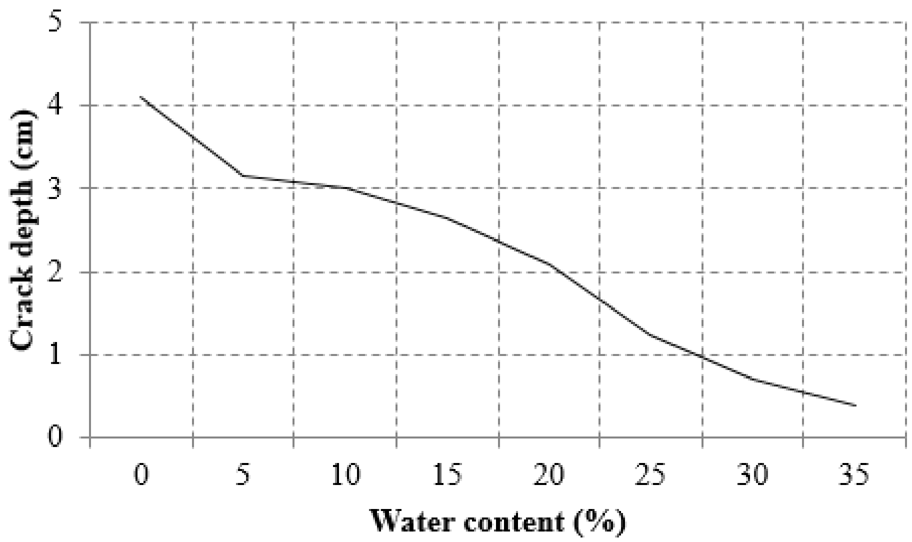

Figure 4.7 Relationship between crack depth and water content of clay

4.2.2 Relationship between UPV and Compressive Strength.

Many researchers have examined how UPV can be correlated with concrete strength. According to previous research by Tharmaratnam (1990). The compressive strength and UPV values are related by the following equation:

$$f_c = -0.0013V_c + 33.948 \quad (4.1)$$

Where:

F_c = Compressive strength

V_c = Pulse velocity (m/s)

$$R^2 = 0.96$$

There was an adequate linear relationship between UPV and compressive strength. Because R^2=0.96, we can say that 96% of the variation in the values of compressive strength is represented for by linear relationship with UPV (see Figure 4.8).

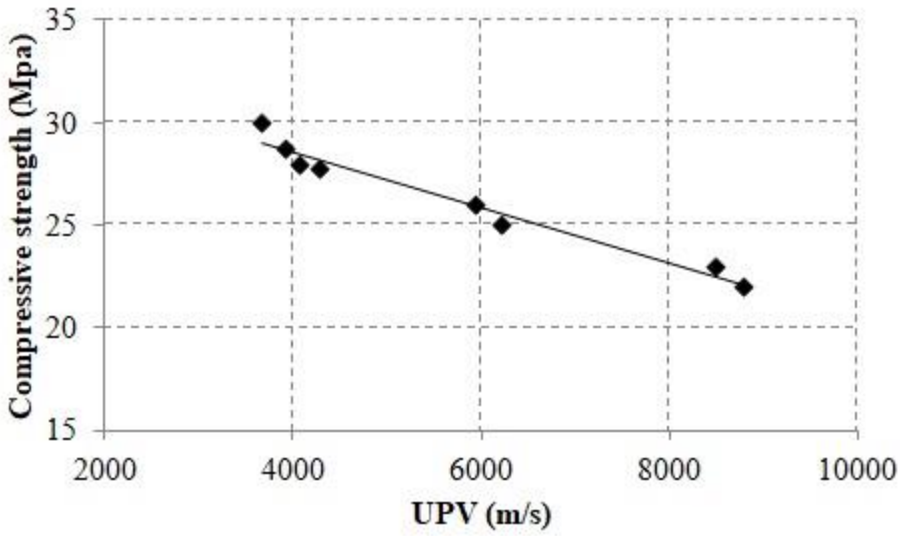

Figure 4.8 Relationship between UPV and compressive strength.

