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Mohanad Isam KWANA DWLE

ABSTRACT

EFFECT OF GLASS POWDER ADD GROUT FO DEEP MIXING OF SAND

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The deep mixing column is one of the soil improvement methods that is extensively used to improve the weak or problematic soils in order to increase the bearing capacity and reduce the settlement applied by creating mixed columns which include in-situ mixing of soil and Portland cement or lime with special machines. The goal of this study was to estimate the possibility of replacing waste glass soda powder with Portland cement in the binder for stabilization of sandy soil using the deep mixing method in order to reduce the consumption of cement. The grounded waste glass soda to a fine powder shows some pozzolanic properties due to the silica content. Three laboratory tests were carried out (Vicat test, unconfined compressive test and Ultrasonic pulse velocity) in order to investigate the effect of the glass powder that replaced with cement in the binder at different proportions (0%, 3%, 6%, 9% by dry weight) has been experimentally investigated for the deep mixing on the performances of loose sand with various clay contents (4%, 8%, 20% by dry weight). It is found from the testing results that i) the glass powder is not able to accelerate the setting time of grout, ii) the bulk density does not significantly change with the glass powder, clay content and curing time, iii) The best value of UCS can be obtained at the 28-days curing time due to the addition 3% of glass powder at the 20% clay content of sand, iv) the elastic modulus correlates well with the UCS values ($R \geq 83$) at the majority of soilcrete samples and v) the best UPV can be obtained at the 28-days curing time due to the addition 3%of glass powder at the 4% clay content of sand.

Keywords: Deep mixing, sand, glass powder, cement, clay.

ÖZET

CAM TOZUNUN DERİN KARIŞTIRILMASINA KATILMASINA ETKİSİ

KWANA DWLE, Mohanad Isam

Yüksek Lisans İnşaat Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Hanifi ÇANAKÇI

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63 sayfa

Derin karıştırma kolonu, zayıf veya problemli toprakları iyileştirmek için yaygın olarak kullanılan toprak geliştirme yöntemlerinden biridir taşıma kapasitesini arttırmak ve yerleşimi azaltmak için kullanabilir. Karışık sütunlar oluşturarak uygulandı içerir Toprak ve Portland çimentosu veya limonun özel makinelerle yerinde karıştırılmasını. Bu çalışmanın amacı çimento tüketimini azaltmak için atık cam tozu Portland çimento ile değiştirilme olasılığını tahmin etmektir, kumlu zeminin stabilizasyonu için derin karıştırma yöntemini kullanarak. Öğütülmüş cam sodadan ince bir toza kadar silika içeriğinden dolayı bazı puzolanik özellikler gösterilmektedir. Farklı oranlarda (% 0,% 3,% 6 ve 9%kuru ağırlık ile) çimento ile değiştirilen cam tozunun etkisini araştırmak için üç laboratuvar testi gerçekleştirildi (Vicat, serbest basınç (UCS), ultrasonik hız (UPV)) incelenmiştir (% 4 ve% 8 ve% 20) kil, farklı içeriği ile gevşek kum performanslarında derin karıştırma için deneysel olarak araştırılmıştır. Deney sonuçlarına göre, i) cam tozu, ayar süresini hızlandıramıyor, ii) birim hacim ağırlık, cam tozu, kil içeriği ve sertleşme süresi ile önemli ölçüde değişmez, iii) serbest basınçnin en iyi değeri 28 günlük kürlenme süresinde elde edilebilir dolayı 20 % kil içeriği ve cam tozu 3% Kuma eklendi. iv) Elastik modül, toprak numunelerinin çoğunluğunda UCS değerleri ile ($R \geq 83$) iyi ilişkilidir ve v) en iyi UPV, cam tozunun% 3'üne yüklenmesinden dolayı 28 günlük bekleme süresinde elde edilebilir % 4 kil kum içeriği.

Anahtar Kelimeler: Derin karıştırma, Kum, Çimento, Cam tozu, Kil.

Dedication

To

My Father

and

Mother

ACKNOWLEDGMENTS

First, praise be to "ALLAH" who gave me the health and strength to finish this work.

I would like to express my deepest gratitude to my supervisor Prof.Dr. Hanifi ÇANAKÇI, who has always supported and guided me throughout this study. Without his supports this research would be impossible.

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CHAPTER 1

INTRODUCTION

The deep mixing is the one of the ground improvement techniques that has been successfully applied for obtaining the soil-cement columns for weak or problematic soils. In such a case, it is required to enhance the soil using suitable soil improvement techniques. The inclusion of soil- cement columns utilizing by deep soil mixing method is one of the stabilization technologies that have been successfully applied in all parts of the world. Using the deep mixing method is widely to develop the Geotechnical characteristics of soft soil in different construction projects so as to decrease the settlement and increase the bearing capacity (Massarsch 2005). For this reason, particular rotating blending apparatus is utilized which generally produce a cylindrical column formed having a strength higher than the initial soil.. The formed columns normally reach their strength through the time and result in the redaction of the settlement in addition to enhancing the bearing capacity in loose and weak soils (Tabbaa et al., 2000). The interaction of in situ soil with soil cement columns leads to improve the bearing capacity and diminishment in the settlement of overlaid structures. Additionally a low deformability and permeability obtained when the soil mixing with cement (Yin and Fang 2010; Moseley and Kirsch 2004). The method principle is based on ricing the stiffness of original soil by adding reinforcing admixture material like cement and lime. The utilizing of cement as an additive factor performed cemintitious material due to the reaction between mixing soil with a uniform measure of cement and water. In this situation compact the formed soil-cement columns to a high relative density to make their characteristics similar to that of soft rock (Farouk et al., 2013), but the operation of cement production needs to energy consumption, which represent 5% of the industrial energy consumption and 3% of the total energy consumption globally.

Therefore, to decrease the using of cement there is a necessity to replace a part of cement with some pozzolanic materials.

Many researchers examined the using of waste materials and industrial products as cement replacement, also, efforts to use waste glass as partial replacement of fine or coarse aggregate and cement in concrete have been focused.

Glass is a diaphanous material manufactured by melting a mixture consist of some materials like silica $CaCO_3$ and soda ash at high temperature followed by cooling. Glass is commonly utilized to produce glass such as bottles, sheet glass, vacuum tubing and glasswares (Banadaki et al., 2012). The glass powder is a very recent material of admixture that could be used together with the cement as a part of the binder for modification of the engineering characteristics of soil based on the findings obtained in the previous efforts (Nuruzzaman and Hossain, 2014; Fauzi et al., 2016; Canakci et al. 2016). The past studies (Nuruzzaman and Hossain, 2014; Fauzi et al., 2016; Canakci et al. 2016) show that the powder form of waste glass is suitable for stabilization in the viewpoint of the economy when replaced with the cement and friendly environment due to the waste disposal. It is reported that (Fauzi et al. 2016) that the glass powder addition is able to increase the maximum dry density and to decrease the optimum moisture content and Atterberg limits of soft soil.

Globally The attention of many researchers focused on the use of recycled glass materials in the cement and concrete because of increasing environmental concerns and rising disposal prices. The using of waste glass as a powdered additive in concrete represents a possible choice for recycling waste glass materials furthermore the use of crushed glass to fine materials in concrete would help to reduce cement consumption. Many researches explained that powdered waste glass is suitable, safe and economical when using it as cement replacement.

1.1 History of the Deep Soil Mixing Techniques

Deep soil mixing technology, which was invented in the 1960s, was first presented for the first time in literature during the early 1970s (Broms and Boman, 1979; Holm et al. 1981; Rathmayer, 1996; Okumara, 1996; Kamon, 1996; Porbaha, 1998). Deep mixing (DM) technology includes the mixing auger of soils with cement, lime, or other kinds of stabilizers reaching to a great depths. The deep mixing method is one of the land rehabilitation technology that improves the efficiency of land by in situ stabilization of soft soil (Porbaha, 1998). The improvement mechanism generally takes place by mechanistic dry mixing or wet mixing (Rathmayer, 1996; Porbaha, 1998; Holm, 1999). Wet mixing is used in the arid and dry zones with deep levels of the water table. Deep mixing columns can be shaped into various forms such as isolated columns, grids, panels, and compound columns. Each of these forms is utilized in various conditions of the site contingent on site soil properties, project requirements, settlement characteristics, and load transfer mechanisms (Bruce, 2002; Puppala, 2003).

1.2 Research Methodology and Objective

The behaviour of DMM column has been studied at a laboratory work. In laboratory mixed samples were prepared with (cement and cement with different percentage of glass powder). Unconfined compression tests and ultrasonic pulse velocity were then applied to curing samples (curing times: 7, 14, and 28 days). Using the results of these tests, the most efficient binder mixes were determined as the column material.

The realized objectives of this research are summarized as follows

1- Investigate the performance of DMC which include cement and cement partial replaced with glass powder at the ratios (3,6 and 9) and compare them with the control mix, which contains just cement used as a binder without glass powder by the unconfined compressive strength and ultrasonic pulse velocity.

2- making v cat test to the binders which used in this study to find the initial setting time and final setting time and compare between them.

3- Reducing the pollution due to Cement production that due to waste glass materials (Which are non-biodegradable) at the same time by recycling and mild waste glass materials to a fine size and use them as cement replacement.

4- The deep mixing method is used to improve the Geotechnical properties of the sand in order to reduce the settlement and increase the strength within the soil mass.

1.3 Thesis Organization

This thesis is organized as follows: Chapter 2 gives the background work for DMMs and using waste glass powder as a cement replacement in concrete. The experimental setup and testing procedure are given in Chapter3. The Results of these tests and the discussion are given in Chapter 4. Finally, the conclusions are provided in Chapter 5.

CHAPTER 2

REVIEW OF LITERATURE

The objective of DMM improvement is to improve the strength of the soil to decrease compressibility by a method for cementation happening between soil and binder In this chapter the binder that used in this method is presented. Typical properties of regions of utilizations for DMM are given in Figure (2.1).

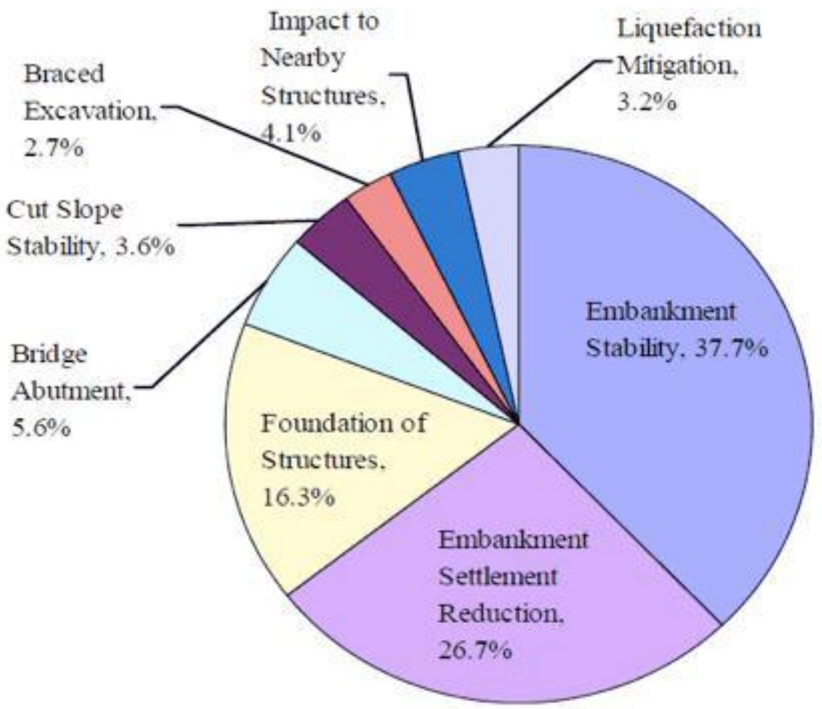


Figure 2.1 Typical areas of utilizations for DMM (Terashi, 2009)

Al-Tabbaa (2005) portrayed the general composition for a stabilized soil as appeared in Figure (2.2).

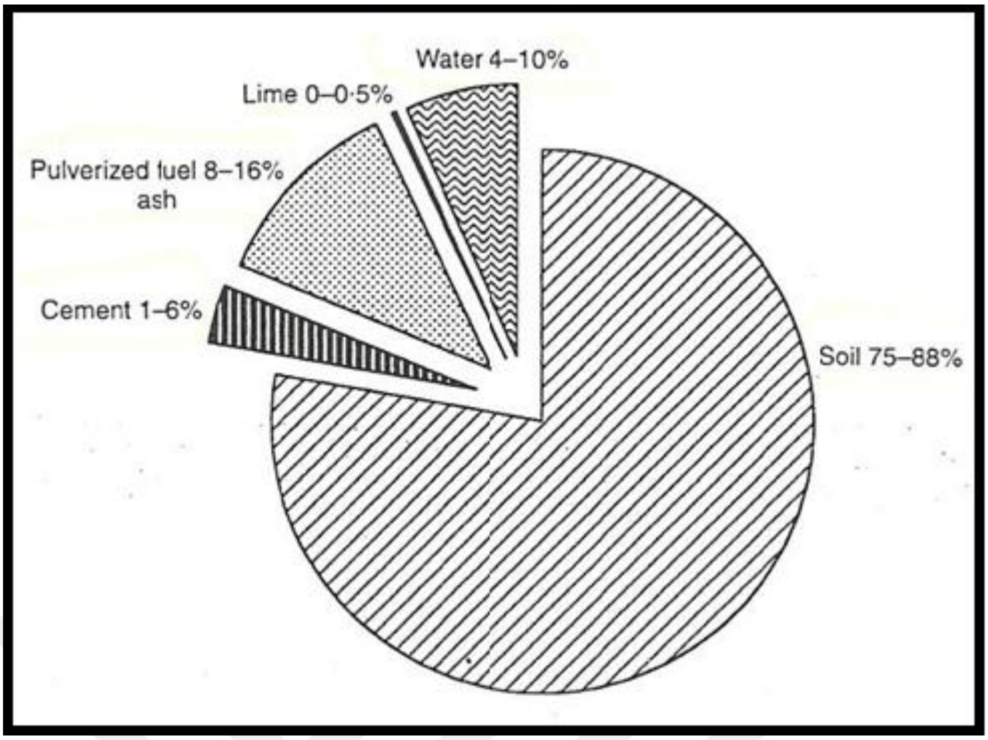


Figure 2.2 Typical ratios constituents for stabilizing sample of soil (Al-Tabbaa, 2005)

2.1 Soil Improvement by Deep Soil Mixing Column Technique

In the deep soil mixing utilization for soft soil improvement, the columns of soil could be installed in the form of stabilised grids, blocks and single columns relying upon the reason of improving as appeared in the Figure (2.3) (Kitazume and Terashi, 2013). The mode of installation may vary with different projects. The columns diameter, usually ranging from 0.5m to 0.75m and the spacing from centre to centre between them ranging from 1m to 1.5.To support five story building in Japan a 1.0 m diameter column with content of cement 200 to 300 kg/m^3 and unconfined compressive strength ranged from 2 to 4 MPa has been utilized. (Banadaki et al., 2012). The factors that influence on the bearing capacity and to the soil column improved parameters are the content of cement, the proportion of replacement, the column diameter and the methods of testing.

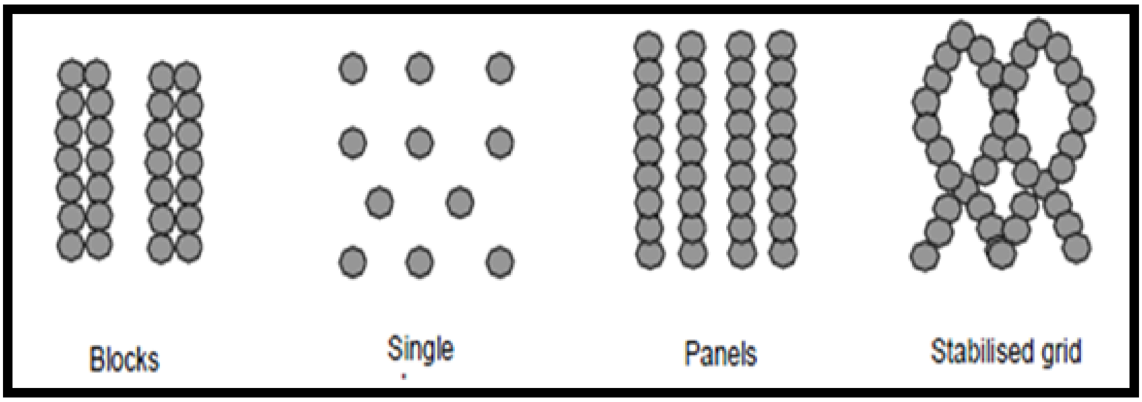


Figure 2.3 Various types of installation modes for deep mixing column, (Kitazume and Terashi, 2013)

2.2 Strength of Deep Mixing Column Improved Ground

The factors that influence on the unconfined compressive strength of deep mixing column improved ground are the type of soil that need to improve, time of mixing, curing technique, type of binder that used and content of binder. (Kitazume and Terashi, 2013) appears the scope of binder dosage and the comparing compressive strengths for for various soil types.

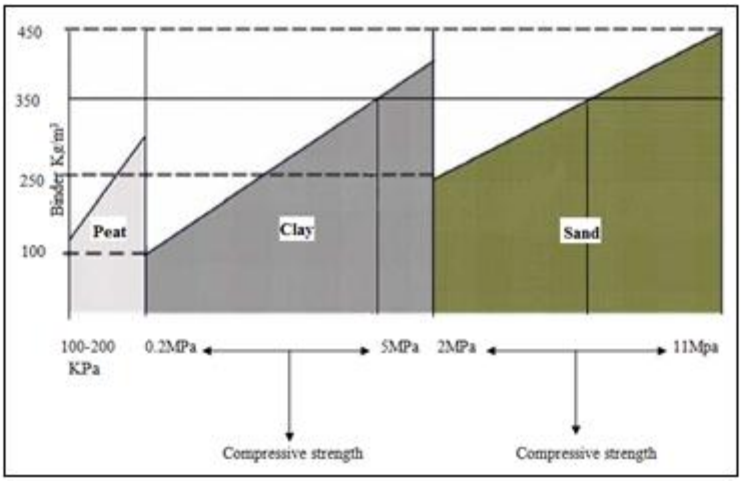


Figure 2.4 Represents the compressive strength of enhanced soils for various scopes of binder dosage, (Kitazume and Terashi, 2013)

Furthermore the strength of the enhanced soil may be affected by temperature and other ecological changes. The temperature is impacting on the chemical reaction of the treated soil with the binder. Through the process of interaction of the soil with the binder, the evolution of heat may change for a various binder. In cement and lime improvement methods, the temperature that required for reaction originates from these binders and does not completely rely on the temperature of the soft soil. For curing time, EuroSoilStab, (2002) reported that the progress of strength in cement enhanced soil is through the first month and for lime enhanced soils; the strength progress continues for a several months relying on the rate of pozzolanic reactions between the soft soil and lime.

2.3 Factors Influencing Strength of DMC Improved Ground

2.3.1 Effect of soil type

Soil type impacts the unconfined compressive strength of a lime enhanced soil as appeared in the Figure (2.5). The figure explained the effect of soil sort on the UCS of a hydrated lime enhanced soils. The enhanced soils were mixed at various moisture content and cured in a time of 91 days curing (Kitazume and Terashi, 2013). Figure (2.5), (Kitazume and Terashi, 2013) demonstrates that the type of soil obviously impacts the unconfined compressive strength increment, independent of the nature of the soil (marine or on-land soils). Terashi et al., (1977) concluded that the soil grain size distribution likewise impacts the unconfined compressive strength of quicklime enhanced soil.

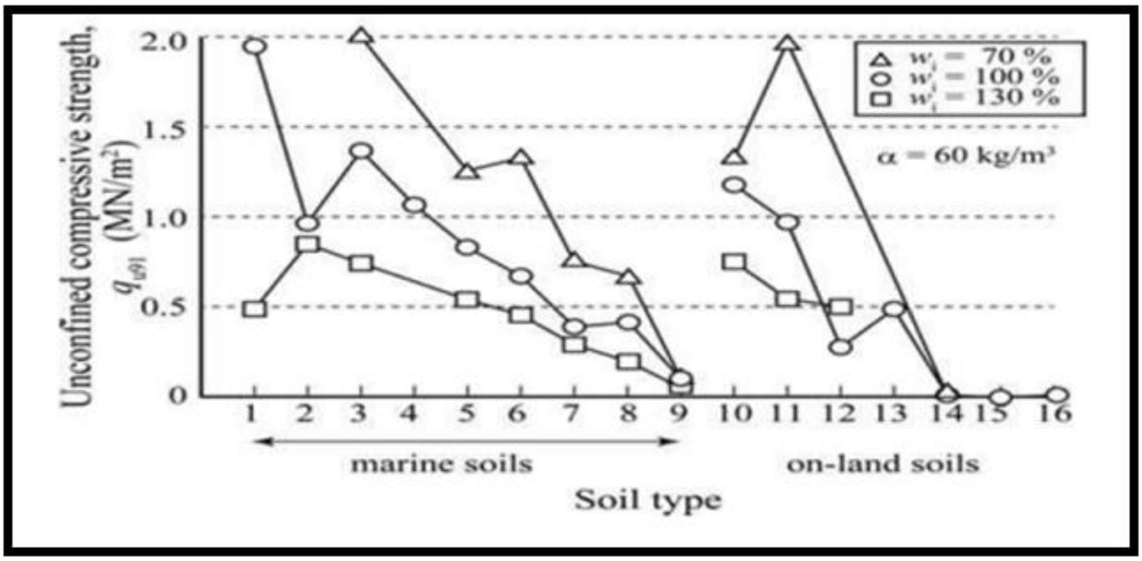


Figure 2.5 Soil type impact on strength at age 91 days curing time, (Kitazume and Terashi, 2013)

2.3.2 Effect of water content

Terashi et al., (1977) investigated that the water content of the surrounding soil influences the unconfined compressive strength of enhanced soil. At the point when curing time is increasing the water content in the original soils gives an upper limit of strength shifts toward the dry side, while the enhanced soil strength diminishes impressively when the initial water content increasing higher than the liquid limit. (Kitazume and Terashi, 2013) stated that in Japan the marine construction might not cause problems in light of the fact that In many instances the initial water content of normally consolidated marine clay somewhat near to its liquid limit. In reclamation areas on-land with pump dredged clay the care should be taken on clay soils because its liquid limit smaller that its water content. In deep mixing technique, the quantity of the binder is a ratio of the mass of the dry soil in a given mass of the soft soil contingent upon the approved mix proportion. The mass of soft soil is directly proportional to the dry soil mass wile proportional inversely to the initial moisture content. The factors may influence the performance of the deep soil mix after installation is any change in physical characteristics of the surrounding soil like the change in degree of saturation.

2.3.3 Effect of curing time

One of the factors that effects on the unconfined compressive strength of the deep soil mix is curing time as appeared in the figure (2.6), (Terashi et al., 1977). This figure demonstrates the effect of curing period (in days) on the unconfined compressive strength of various clay types enhanced by quicklime with constant binder factor of 10% (Terashi et al., 1977). As appeared in the figure (2.6), the unconfined compressive strength is plotted on the ordinate while curing period is plotted on a logarithmic scale along the x-axis. The figure demonstrates that the increase in the strength of the enhanced soil is more reliant upon the soil type even in a constant dosage of the binder, but the enhanced soils strength increase almost linearly with the logarithm of the curing period.

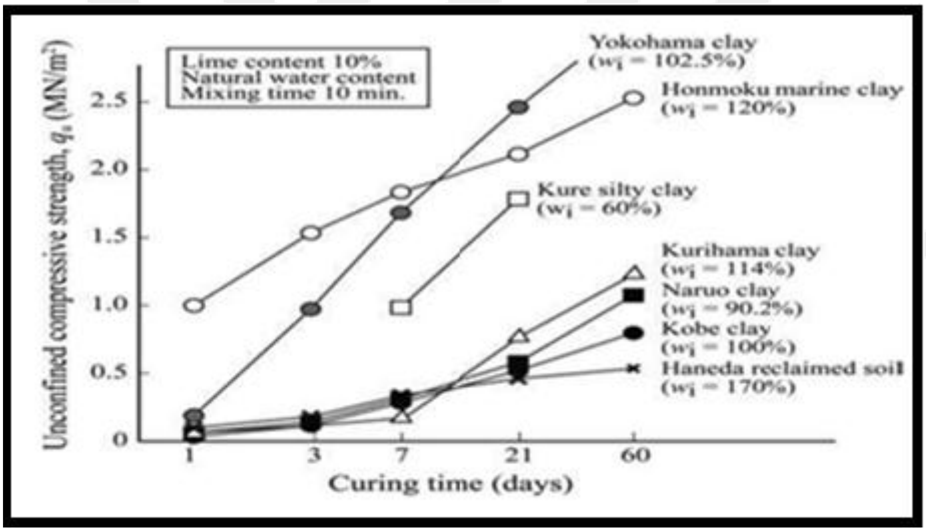


Figure 2.6 Effect of curing time on the unconfined compressive strength of quicklime enhanced soil, (Terashi et al., 1997)

2.3.4 Effect of Mixing Time

Amid mixing, to portray how binder and soil adequately mixed, it is normal that the mixing time ought to be an index. However, other considerations like the properties of virgin soil to be enhanced in the laboratory and kind of mixer Perhaps also effect of mixing degree by this index. Furthermore this index may be effects on unconfined compressive strength for both lime-cement and cement enhanced soil. In a quicklime stabilization test carried out on clay soil with different initial water contents furthermore plastic and liquid limits of 49.7% and 87.8%, respectively, mixing was completed on arbitrary mixing time and the mixing period was 10 minutes, (Terashi et al., 1977). The proportion of stabilized soil strength at an arbitrary mixing time for those prepared at 10 minutes mixing period was called the strength ratio. They noted that the strength ratio reduces to a great extent when the mixing time less than 10 minutes lower binder factor and increasing when the time of mixing higher than 10 minutes as appeared in Figure (2.7) Terashi et al., (1977). It was suggested that the mixing period of about 10 minutes and the utilization of suitable soil mixer ought to be taken into consideration.

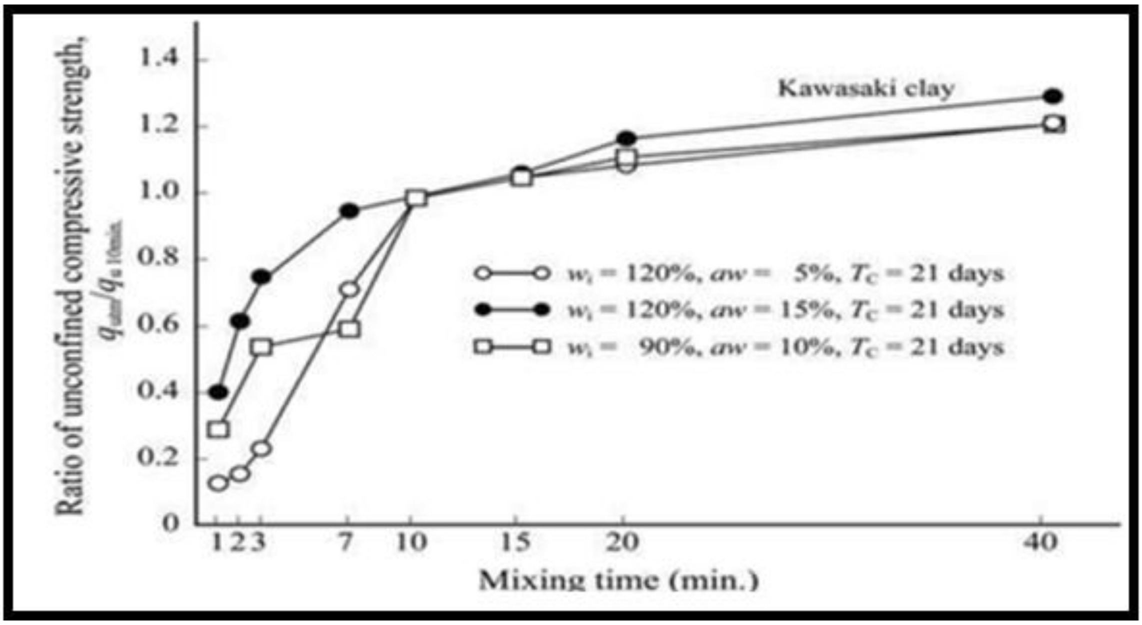


Figure (2.7) effect of mixing tome om unconfined compressive strength, (Terashi et al., 1997)

2.3.5 Effects of binder amount

The increase in cement content leads to increase the unconfined compressive strength of a soft soil. The effects of binder amount on the unconfined compressive strength of lime enhanced soil investigated by Nur et al., (2013). Terashi et al., (1977). As presented in Figure (2.8) Terashi et al., (1977). Two types of marine soils (reclaimed soil and marine clay) with liquid and plastic limits of 92.4% and 46.9%, and 78.8% and of 49.1%, respectively furthermore the moisture content of them

102.5% and 120% respectively have been enhanced and cured for several days. For the reclaimed soil, the UCS increase almost linearly with amount of quicklime, regardless of the period of curing. However, for the marine clay, clear ultimate strength was reached and the binder amount at this strength becomes even greater with a longer curing period. As appeared in Figure 10.0, Terashi et al., (1977).

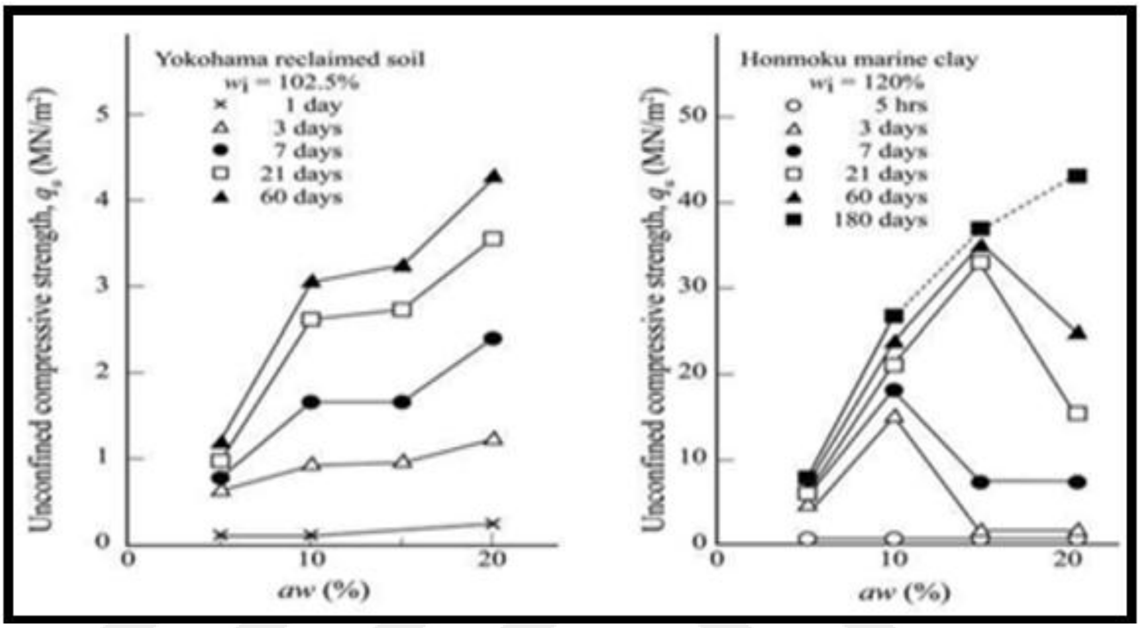


Figure 2.8 Effect of binder amount of strength in quicklime soil enhancement, (Terashi et al., 1997)

2.4 Cement

Cement is the effective material which can use it in soil stabilization. The UCS for the soils stabilized with cement showed increases when increasing the curing time and cement content (aw, dry weight of cement/dry weight of soil) (Bergado et al., 2005; Lade and Overton, 1989; Lorenzo and Bergado, 2004).

Lorenzo and Bergado, (2004) reported this phenomenon by the cement hydration because of the reaction between the ions of calcium with the soil silica and soil alumina this reaction gives pozzolanic materials which bounding the clay minerals and increasing the strength. For the hydration chemical reaction it is accepted that there will be sufficient water. With the continuation of cement hydration and pozzolanic action the soil strength will continue to increase.

Bergado et al., (2005a) investigated with increasing the water content for the specific cement content the UCS of the treated soil will be decreased because of increasing the distance between the soil minerals and minimize the bonding between the minerals due to volumetric increase also consequently decrease the strength of the soil.

Miura et al. (2001) reported the strength of improved soil for 28 days by the following relation:

UCS=A/Bwc/c

Where: USC represent the unconfined compressive strength of improved soil for 28 days, A and B are a constant determined by the type of binder and soil.

Hayashi et al., (2003) reported the strength improvement extends for a long time for the central part of the column and there is a small reduction in strength because of the leaching of Ca ions to the surrounding soil which is causing a small retrogradation.

The cement dosage impacted on the strength of the soil-cement column. In order to investigate that, (Farouk and Shahien, 2013) reported a test on "sh" soil by mixed it with the various cement dosage rate of 160, 200, 240, 340 and 440Kg/m3 using a constant value of the w/c ratio of 1.25. Furthermore, they also reported the influence of the w/c ratio by using a constant cement dosage rate of 240kg/m3 with various w/c ratios of 0.80, 1.00, 1.25 and 1.5. Their result about the influence of cement dosage on the compressive strength were at a high cement dosage the enhanced soil shows a brittle behaviour, but when using a lower cement dosage the behaviour tends to be ductile. Furthermore, they reported that the dosage of cement and the strength of treated soil are correlated exponentially.

2.5 Glass Powder:

Kamali and Ghahremaninezhad, (2015) examined the mechanical strength and durability behavior of cementations materials they use in their study two types of glass powders and fly ash Glass (F) where they performed this materials as cement replacement they reported from this study that cementations materials modified with Glass powder increase the compressive and flexural strengths compared to control concrete (without glass powder) at late ages of curing where the glass powder minimize the alkali-silica reaction expansions of the cementitious materials when mixed with interactive sand and Strengthen the resistance to chloride permeability of cementitious materials farthermore they reported when increase the persentage of glass powder leading to rise the reduction in chloride permeability.