4.3 Microscope

A led illumination 40x white pocket microscope with scale 1div/0.05 were used in this study shows that the cracks width decreased by 0.4% for the concrete that were casted over 0% to 35% clay water content, because of losing moisture.

Table 4.4 Results of microscope crack depth for each water content ratio

Mix	Crack width (mm)
M1 0% CWC	2.8
M2 5% CWC	2.4
M3 10% CWC	2
M4 15% CWC	1.6
M5 20% CWC	1.2
M6 25% CWC	0.8
M7 30% CWC	0.4
M8 35% CWC	0.1

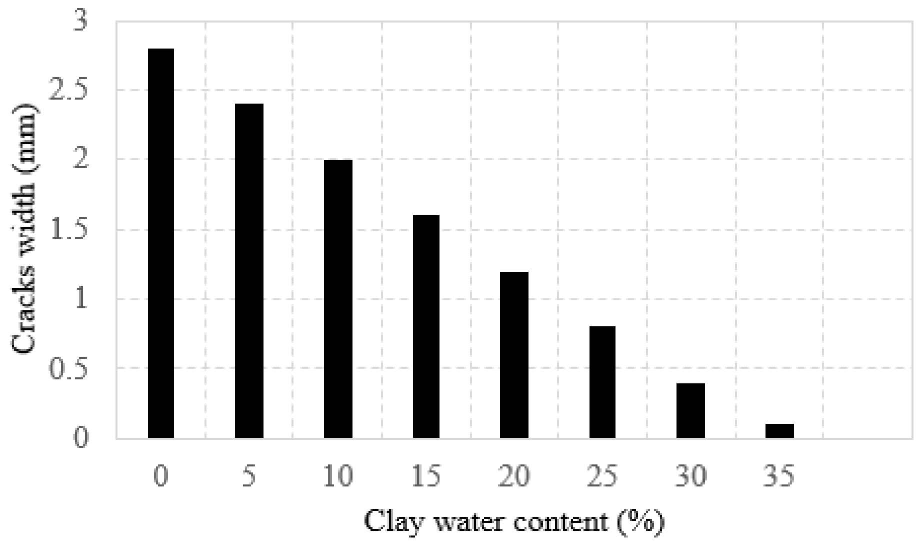

Figure 4.9 Crack depth at each water content ratio.