The betterment of the modified cementitious materials with powder glass with the durability and strength due to the pozzolanic property of the glass powder. They concluded from this study that the effectiveness percentage of glass powder is 10% and 20% in suppressing alkali-silica reactivity in cementitious materials.

Borosnyói et al., (2013) investigated that there is an advantage from using the waste glass powder materials as cement replacement by minimizing the quantity of landfill, by decreasing the conception of non-renewable natural sources, by the diminution of cement production and reduce the releasing of greenhouse gases. On cement paste spacemen laboratory experiments were implemented so the addition of waste glass powder was used as cement replacement at level at 20% or 30% per mass.They reported that the workability of the fresh paste is getting better moreover it can be used efficiently as a replacement for cement for compressive strength.It was reported that the glass pwder particle size (specific surface area) has a stronger influence on the effectiveness of the replacement of cement as compared to the chemical composition.They also reported that the compressive strength at level 20% of waste glass powder replaced with cement higher that the compressive strength at level 30 % replacement.

Khimri et al., (2012) investigated the use of crashed waste glass powder obtained from the containers and building demolition as a partial cement replacement in mortar and concrete and the pozzolanic activity of two types of waste glass powder clear one and green coloured for every type examined three ground patrial size at the level 20% as partial replacement of Portland cement. The glass powder obtained in the laboratory by the grinding the glass in jar mill and sieving to the required sizes, where (A1: ranged from 100-80) ,(A2: ranged from 80-40) and (A3: less than 40)

.The pozzolanic activity estimated by mechanical,chemical and physical methods.By physical and chemical methods, it was reported that the calcium silicate formed because of the alkaline hydrolysis due to the reaction of waste glass powder with calcium hydroxide .By mechanical ,it was concluded that the better pozzolanic activity can be obtained when using the finest size of waste glass powder (less than 40) esspecially in the green colour glass. And also investigated that the waste green glass activity as pozzolanic material better than the clear glasses at the same size particles because of the CaO consumption of the green glass higher than the clear one.

Shekhawat and Agarwal, (2014) studied the cement replacement with waste glass powder to utilization of mild glass powder as a cement replacement in concrete. From the works of various scientists and their exploratory works they reported that the glass powder to some limit can be used as a cement replacement in concrete because of it is workability ricing with the strength characteristics. On the other hand, because the using of waste glass powder in concrete reduces the cement consumption, so it is given economy and in addition helping in diminishing problems of disposal.

Vasudevan and Pillay, (2013) studied the properties of concrete containing powder glass replaced with cement to compare with normal concrete. In the concrete the binder containing cement replaced by 10%, 15%and 20% glass powder. Several laboratory tests are performed to determine the performance of these types of concrete such as slump test to determine the workability density and compressive strength test.. The reported results from this research is that the concrete workability increase with the addition of glass powder. During the strength term, the concrete included 20% glass powder replaced with cement in the binder at the 14 days curing time having a strength higher than reference concrete without glass powder. In the 28 days, the compressive strength of the mixes with glass powder is lower than the control mix (without glass powder) knowing that the mixing waste glass powder in concrete gives a positive value although the value compared to control mix it just less about $1N/mm^2$. During the term of density, the concrete with glass powder is lighter than conventional concrete where the average cube density of concrete with more levels of waste glass powder gives the lowest value compared to control cube consequently the concrete mixed with waste glass powder gives light weight concrete. As appeared in Figures (2.9) and (2.10) strengths and densities of concrete with vries replacement ratios of glass powder:

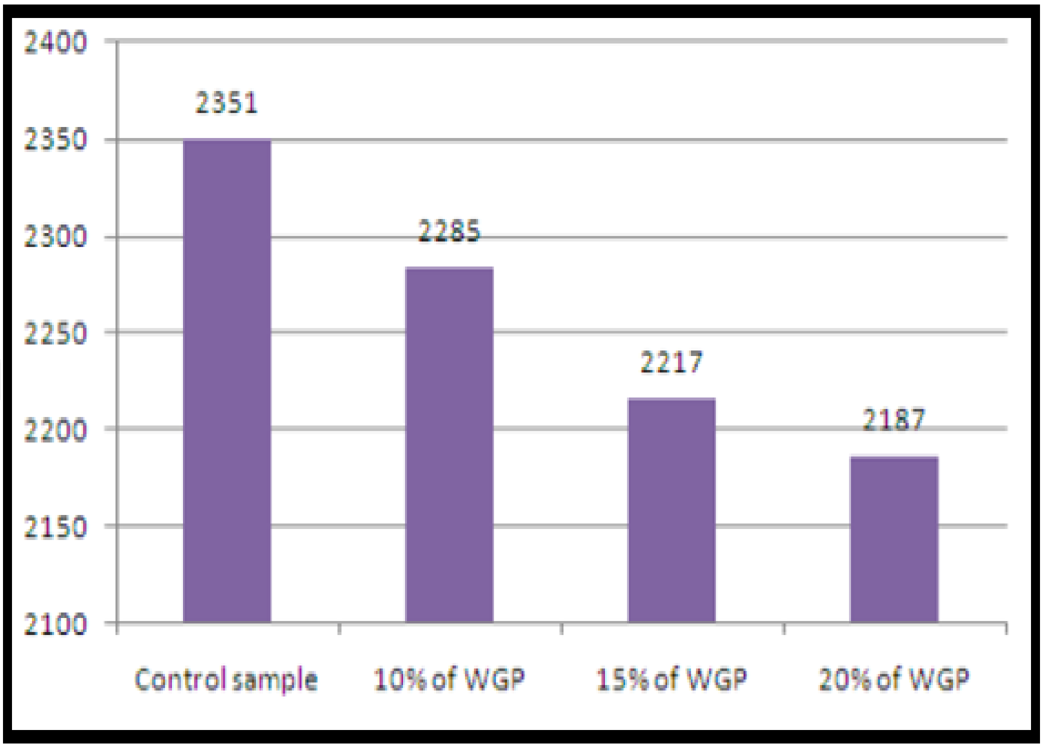


Figure 2.9 Cube density at 28 days

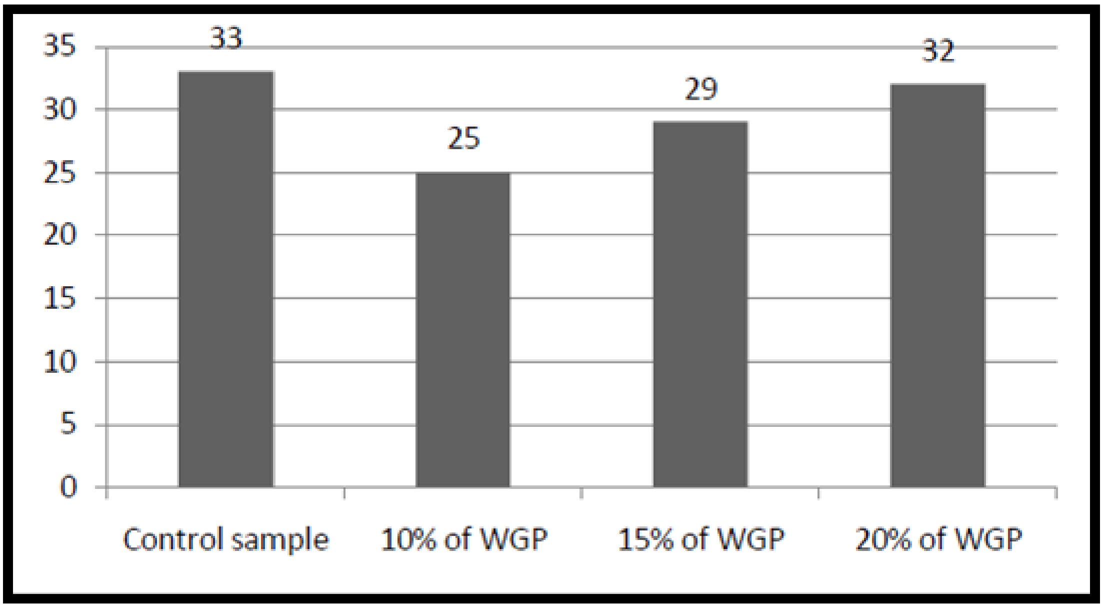


Figure 2.10 Compressive strength at 28 days

Khatib et al., (2012) studied the properties of concrete contained waste glass powders as a partial cement replacement. The (0-40) % of Portland cement was replaced with waste powder glass. Laboratory tests such as compressive strength and UPV were performed. The samples were cured in water at 20 °C. The results indicated from this study that the utilizing milled glass in concrete reduces the use of cement consequently decrease the impact on air pollution and CO2 emission as a result of cement production. Khatib et al., (2012) also concluded that when increasing the addition of glass powder ratio in concrete leads to increase the concrete slump. The maximum compressive strength at 10% glass powder content compared to the control mix, but when increasing the replacement levels of glass powder above 20 % the compressive strength actually decrease as shown in Figure (2.11) The ultrasonic pulse velocity (UPV) for different types of concrete with and without glass powder reduces systematically with increase the percentage of glass powder. It is reported that the lower wave velocity obtained when the 40% of cement replaced with glass powder in a binder. Even at 10% glass powder content the UPV lower than control mix, however, the compressive strength at 10 % glass powder content was higher than the other mixes including the control mix.

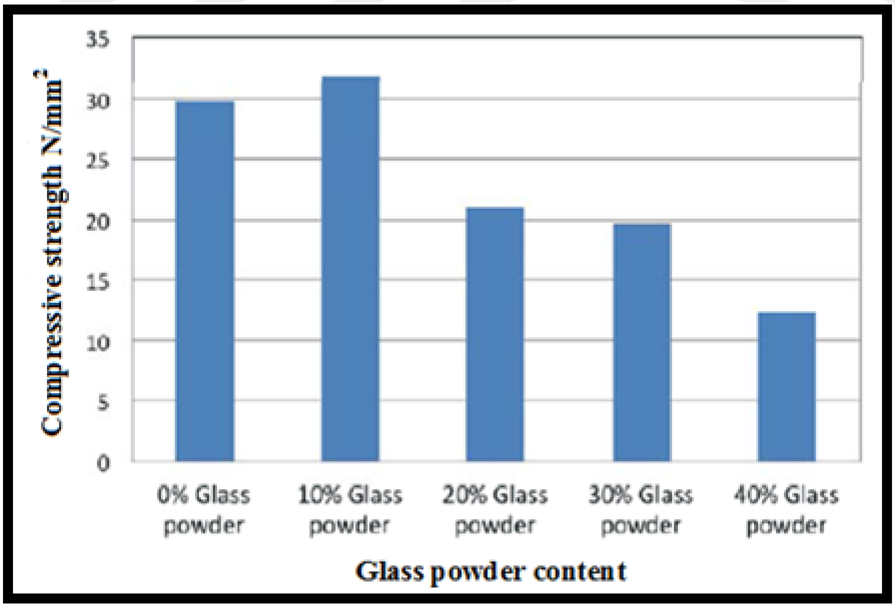


Figure (2.11) Compressive strengths with varies ratios of mild glass at 28 days of curing

Omoniyi et al., (2014) studied the utilizing waste glass powder as a partial substitute for cement in saw dust composite brick in order to estimate its influence on the characteristics of composite and its pozzolanic activity after replaced 0%, 5%, 10%, 15%, 20%, 25%, and 30% of waste glass powder with cement and prepared the samples the test of compressive strength, capillary water absorption, water absorption, and volume porosity were carried out. They concluded from this study that the waste glass powder can be used as a cement replacement up to 30% when the size of the particles less than 100µm as well as the milled waste glass with particle size less than 100 shows a pozzolanic behaviour because of it is a reaction with lime at the early stage of hydration generating extra CSH gel consequently produces a denser cement matrix. The early alkalis utilisation by the particles of glass powder reduce the reaction of alkali-silica by rising durability of composite brick, which is exhibited in the result of volume porosity, water absorption, capillary absorption as well as in the results of sample densities.

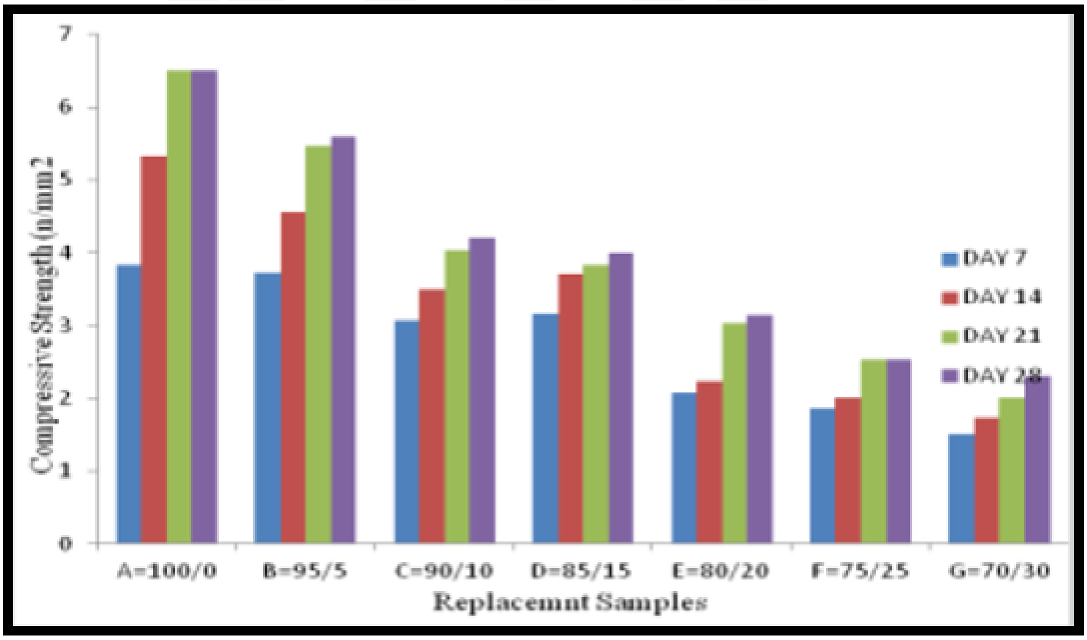


Figure 2.12 Impacts of Curing period on the strength for different ratios of glass powder

Tamanna et al., (2012) Investigated in this study the milled waste glass soda powder as a partial replacement with cement at the replacement levels 0,10,20,30 and 40% to report at which replacement level the highest compressive strength. Furthermore investigated the fineness properties of four sizes for glass partials in the range of 212 µm, 75 µm, 63-38 µm and less than 38 µm using two water cement ratio 0.5 and 0.45. The room tempratue was 32C with humidity 90% During the curing period. The conclusion from this study is the maximum compressive strength can be obtained at replacement level 10% for 28 days compared to the other levels of replacement, but at the same time it is lower than the control mix. The increasing of replacement level leads to decrease the compressive strength. For the particle size less than 38 µm the compressive strength, not only higher than the other replacement levels, but it also shows the same strength of control mix or higher than it at 28 days.

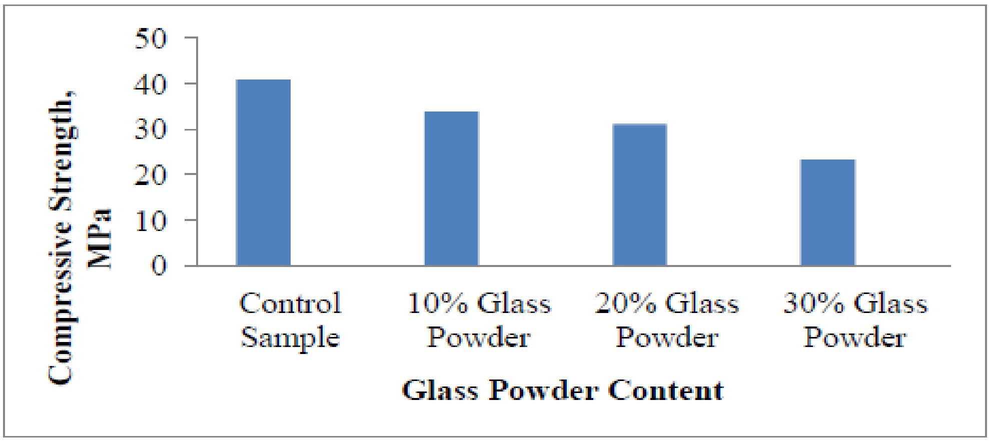


Figure 2.13 The strength in the 28 days curing time for the glass powder size 212 µm GP

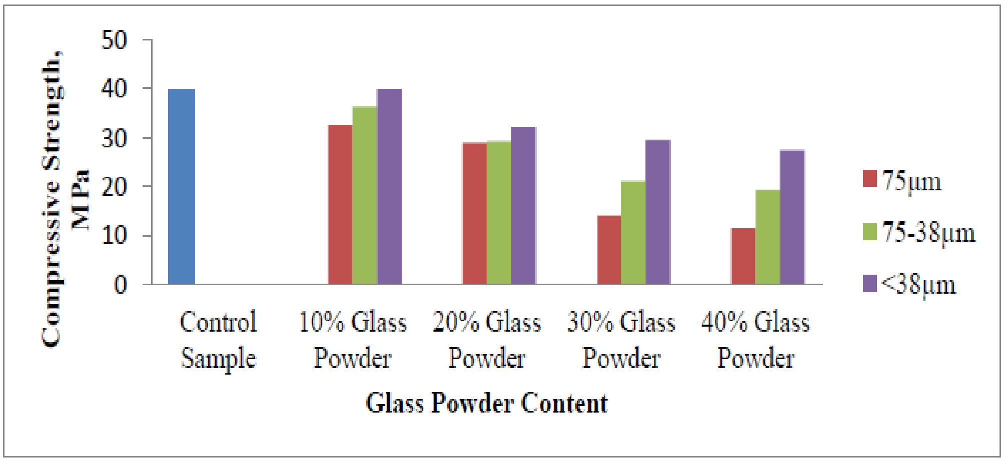


Figure 2.14 The compressive strength of different size particles of glass powder

Canakci et al., (2016) studied the using waste glass soda powder for clay stabilization with particle size 75 μm with various ratios 3, 6, 9, and 12% by dry weight of the clay. The consistency and strength tests were carried out. They concluded that the addition waste glass soda powder into clay can be influenced on the consistency properties and strength of this clay where the waste soda glass powder improve the engineering characteristics of clay clay such as MDD, OMC and atterberg limits. Furthermore the increasing in the proportion of waste soda glass powder in the clay soil leads to rise the value of the CBR. And also concluded the value of unconfined compressive strength of clay was increased when increasing the curing time from 3 to 28 days because of the hydration process between the soil particles and waste soda glass powder is increasing.

CHAPTER 3

This chapter deals with describing the laboratory experiments which concluded the selection of soil, which be used in this research, the type of binders are given too, and the procedure of preparing soil samples for unconfined compressive test (UC) and ultrasonic pulse velocity (UPV).

3.1 Materials And Sample Preparation

3.1.1 Sand

Sand is one of the common materials around us, it is found on beaches, stream banks, deserts other landscapes around the world furthermore, it is a loose granular material that occurs naturally consist of mineral particles. Because of its size larger than silt and smaller than gravel so it is characterized by size . According to this scale the diameter sand particles have ranged from 1/16 to two millimetres, while the particles larger than two millimetres are known as gravel and when they are smaller than 1/16 millimetres called silt. The sand which used in this study was obtained from civil engineering laboratory and it is free from organic and chemical substance with a specific gravity (Gs) 2.667 and particles size larger than 2mm and smaller than 0.15 mm.

3.1.2 Clay

The clay which used in this study taken from Gaziantep university campus. The site is nearby civil Engineering laboratory was extracted by hand; then the clay samples are taken to Geotechnic laboratory. The clay was dried for 24 hours using the oven at temperature 110 C. After drying, to increase the workability of the clay the bulk mass was broken into small particles; then sieved from sieve No. 40 (0.425sieve opening) in

order to mix it with sand samples in Different percentages after performing the standard classification the cleaned clay to know its characteristics (specific gravity and sieve analysis). From the laboratory specific gravity was 2.77 g/cm3.The liquid limit (LL) was 41.13% and the plastic limit was 25.30%. So the plasticity index of the soil was determined to be 15.87%. Then this clay is mixed with sand in different percentage according to mix design to get three samples of sand in different clay content in order to get the artificial sandy soil that needs to improve. The sand to be treated in situ is assumed to have the different clay contents of 20%, 8% and 4%. In accordance with the USCS, the sand deposit, including clay to be treated is respectively classified as: i) SC (clayey sand), ii) SP-SC (poorly graded sand with clay) and iii) SP (poorly graded sand). As regard to the soil used to be treated, the sand (S) included in the soil deposit is the poorly graded sand and the clay (C) is the low plasticity clay in accordance with USCS. Some index and physical properties of soil (sand and clay) have been given in Table 3-1. The particle size distributions of sand and clay has also been illustrated in Fig.3-1.

Table 3.1 Some index and physical properties of soil (sand, clay) used in the study

Property	Sand	Clay
Soil classification (USCS)	SP	CL
Specific gravity, G*S*	2.667	2.77
D10, mm	0.24	-
D30, mm	0.59	-
D60, mm	1.8	-
C*u*	7.5	-
C*c*	0.806	-
Liquid limit (LL)	-	41
Plastic limit (PL)	-	25
Plasticity index (PI)	-	16
Swelling (%)	-	3.58

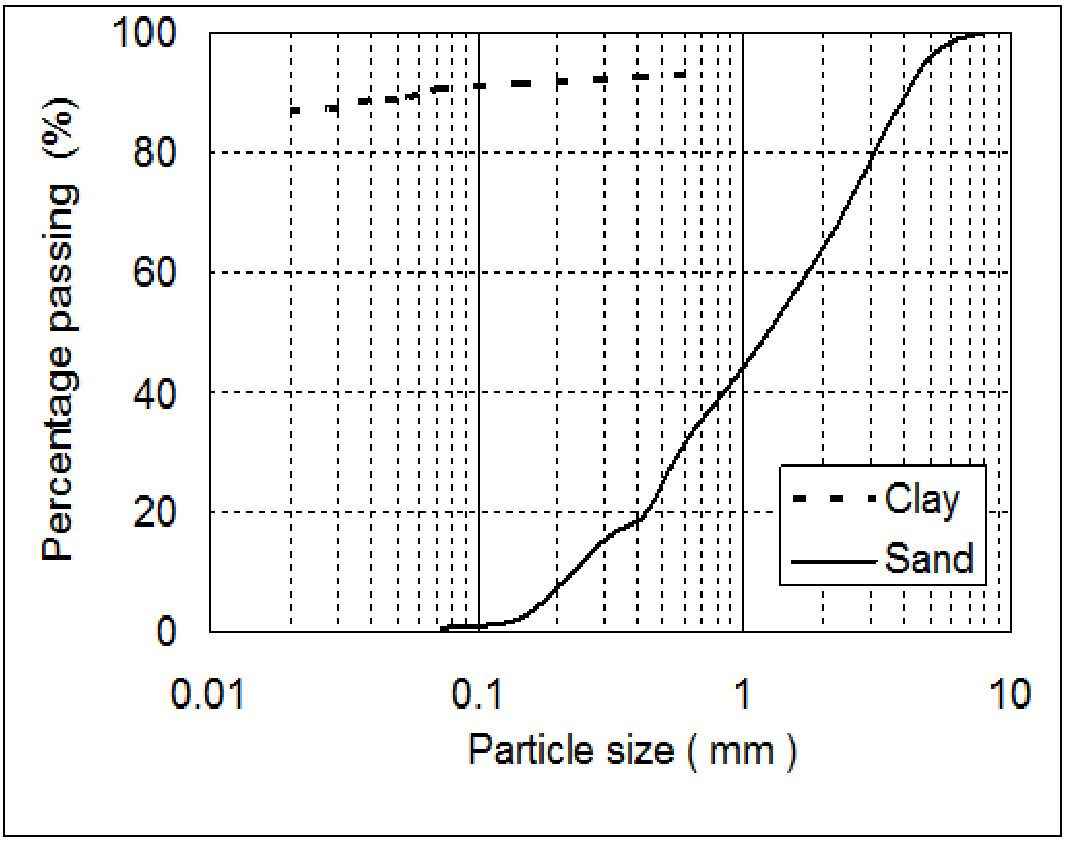


Figure 3.1 Particle size distribution of sand and clay

3.2 Binder Materials

The selection of binder materials was an important step of this study .The materials which used as binder in this research were summarized as follows:

3.2.1 Cement

Ordinary Portland Cement (OPC) was used in this study with specific gravity (3.1), conforming to ASTM C150/ C150 M (2015).The initial setting time 183   minutes, final setting time 210.In the following table the physical and Chemical properties of Portland cement which used in this research

Table 3.2 some chemical and physical properties of cement used in the study

Item	Portland cement
CaO (%)	62.12
SiO2 (%)	19.69
Al2O3 (%)	5.16
Fe2O3 (%)	2.88
MgO (%)	1.17
SO3 (%)	2.63
K2O (%)	0.88
Na2O (%)	0.17
Loss on ignition (%)	2.99
Specific gravity	3.15
Blaine Fineness (m^2/kg)	394

3.2.2 Glass powder

The glass powder used in this research is produced by crashing waste glass green soda bottles to a fine particles by hand using the manual treadmill until reaching to the required size. The waste soda bottles are collected from the bin furthermore all the unwanted materials, like corks, labels are removed. The size particles of the glass powder which used in this study are 150 micrometers with specific gravity (2.52) according to the previous study (Rahman and Nateriya 2015). Table 3.3.

Table 3.3 Some proposed chemical and physical values for the waste soda lime glass powder

Constituent	Value
Silica (SiO_2)	74%
Sodium oxide (Na_2O)	13%
Lime (CaO)	10.50%
Alumina (Al_2O_3)	1.30%
Another components accumulate	1.20%
Density at 20° (g/cm^3)	2.52
Young's modulus at 20° (GPa)	72

Figure 3-2 soda waste glass powder

3.3 Experimental work and mix design

One of the important parameters that has a noteworthy effect on the unconfined compressive strength of deep mix is a clay content ratio. Therefore, in this study different ratio of clay (4,8 and 20) % were used in sand to investigate the effect of waste glass soda powder on the deep mix. Twelve mixtures with water-binder ratio (1.2) were prepared to report the effect of three ratios of waste soda glass powder (3%,6% and 9%) as a cement replacement on the binder which using in the deep mix at the sandy soil with different ratios of clay. As for the grout, the water/binder ratio was employed as 1.2. This is in accordance with the previous study (Esmaeili et al., 2014), where it is reported that among the three w/b ratios (0.8, 1 and 1.3) using for deep mixing the best one is obtained as w/b=1 regarding the performance of unconfined compressive strength. However, While using the w/b=1 for preparing the grout mixtures in this present results in voids in the samples that visually can be seen in the mixture. On the other hand, the water to binder ratio of 1.2 is found to produce the grout to be more homogeneous and workable with less voids. Thus, the water to binder ratio of 1.2 is decided to be appropriate for the study. In concerned with the glass powder addition to the grout, the glass powder as an admixture in the binder (i.e., cement+glass powder) was tested for the proportions 0%, 3%, 6% and 9%, by dry weight of the binder, as shown in in Table (3-4). The decisions of these proportions strongly benefited from the previous studies (Khatib et al. 2012; Canakci et al. 2016). It is found in the previous study (Khatib et al., 2012) that the 10% glass powder addition contributes higher strength than the remaining proportions (20%, 30% and 40%).

The weight of binder to the soil in this present study for all testing is taken as 18.2 % in accordance with the previous suggestion (Faruk and Shahin, 2013), where it is reported that it is better to use the binder less than 20% of the soil in the soil-cement columns for deep mixing. This could be considered as an economical proportion for the cement usage due the ground improvement as well as the strength enhancement.

Table 3.4 Experimental testing program employed in the study

	Grout						Soil			
Mix ID	w/b	Binder (%)		Water quantity, gr	Binder quantity, gr		USCS classification	Clay content (%)	Sand (gr)	Clay (gr)
		PC	GP	w	PC	GP			S	C
M1	1.2	100	0	156	130	0	SC (Clayey sand)	20	571.2	142.8
M2	1.2	97	3	156	126.1	3.9	SC (Clayey sand)	20	571.2	142.8
M3	1.2	94	6	156	122.2	7.8	SC (Clayey sand)	20	571.2	142.8
M4	1.2	91	9	156	118.3	11.7	SC (Clayey sand)	20	571.2	142.8
M5	1.2	100	0	156	130	0	SP-SC (Poorly graded sand with clay)	8	656.88	57.12
M6	1.2	97	3	156	126.1	3.9	SP-SC (Poorly graded sand with clay)	8	656.88	57.12
M7	1.2	94	6	156	122.2	7.8	SP-SC (Poorly graded sand with clay)	8	656.88	57.12
M8	1.2	91	9	156	118.3	11.7	SP-SC (Poorly graded sand with clay)	8	656.88	57.12
M9	1.2	100	0	156	130	0	SP (Poorly graded sand)	4	685.44	28.56
M10	1.2	97	3	156	126.1	3.9	SP (Poorly graded sand)	4	685.44	28.56
M11	1.2	94	6	156	122.2	7.8	SP (Poorly graded sand)	4	685.44	28.56
M12	1.2	91	9	156	118.3	11.7	SP (Poorly graded sand)	4	685.44	28.56

w/b=water/binder, Binder=Cement+Glass powder, PC=Cement, GP=Glass Powder, S=Sand, C=Clay, USCS: Unified Soil Classification System

3.4 Sample Preparation

In order to reach a better understanding of the behaviour of the waste glass soda powder as a replacement material with cement in the DMC a research method was carried out, involving laboratory tests, to estimate the effect of the GP ratio as a binder with cement and comparing it with the control mix in the DMC. Artificial sandy soils with different determined content of clay were utilized, containing 4, 8, and 20 % clay. The procedure given in previous guides (JGS 0821-2000; ASTM D4320/D4320M−09; Bhadriraju et al., 2007) is followed in preparing the sample mixtures in this research. First, the cement, glass powder and water are mixed together for 1 minute to obtain the grout. Then, the grout is added to the sand and clay. After that the grout and soil (sand and clay) are mixed together using a laboratory mixer with 5-L capacity for 10 minutes which shown in Figure 3-4. In order to obtain the sample mixtures to be homogeneous, the mixing velocity is allowed to be 280rpm for the mixtures.. The prepared mixture placed in a cylindrical moulds which made from Plastic material with a height to diameter ratio of 2:1 according to D2166-91 in ASTM (1995) as shown in Figure (3-5) (Diameter: 55 mm, Height: 110 mm). In order to make the extraction of the simple easier the inner of the moulds were lubricated. The prepared mixture was placed in the moulds in the form of three layers. For each layer compaction should be done using a 5-mm rod about 30 times covering the entire surface of the specimen to remove the entrapped air bubbles. After compacting each layer the final layer of the specimen should be leveled in order to avoid the error during the testing of UCS (Tatsuoka and Kohata, 1996). The bleed problem which mostly happening in the initial two hours (Lee et al., 2005) was controlled by tying a cardboard, plastic collars to the top of the mould. Then, to prevent the escaping the water, the moulds with collar were secured by plastic bags. Then the samples are extracted from the moulds after 24 hours and storing in the water bath Figure (3-6) in a control room with temperature control at 20±3°C in a curing time (7,14 and 28) days. The curing times are selected in accordance with the previous work (Hansson et al., 2001) suggested for deep mixing to prepare the samples as shown in Figure (3-6) for the unconfined compressive test and Ultrasonic pulse velocity.

Figure 3.3 The ingredients that used in this study before mixing

Figure 3.4 Electrical mixer that used to mix the ingredients in this study

Figure 3.5 Plastic moulds used and sample preparation

Figure 3.6 The curing of the samples

Figure 3.7 The extracted samples with different content of clay

3.5 Unconfined Compressive Strength Test

In regard to the unconfined compressive strength (UCS) testings of the specimens (for the 7, 14 and 28 curing days), they have been carried out following the procedure given by ASTM D5102−09. The compression machine used for the UCS testings is the mechanical control type with the capacity of 50kN. All the UCS testings have been performed under the constant strain rate of 1%/min. The UCS response is either the maximum axial stress or the stress at 5 % axial strain, whichever occurs first during the performance of testing. From the stress -strain curves of the specimens due to the UCS tests, the elastic modulus of the mix compositions regarding the secant modulus has been estimated. It is reported (Terashi and Kitazume, 2011) that the UCS values could be considered as the key parameter for the quality measurement of deep mixing. Thus, in this present investigation the UCS tests become the main effort of experimental study in order to understand the performances of the sample mixtures for deep mixing.The Figures 3.7 shows the UCS machine and the Figure 3.8 and Figure 3.9 shows the sample during and after the unconfined test.