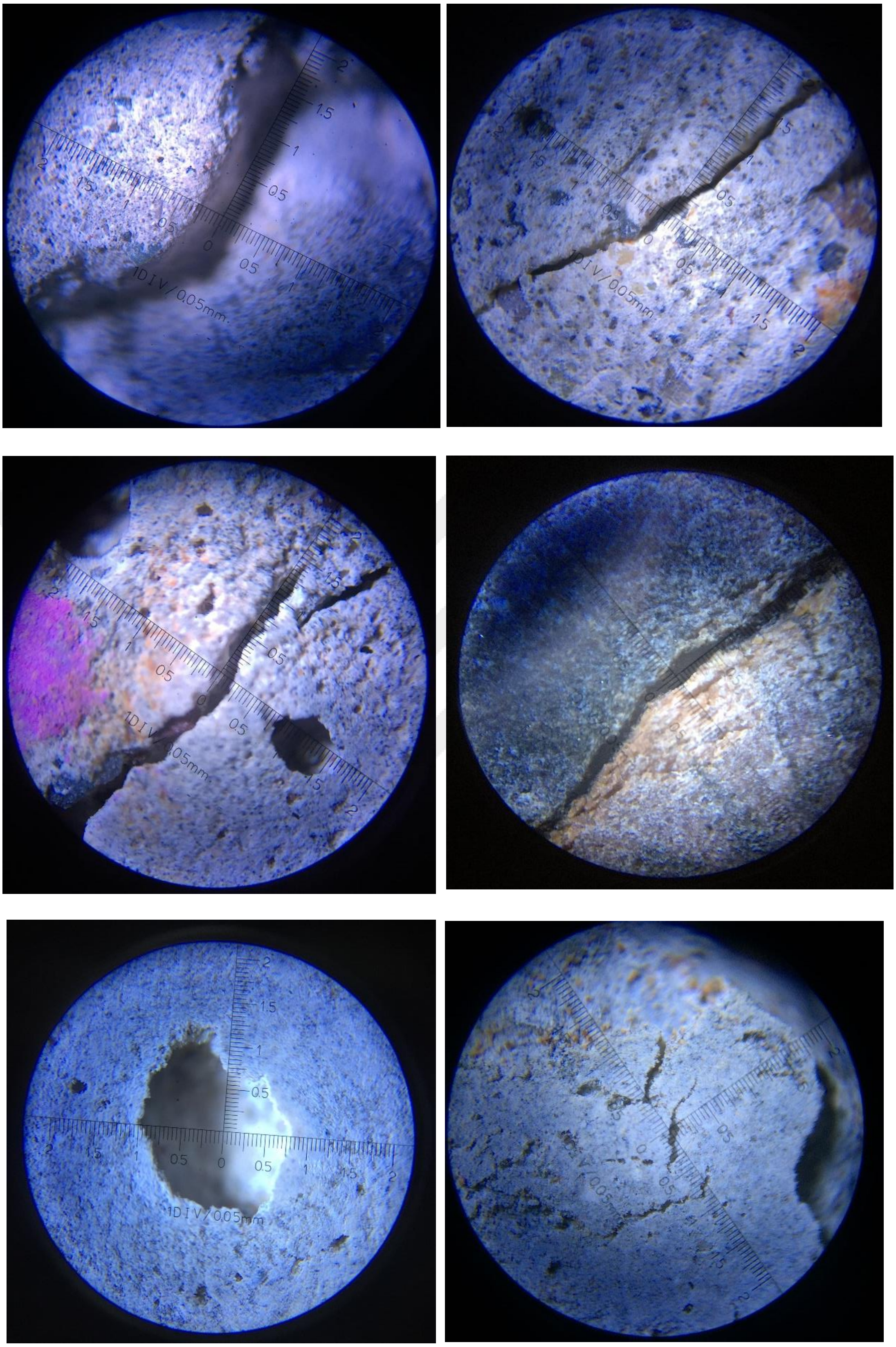

Figure 4.10 Open surface crack from microscope.

4.4 Shear wave's P- Wave's Results

Table 4.5 P-wave velocities (m/s) at points in slabs

Test Point	I	II	III
M1 0% CWC	3002	3301	3295
M2 5% CWC	3136	3333	3283
M3 10% CWC	3254	3197	3281
M4 15% CWC	3429	3339	3318
M5 20% CWC	3130	3268	3104
M6 25% CWC	3108	3268	3300
M7 30% CWC	3191	3207	3207
M8 35% CWC	3334	3374	3271

Min: 3002

Max: 3472

Avg (m/s): 3285

Std (m/s): 97

Where:

Avg = average of velocity and STD = standard deviation

Table 4.6 S-wave velocities (m/s) at points in slabs

Test Point	I	II	III
M1 0% CWC	1830	1870	2020
M2 5% CWC	1950	1870	1840
M3 10% CWC	1880	1840	1840
M4 15% CWC	1890	2160	1890
M5 20% CWC	2020	1890	2010
M6 25% CWC	1800	1900	1950
M7 30% CWC	1890	2020	1870
M8 35% CWC	2040	1900	2120

Min: 1780

Max: 2160

Avg (m/s): 1911

Std (m/s): 95

Where:

Avg = average of velocity and Std = standard deviation

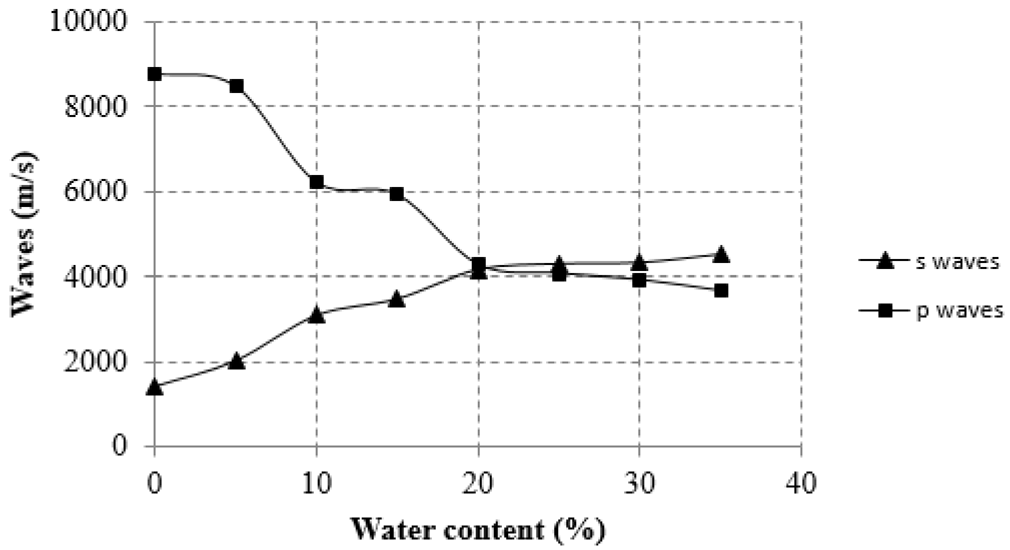

Figure 4.11 Relationship between s-p waves and clay water content

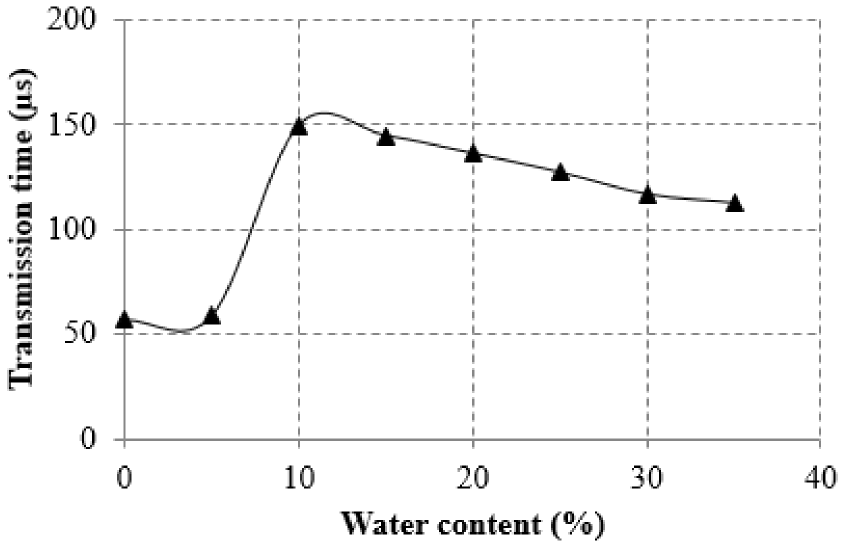

Figure 4.12 Relationship between transmission time and clay water content

CHAPTER 5
CONCLUSIONS

5.1 General

This chapter represents the summery of the experimental work that carried out in order to investigate the effects of the clay on the concrete placed directly above. The summery of the results listed below:

1- The changing in water content of the compacted clay effected the compressive strength of the concrete that placed directly above in a positive manner. The compressive strength recorded high at the high water content.

2- The shrinkage of concrete influenced inversely with the water content. The more water content of the clay, the less shrinkage of concrete.

3- The water content effected the ultrasonic pulse velocity (UPV). The UPV changed from 8787 m/s to 3666 m/s by changing the water content from 0% to 35%.

4- The relationship between the compressive strength and the UPV of the concrete considered to be linear relationship with a very good correlation factor (R^2 = 0.96).

5- E-modulus increases with the increasing of water content.

6- S-waves increased with the high water content while p-waves decreased with increasing water content.

7- Transmission time µs recorded its maximum value at water content of 10%.

8- Width of cracks decreased with increasing water content.

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