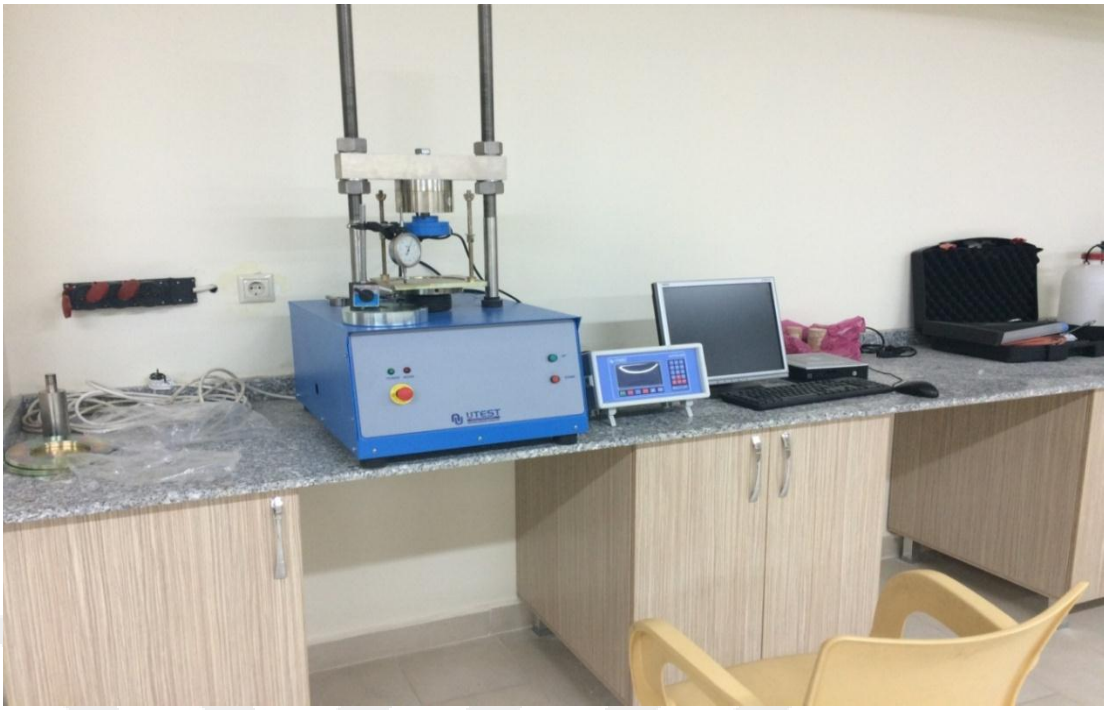


Figure 3.8 the uniaxial compressive strength machine test

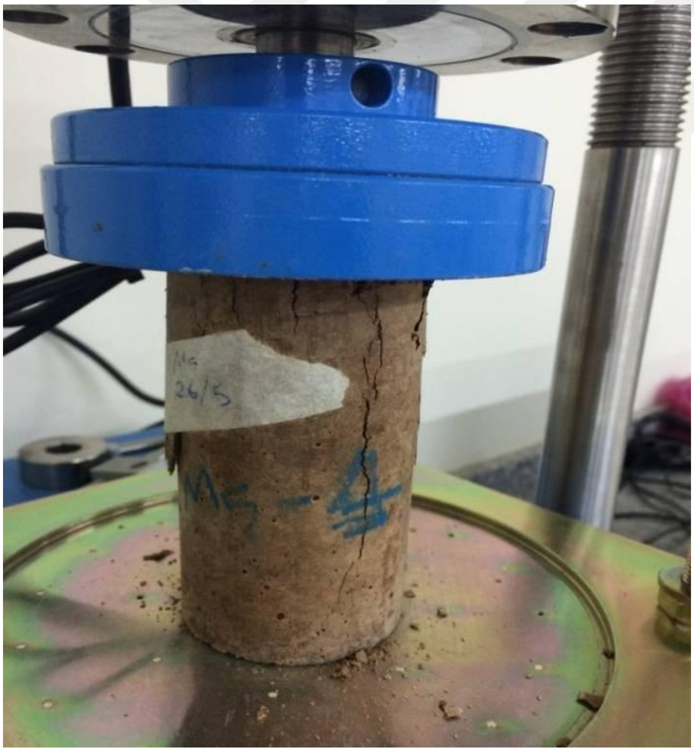


Figure 3.9 The cylinder sample through the testing of unconfined compressive strength

Figure 3.10 Sample after failure

3.6 Ultrasonic Pulse Velocity

UPV according to ASTM C597−16 considered one of the non-destructive test methods to examine the material homogeneity. By utilizing the investigation of the propagation, varieties of ultrasonic pulse velocity, it has helped to check the limit or exhibit heterogeneous regions in the material. The UPV results can be utilized for finding, visualization and quality control. The principle of this technique depends on the spread of a high frequency sound wave that pass through the material (Lorenzi et al., 2007). The wave speed depends on the function of the material density, permitting the estimation of the porosity and the discovery of discontinuities. The thought is to extend the sound inside a material and determine the time important for the wave to propagate through it. Since the distance is known then it is possible to estimate the average pulse velocity, which will rely upon a few variables, for example, the presence of water in the pores and the nature of the material (Lorenzi et al., 2007). The technique is ordinarily depends on the use of portable devices, formed by the source/locator unit and the surface transducers, which works in the frequency scope of 25 to 60 kHz (Popovics, 1998).

The tests start when ultrasonic pulse is created and transmitted for an electro-acoustic transducer, set in contact with the surface of the material. After passing the specimen the vibrations are received and converted by the electro-acoustic transducer. Then, the spent time of the wave between the input and output is determined with an accuracy of at least 0,1 μs (Neville et al., 1997). The fundamental thought is to investigate the way that ultrasonic speed waves are the density of the material function and that they are corresponded with the compressive strength. The relation is not generally reliable once there are a considerable measure of factors that influence on the strength of the cylinder of the DMC sample, for example, the water/binder ratio, the size and type of the soil, the moulding methodology, the sample size and the type of cement. UPV estimation is normally performed utilizing a couple of transducers in contact with the sample through a coupling medium. Piezoelectric transducers are utilized for producing ultrasonic waves. Ultrasonic waves are produced by energizing the piezoelectric component in one transducer by an electrical voltage signal in the shape of a spike, which causes it to vibrate at its resonant frequency. The time of flight is defined as that the time takes for the ultrasonic wave to propagate to the getting transducer is measured (Yaman et al,. 2001) . From the distance of the transducers and the flight time the UPV is evaluated.

There are two methods for making Ultrasonic estimation (IS 13311,1992) :

1) By direct Transmission 2) By Propagation along the surface

Where the way that used in this study was direct transmission. This test is based on the velocity of the of sound in a solid material, V is a function of the square root of the ratio of E and its density (d).

$$V = f(\frac{gE}{d})^{1/2}$$

g= acceleration due to gravity, m/sec^2

The time of the waves takes to pass through the cylinder sample recorded in order to find the velocity from the equation: V=L/T and after determining the velocity it is possible to obtain the cylinder of DSM specimen quality, uniformity, strength. The apparatus of UPV consists of transducers, i.e. receiver and transmitter with frequency 54 kHz (Rao et al., 2016). The Figure (3-10) shows the apparatus of UPV that used in this study.. The ultrasonic pulse velocity test is carried out on the samples at (7,14 and 28) days in accordance with ASTM C597-16. A PROCEQ type apparatus having the ability wide range of transducers from 24 kHz to 500kHz is used for UPV testing. The tests start when ultrasonic pulse is created and transmitted for an electro-acoustic transducer, set in contact with the surface of the material.

Figure 3.11 Taking UPV for the cylindrical DMC samples

3.7 Vicat Test

It is a test that used to find the consistency, initial and final setting time of paste in accordance with ASTM C191-04b. The apparatus of Vicat consists of frame as shown in the figure (3-11) which contain a movable rod with weight 300gm. In order to prepare the paste at the first the normal consistency test was carried out to find out the measure of water to be added to cement or cement with glass powder. Vicat apparatus consists of a plunger used to estimate the normal consistency of paste with a 10mm diameter with another two needles the first one using to measure the initial setting time with a diameter 1mm furthermore the length of this needle shall be not less than 50mm and the second one using to estimate the final setting time. The specimen that put under the needle shall be leveled plane and at an angle perpendicular to the rod. These needles are designed to fall freely into a mould filled with the paste and the amount of penetration of needles into the mould can be noted utilizing the vertical graduations from 0 mm to 50 mm.

3.7.1 Consistency test

To find the normal consistency of cement a dry sample have been taken about 400gm then mixing with about 25% of water by weight.The formed paste should be placed in the Vicat's mould and leveled. The 10 mm diameter plunger is used for estimating the normal consistency by fixed to the arrangement until touch the top surface of the paste. Then the needle should have freely fall to know the amount of penetration. Arguably the paste is in normal consistency when the range of vertical graduation is ranging from 5mm to 7 mm. Generally the water that required for normal consistency is about 30%.

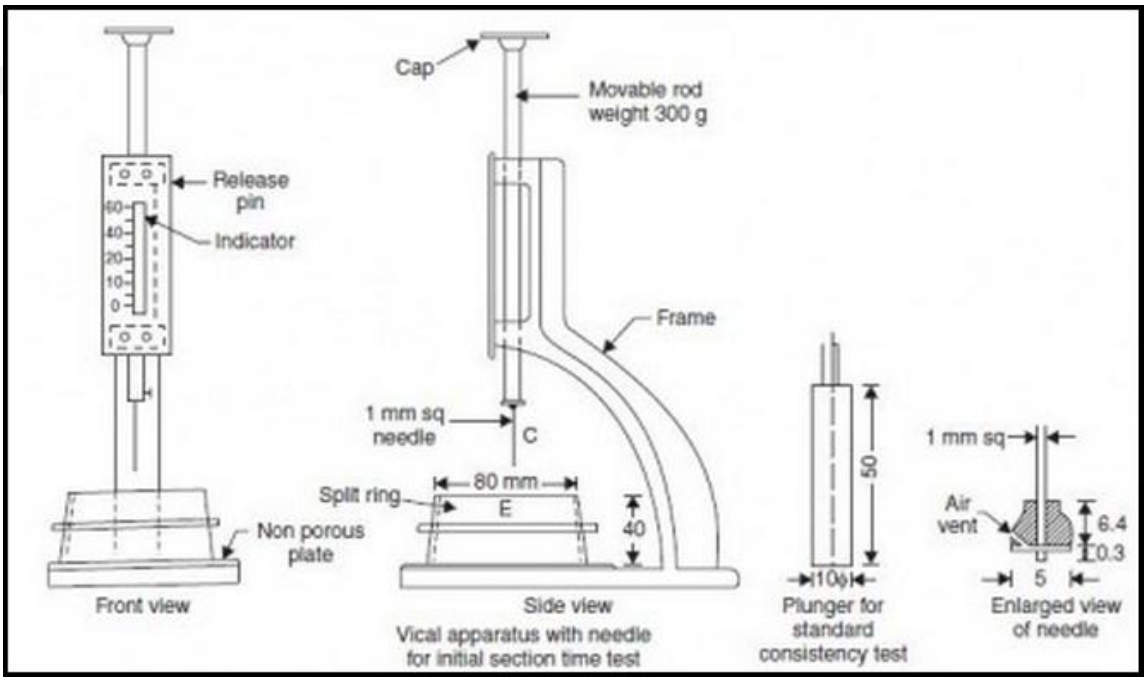


Figure 3.12 Vicat apparatus

3.7.2 Initial setting time

It is defined as the time required by the cement for its early setting. Before reaching the initial setting time of cement, the cement paste should be applied in the place of its use so it is important to measure the initial setting time of cement. For this purpose a 1mm needle was used which fixed on the movable rod in Vicat apparatus. After making the needle of initial setting time at the top surface of the cement paste which placed in the mould and touching it. The cement paste reaches to its initial setting time when the needle of initial setting time of Vicat apparatus becomes 5 mm above the bottom of the plate or mould. Generally the initial setting time for cement should not less than 45 minutes.

3.7.3 Final setting time

To estimate the final setting time the third needle of Vicat apparatus is used which is consist of 5 mm hollow cylindrical base expanded. Final setting time It is the time period that started with the addition of water to dry cement until emergence the mark of the needle without the emergence of the metallic hollow cylindrical part that combined around the needle.

Figure 3.13 appeared the needles of Vicat apparatus

Where (A) used to estimate the normal consistency, (B and C) are used to estimate the initial and final setting time respectively.

In this study, After estimating the initial and final of Portland cement, the cement will replace with 3%,6% and 9% of waste glass soda powder in order to study the effect of waste glass soda powder on the initial and final setting time.

Figure 3.14 Appeared the preparation of cement mixed with soda waste glass powder for Vicat test

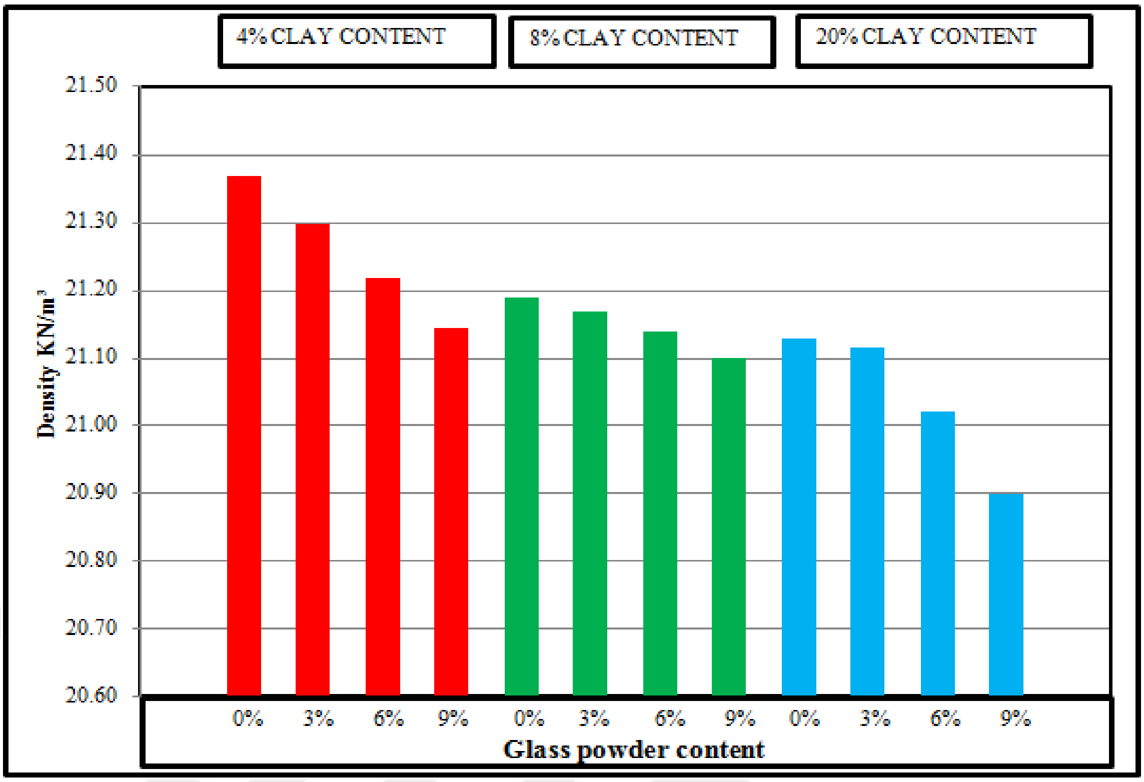
Figure 3.15 The Vicat apparatus that used in this study during the test process

CHAPTER 4

THE RESULT OF TESTS AND DISCSSION

4.1 Bulk Density

As for the bulk densities obtained by the averages of 7, 14 and 28-day curing time (Figure 4.1), it is appeared that there is no significant change in the bulk density due to the glass powder addition as well as the clay content of sand. On the other hand, it was found in the past study (Carasca, 2016) that the density significantly decreases with the increased clay content. As a replacement of cement in the concrete technology, it is found (Vasudevan and Pillay, 2013) that increase in the addition of glass powder leads to decrease the density of samples. The differences in the bulk density compared to the past works could be attributed to the mix proportions employed in this present study. However, it should be emphasized that since the magnitudes of bulk densities do not significantly change compared to the native cement (i.e., 0% glass powder) in this study, they could be assessed as favourable for the strength considerations.



The Figure 4.1 Shows the effect of clay content and waste soda glass powder content in the binder on the density of the specimens

4.2 Effect Of Glass Powder On Initial Setting Time And Final Setting Time Of Cement

The initial setting time for the cement without replacing with soda waste glass powder was 183 minutes and final setting time was 210 minutes. The replacing 3% of cement with waste soda glass powder leads to increase the initial setting time to 202 minutes and final setting time to 203 minutes compared to the initial and final setting of cement (without glass powder) and when the ratio of glass powder as a replacement with cement increased to 6% the initial and final setting was increased to 223 and 251 respectively. Furthermore, when continues to increase the replacement ratio to 9% the initial and final setting continues to increase to 275 and 240 respectively. So the addtion of glass powder to the cement leads to increase the initial and final setting time of this cement as shown in Figure (4.2) and when increasing the ratio of glass powder the initial and final will be increase that maybe because of the particle of soda waste glass powder is larger than the particles of cement so they need more time for initial and final setting furthermore the workability of mix with glass powder is better than the workability of mix without glass powder (Borosnyol et al., 2013)

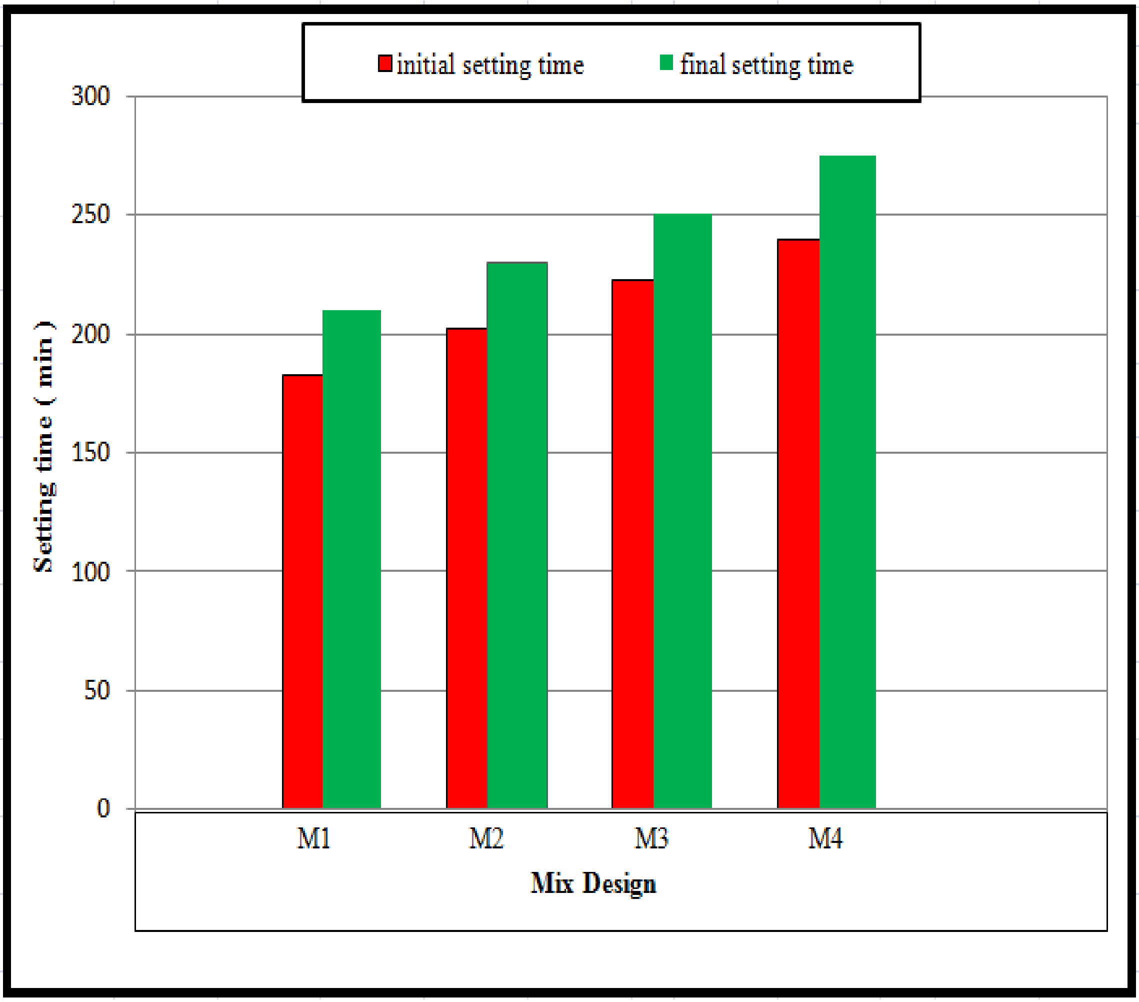


Figure 4.2 Shows the relation between the ratio of glass powder content and initial and final setting time

4.3 Unconfined Compressive Strength (UCS) results

The Unconfined Compressive Strength for the curing time period 7,14 and 28 days of cylinder samples that containing sandy soil with different content of clay ratios (4%, 8% and 20%) mixing with cement replaced with 3%, 6% and 9% soda waste glass powder was expected by mass with a w/b ratio (1.2) concluded from the experimental and previous studies in the literature review (Esmaeili et al., 2014) are shown in Figure (4.3).

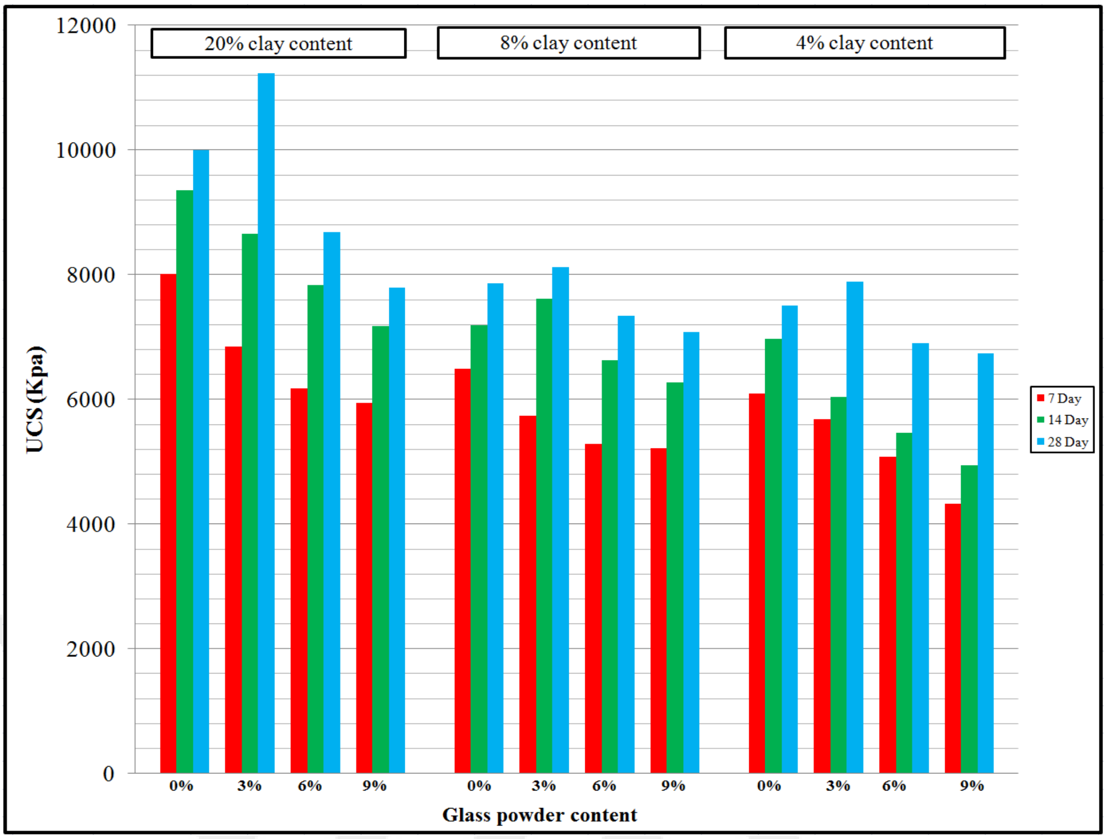


Figure 4.3 Unconfined compressive strength for the specimens at the curing time (7,14 and 28) days at different content of clay (4,8 and 20)%

4.4 Effect Of Clay Content On Unconfined Compressive Strength

On the effect of clay content to the UCS performances of soilcrete samples (Figure 4.3), it can be generally said that the UCS performances increase with the increased clay content up to the limited rate (i.e., 20% in this study). It is found from the results that the 20% clay content (i.e., the soil classification of SC) produces the best UCS performances for deep mixing. On the other hand, the UCS performances of soilcrete samples decrease, when the clay content is reduced to 8% (i.e., SP-SC) and 4% (SP). In conclusion, the poorly graded soil with clay (i.e., SC) appears to be more favourable for attempting via deep mixing. Here, it is important to note that beyond 20% of clay in the sand for the developed experimental program in this study, the strength could decrease and be problematic for deep mixing. The increase in the strength due to the rise of clay content (but up to the limited rate of 20% in this study) may be attributed to the contributions of cohesion and friction in both developed between the solid particles of soilcrete samples (Coduto, 1999; Holtz et al., 2011; Dafalla, 2013). This increase could also be explained in the physicochemical viewpoint. When the clay content increases in the sand+clay mixtures for the given water content, the pore sizes between the particles decrease that results in increase the ratio of bound water (i.e., water associated with the molecular and electrical forces surrounding the clay particles) to unbound water (i.e., the water between the particles and located outside the limits of bound water). Since the strength is related to the forces that bind the water to the clay particles, it proportionally increases with the increased relative bound water (Trask and Close, 1957). As reviewed in the previous studies (Szymkiewicz, 2011; Carasca, 2016; Helson et al., 2017), the sand deposits including up to the limited amount of clay content (i.e., 10% by Carasca, 2016; 15% clay by Helson et al., 2017; 25% by Szymkiewicz, 2011) present better strength improved by different cement dosages. From this it can be said that the strength range obtained better due the clay content in this study (i.e., 20%) for deep mixing appears within the ranges proposed by the past studies.

4.5 Effect of Soda Waste Glass Powder on Unconfined Compressive Strength

The addition 3% of waste glass soda powder in the binder for the specimen samples when the content of clay was 20% in the sand leads to increase the UCS 11% more than the control samples for the 28 days curing time period, but it leads to lower values of UCS for the 7and 14 days curing time about 14.58% and 7.48% in compression to the control samples (without glass powder). The Figures (4.4) and (4.5) explain the results of UCS for the specimens at varying ratios of glass powder content and at 7,14 and 28 day curing period. As it is clearly shown in the Figure (4.4) when increasing the amount of waste glass soda powder to 6% and 9% in the binder as a replacement ratio with cement leading to reduce the values of UCS at all the curing periods for the samples comparison to the control samples.Since for the specimens, which consists of sand with content of clay 20% mixed with cement-soda waste glass powder, the addition 6% of glass powder in the binder with cement leads to reduce compressive strength of soilcrete about 13% lower than reference samples furthermore when the replacement ratio to increased to 9% the reduce in compressive strength of samples increased to 22% comparing with the control mix were similar to the same studies about concrete in litrature review which reported that the addition a limited ratio of glass powder to the binder can be increase the compressive strength, but when increasing the ratio of waste soda glass powder in the binder as a replacement with cement more than the limited ratio leads to decreasing the compressive strength (Khatib et al., 2012).

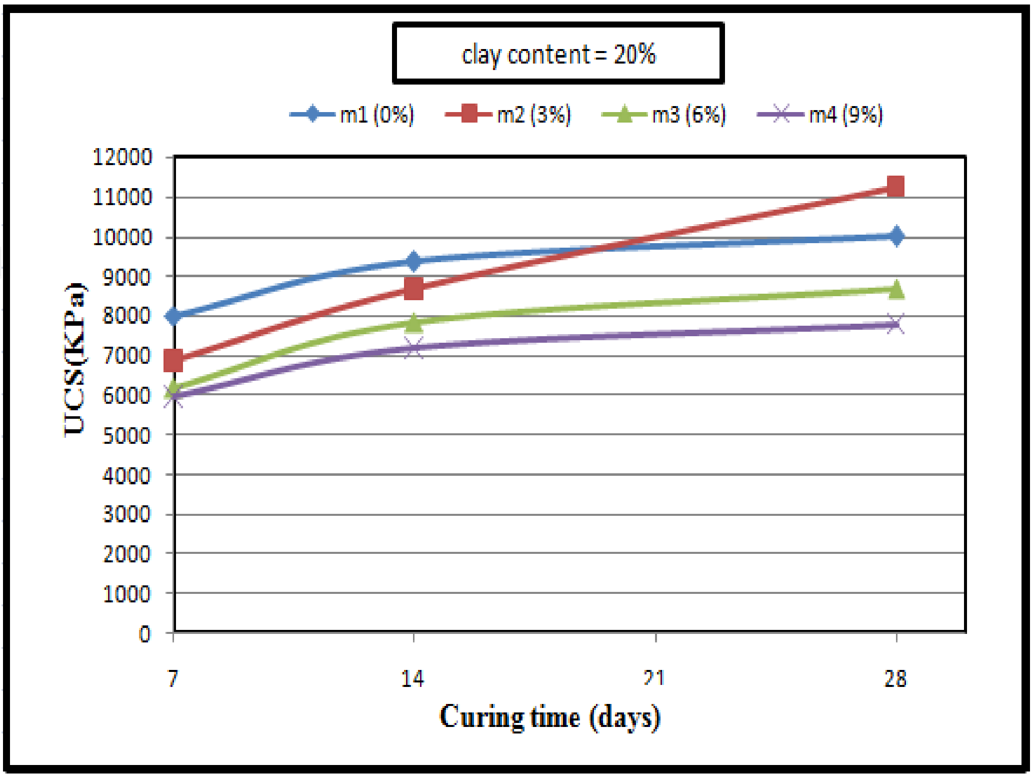


Figure 4.4 UCS results at the 3%, 6% and 9% glass powder in the binder that replaced with cement at the 7,14 and 28 days curing time when the content of clay is 20% in the sand for specimens

When the content of clay was 8% in the artificial sand simple The greater value of unconfined compression in the age 7 days curing period at the control mix and the value of UCS was decreased to 11.54% when replaced the cement with 3% glass powder and it is continuous to decrease to 18.44% and 19.5% when increasing the replacement ratios to 6% and 9% respectively. But at the ages 14 and 28 days the better value of unconfined compression of the replacement ratio 3% glass powder where it is in the 14 and 28 days was 5.6% and 3.3% greater than reference samples respectively. But the increasing of the replacement ratio to 6% and 9%, respectively reducing the UCS values comparing with the reference samples at all curing times as shown in Figure (4.5)

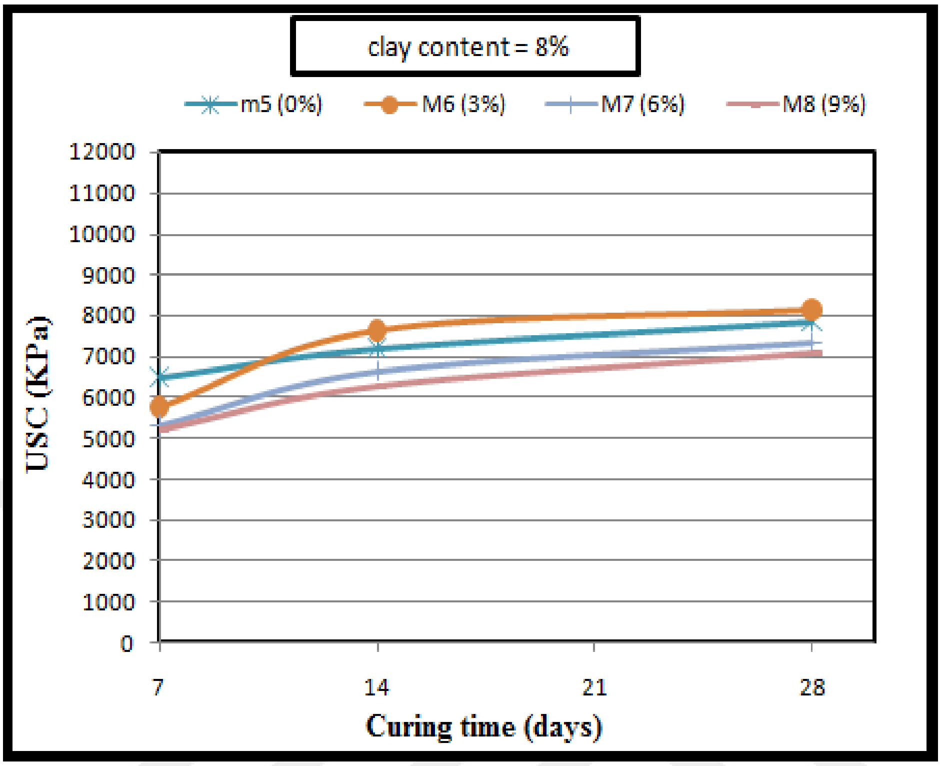


Figure 4.5 Explain the influence of curing time on the UCS in the sand simple for 8% clay content with different replacement ratios of glass powder

When the clay content is 4 % in the sand, the better value of UCS of the control samples of the 7and14days curing period, but in the 28 days the better value of UCS can be obtained when 3% of cement was replaced with soda waste glass powder where it was 5% better than control mix, but also when increasing the ratio of glass powder in the binder to 6% and 9% causing reduction in the UCS about 7.88% and 8.34% respectively at 28 days curing period as clearly shown in Figure (4.6).

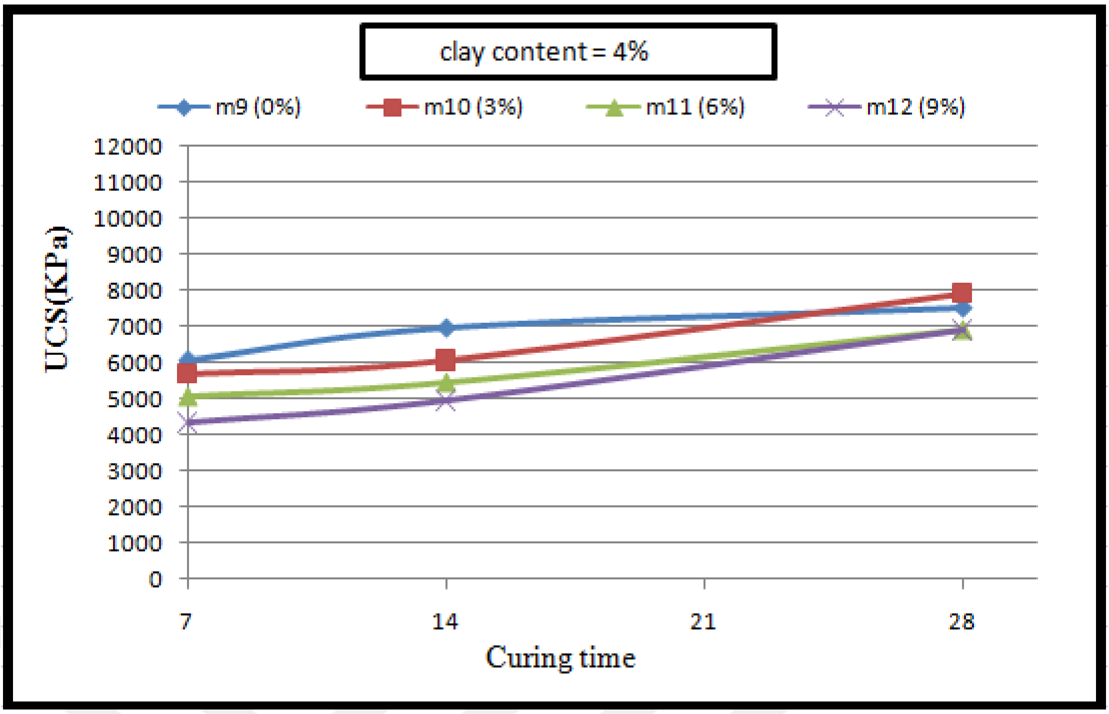


Figure (4.6) explain the influence of curing time on the UCS in the sand simple for 4% clay content with different replacement ratios of glass powder

4.6 Secant Elastic Modulus

The elastic modulus for 7,14 and 28 days curing time of sandy soil samples with different content of clay (20%, 8% and 4%) which their binders consist of cement replaced with 3%, 6 and 9% soda waste glass powder are appearing in Figure (4.7). The values of secant elastic modulus were estimated from the stress-strain curves which obtained from the UCS tests for the samples. As explained in the Figure (4.7) when the clay content in the sandy soil specimens 20%.(i.e., the poorly graded soil with clay inclusion, SC) and the replacement ratio of glass powder with cement was 3% in the binder the higher value of the secant elastic modulus (710 MPa) can be obtained in the 28 days curing time. While the lowest value of elastic modulus (322 MPa) can be obtained in the 7 days curing time in the specimen of sandy soil with 4% clay content and with the 9% addition of glass powder as a cement replacement in the binder.

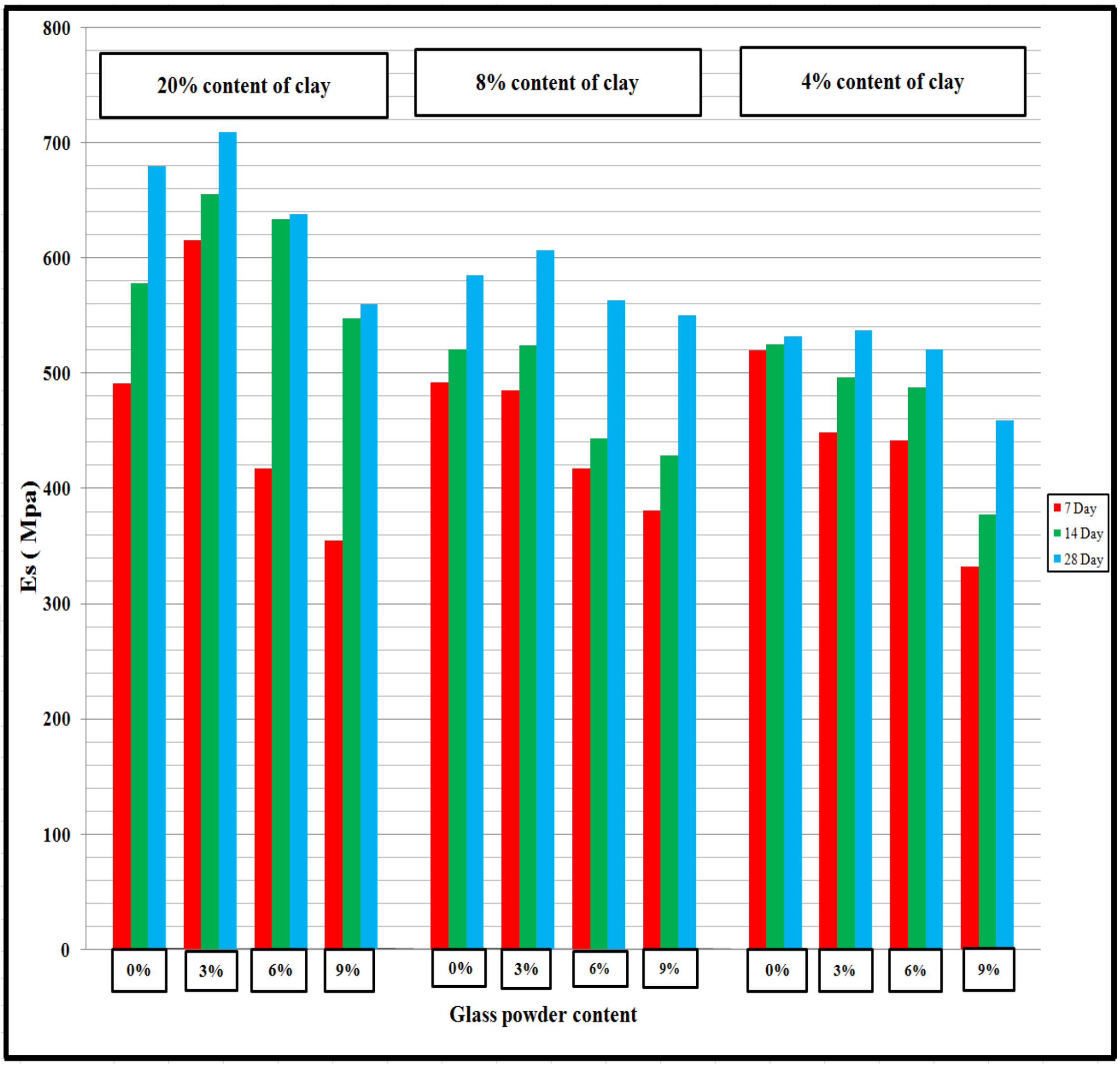


Figure 4.7 The elastic modulus results at the curing time (7,14 and 28 days) for the specimen with different content of clay (20%,8% and 4%) at the different replacement ratio of glass powder with cement.On the other hand, of influence of glass powder on the binder, as clearly shown in the Figures 4.8,Figure 4.9 and Figure 4.10, for all specimens with different content of clay the higher values of the secant elastic modulus can be observed at the 3% of cement in the binder replaced with soda waste glass powder as well as the increasing the replacement ratio to 6% and 9% leads to reduce the value of elastic modulus.

As shown in the Figure 4.8, Figure 4.9 and Figure 4.10 the increasing in the curing time leads to increase the elastic modulus of the specimens

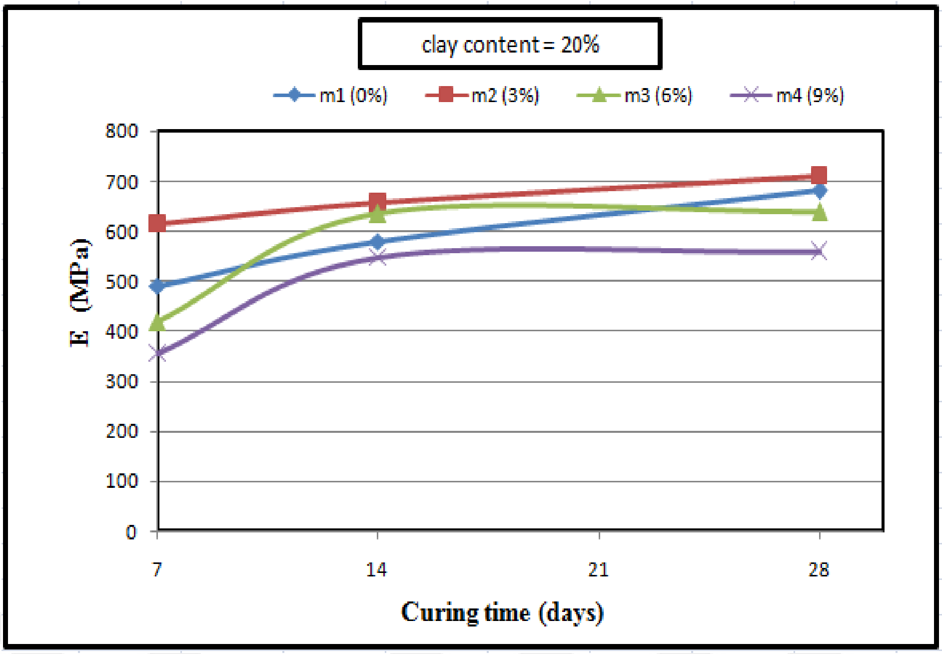


Figure 4.8 The relation between the curing time and elastic modulus with varying ratios of glass powder replaced with cement for the specimen of sandy soil with clay content 20%

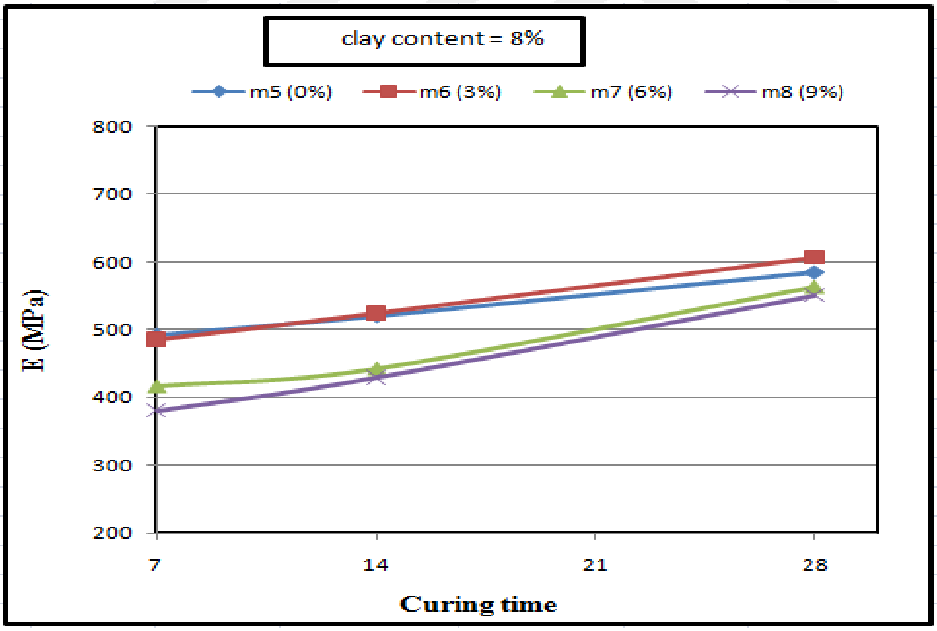


Figure 4.9 The relation between the curing time and elastic modulus with varying ratios of glass powder replaced with cement for the specimen of sandy soil with clay content 8%

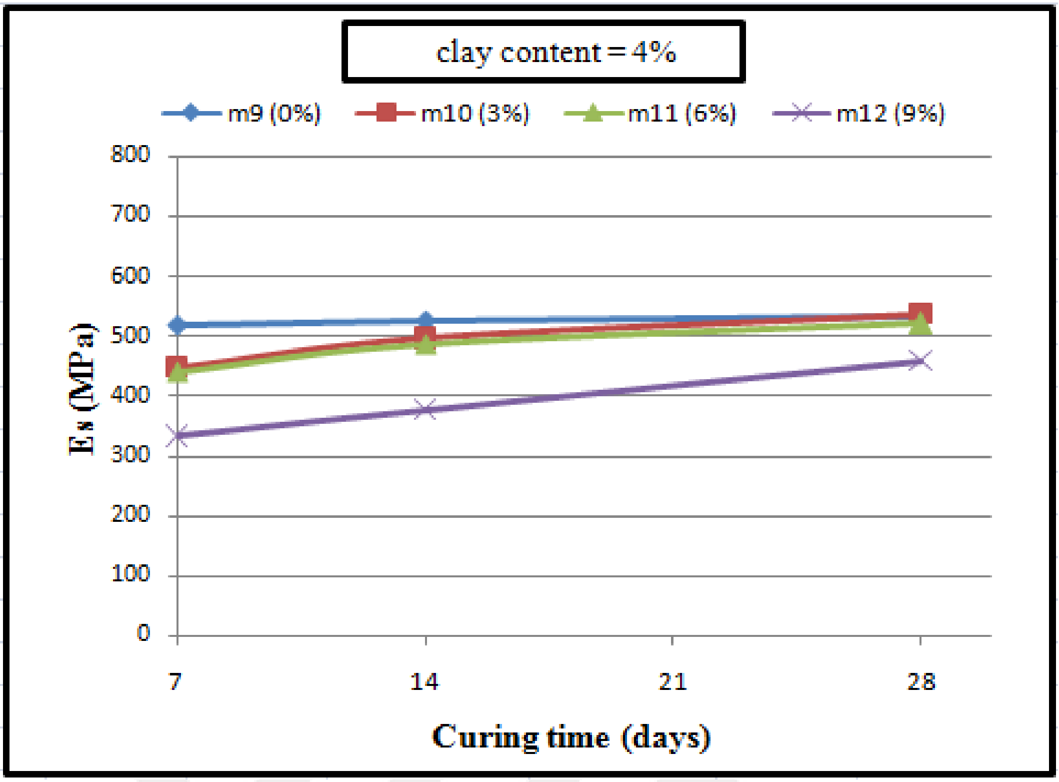


Figure 4.10 The relation between the curing time and elastic modulus with varying ratios of glass powder replaced with cement for the specimen of sandy soil with clay content 4%

As concerned with the elastic modulus (Es) of soilcrete samples Figure (4.7), it is estimated that the Es of the tested samples are able to perform the responses in the range nearly from 300MPa to 700Mpa. The obtained range for deep mixing in this study appears in agreement with the past studies (Farouk and Shahien, 2013; Esmaeili et al. 2014), in which the elastic modulus is nearly estimated between 200MPa-700MPa for silty sand soils with different cement dosages (Farouk and Shahien, 2013) From the range obtained here it can be interpreted that the estimated Es of soilcrete samples indicate a relatively good stiffness for the soil-cement columns to improve the loose sand.

As for the correlations of Es versus UCS for the soilcrete samples Figure (4.11), it is observed that the Es performances increase with the increased UCS values resulting in varied level of correlations. It is illustrated in Figure (4.11) that majority of Es versus UCS responses (i.e., 20% clay content of 28-day, 8% clay content of 7, 14 and 28-day, 4% clay content of 14-day and 7-day) yield to well correlation peformances in the strong level of correlation coefficients (R≥83). In the remaining ones (i.e., 20% clay content of 7 and 14-day, 4% clay content of 28-day), it can be said that there still exit some correlations between Es and UCS (0.29≤R≤0.72), where the low performance is obtained by the 20% clay content of sand at 14-day curing time. The low correlation performance could be attributed to the stress-strain response estimated for Es. However, it needs a future study recommended for the confirmation due to the effect of curing time. From the correlations of Es versus UCS Figure (4.11), in conclusion, it can be said that the Es values mostly correlate with the UCS values. This could provide the engineer in practice to more understand the factors (i.e., curing time, clay content, glass powder addition) that affect the strength and stiffness responses of the soil-cement columns via deep mixing.

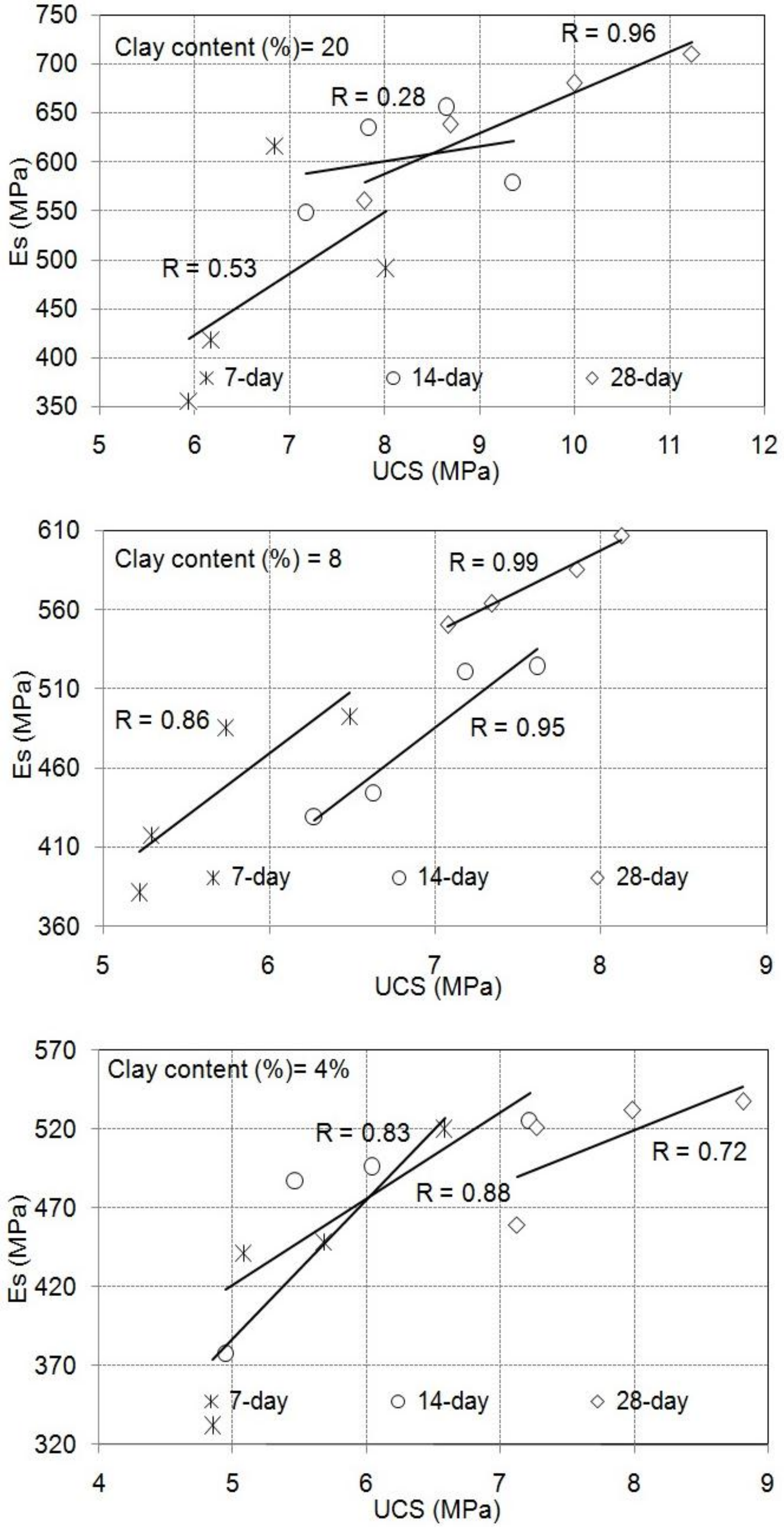


Figure 4.11 The relation between secant modulus and UCS for the specimen of sandy soil for different content of clay

4.7 Ultrasonic Pulse Velocity

The Ultrasonic pulse velocity for the different sample mixes with and without glass powder for the different content of clay was appeared in the Figure (4.12) The pattern is not like the UCS where the best UPV was in the sample with clay content 4%. However, the highest unconfined compressive strength was in the samples with 20% content of clay. At the term of glass powder content, the maximum value of UPV Can be obtained when 3% of cement in the binder replaced with waste soda glass powder if compared with control samples for 28 days age with different content of clay in sand samples.

As explained in Figures (4.13) the effect of glass powder content and curing time on the ultrasonic pulse velocity at the 20% content of clay the highest reading of ultrasonic pulse velocity was at the samples with 3% of cement replaced with waste glass soda powder in the binder at 28 days curing time comparing with the control samples (without soda waste glass powder) although it cannot be considered significant difference where it is about 0.8 % more than reference samples.

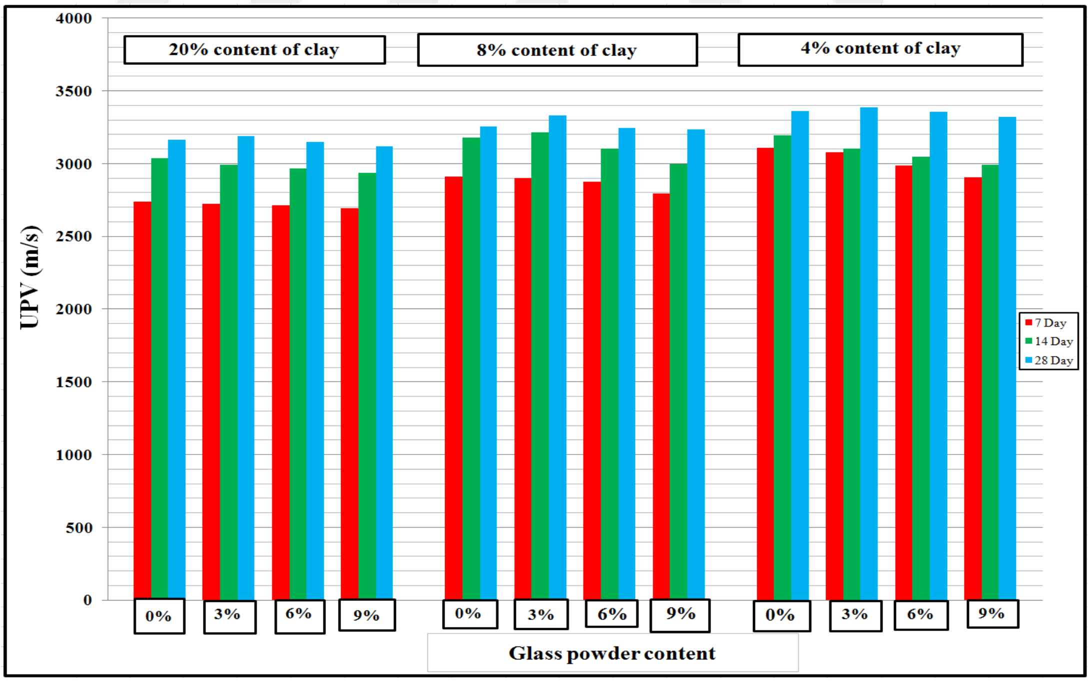


Figure 4.12 Explain the effect of clay contents and curing period on the UPV for different glass powder ratios

But at the 7and 14 days curing time the velocity of the wave of ultrasonic pulse velocity of the control samples was higher than the samples that contain 3% of waste soda glass powder as a cement replacement in the binder.

The increasing the replacement ratio of soda waste glass powder as a cement replacement in the binder to 6% and 9% leads to decrease the wave velocity of ultrasonic pulse velocity advice for all the curing periods. Where at the 28 days curing time the velocity of the wave reduced to 0.547% and 1.42%, respectively compared with the reference samples.

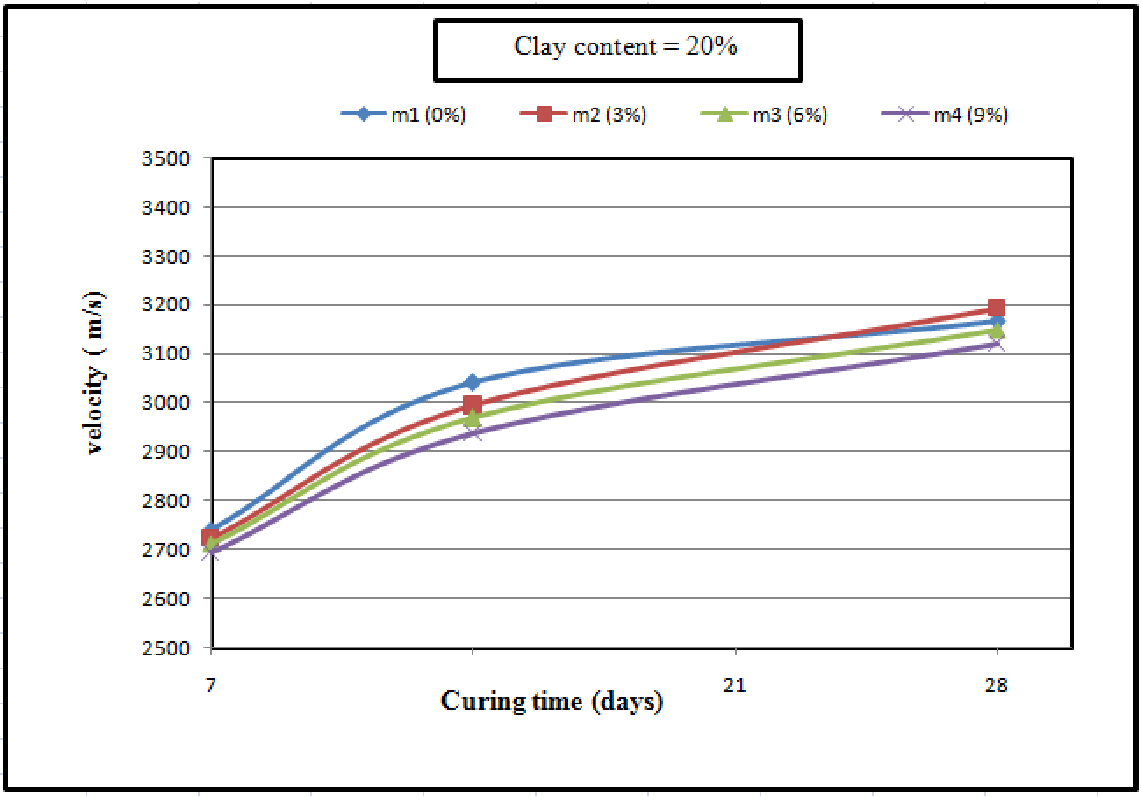


Figure 4.13 Explained the effect of curing time on ultrasonic pulse velocity when the content of clay was 20% in the sandy soil specimens for various content of glass powder replaced with cement in the binder

When the clay content in the sand was 8% at the age 7 days the higher speed of the wave at the control samples and the addition 3% of waste soda glass powder to the binder leads to reduce the speed of the wave to 0.343% comparing with the control simples but at 14 and 28 day the speed of the wave was about 1% and 2.31% respectively higher than the reference samples.Furthermore the increasing of replacement ratio of waste glass powder with cement in the binder to 6% and 9% respectively leads to reduce the velocity to 0.327% and 0.67% respectively comparing with the control references.The Figure (4.14) show the soilcerte samples with content of clay 8% in the sand with different content of soda waste glass powder on the speed of the wave of ultrasonic pulse velocity at (7,14 and 28) days curing time.

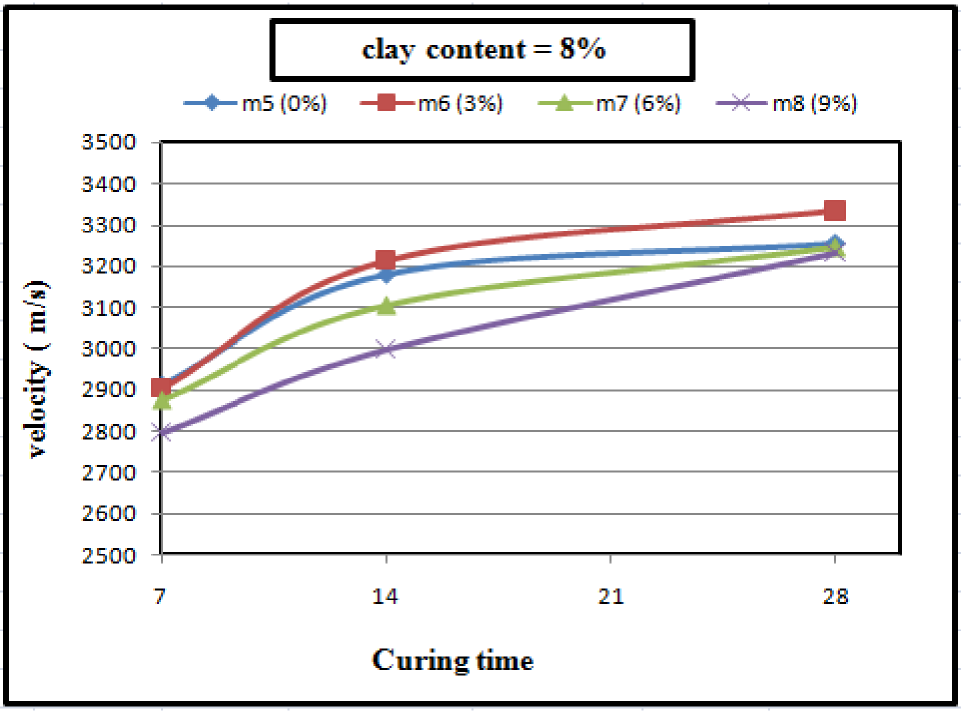


Figure 4.14 Explain the effect of curing time on the ultrasonic velocity at the replacement ratio 3%, 6% and 9% of cement with waste soda glass powder when the clay content 8%

When the content of clay was 4% in the artificial sand samples the speed wave of ultrasonic pulse velocity of the specimens are higher than the samples with clay content 8% and 20% respectively so the increasing of the clay ratio leads to decrease the speed wave of ultrasonic pulse velocity.At the term of glass powder, the addition of waste glass soda powder leads to increase the speed wave about 0.855% higher than control samples but the increasing of replacement ratio of cement with waste glass soda powder to 6% and 9% leads to decrease the velocity of the wave comparing with the control simples.

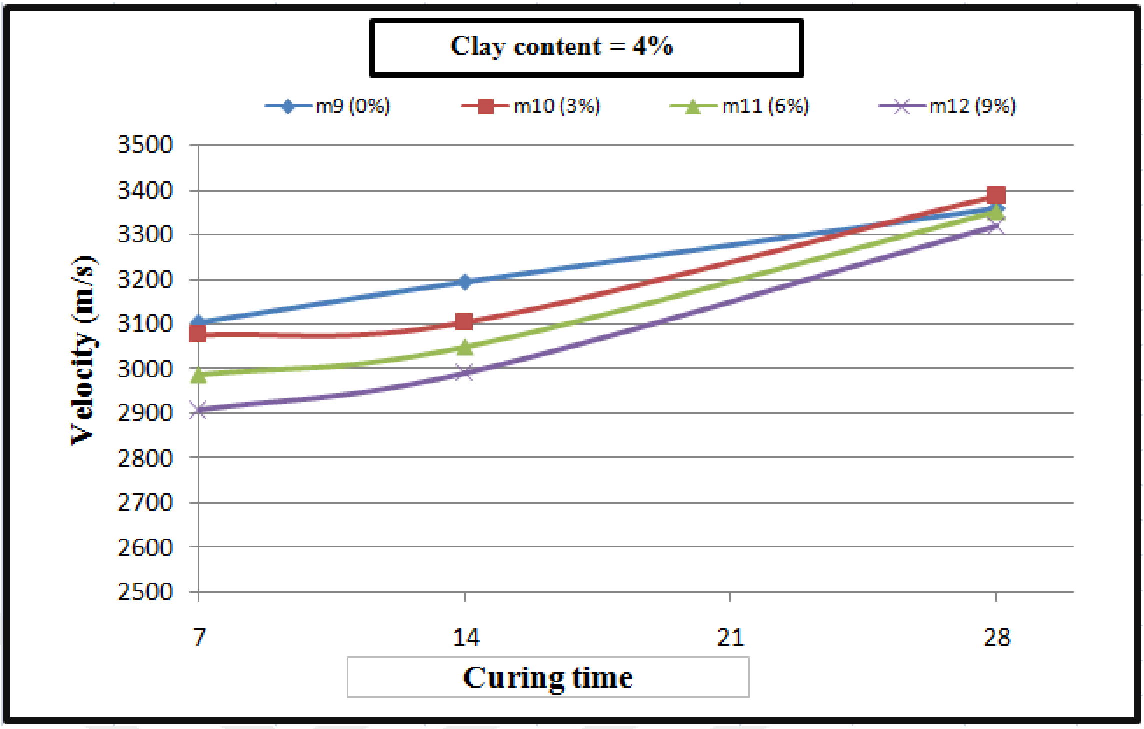


Figure 4.15 Explain the relation between the curing time and the velocity when the content of clay is 4% for 0,3,6 and 9% content of glass powder

The maximum UPV can be obtained when the content of clay was 4% in the replacement ratio 3% of waste glass soda powder with cement and the decreasing the clay content leads to increase the velocity of the wave because of of the decreasing in the clay content means increasing in the density which is leads to affinity particles Thus, voids are less and higher velocity (Loreni et al., 2007). Which is opposite with the maximum value of UCS for this reason there is no correlation between the UCS and UPV. On the other hand, when increasing the replacement ratio more than 3% leads to increasing the decrease the UPV (Khatib et al., 2012)

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CHAPTER 5

CONCLUTION

In this research, in order to examine the influence of sandy soils stabilized by DMM column using soda waste glass powder as replacement with cement, Vicat test unconfined compression tests and ultrasonic pulse velocity were carried out on the samples. The following conclusions are summarized based on the results reported in this research:

1- In this study it found that with the addition of glass powder as partial cement replacement to the pastes, the setting times (initial setting and final setting time) of the pastes increased.

2- The bulk density of the specimen after 24 hours of preparation of the mixtures were measured and found that it slightly decreases with the addition of the glass powder for all the mixtures. On the other hand, it observed that with increasing the clay (4%, 8% and 20%) to the mixtures resulted to decrease the bulk density.

3- The unconfined compressive strength of the samples has been found that decreases with the addition of glass powder for all the mixtures in 7 and 14 -day, will add 3% of glass powder resulted to achieve the higher value of the UCS for all three additions of clay at 28 day curing time.

4- From this study concluded that as the clay content increases to limited ratio in the mixtures the unconfined compressive strength of the specimen increases for all the mixtures and all curing time where the UCS for the sand sample with clay content of 20% is better than the other samples that prepared with content of clay

8 and 4%, regardless the replacement ratio of glass powder with the cement in the binder

5- It noted that the UCS of the samples for all the mixtures increases with curing time same as the previous studies that found in the literature.

6- Like unconfined compressive strength, the modulus of elasticity of the specimens increases with increase the addition of the clay for all the mixtures.

7- It has been found that curing time has an effect on the mechanical properties of the specimen. In this study modulus of elasticity increases slowly or rapidly with curing time.

8- The ultrasonic pulse velocity of the specimen has been found that decreases with increasing glass powder for 7 and 14 days for all the mixtures. On the same hand, founded that it increases with addition up to 3% of the glass powder at 28 days.

9- Test results indicated that as the clay content increased in the mixtures resulted to decrease the ultrasonic pulse velocity of the specimen for all mixtures and for all curing time. Such as the UCS and modulus of elasticity the ultrasonic pulse velocity increases with curing time but with small variations.

RECOMMENDATIONS FOR FUTURE STUDIES:

1- choosing other materials could replace with cement in the binder (having a pozzolanic behavior) for the deep soil mix with different ratios in order to study the behavior of this new material and comparing them with the present study

2- choosing a different proportions of waste soda glass powder in order to investigate the influence of them with on the binder in the view point of deep mixing.

3- Using a finer size of soda waste glass powder in the binder as a cement replacement that could give a better performance Because the surface area for interaction increase.

4- Using a different content of clay in artificial sand samples to find the effect of clay on the strength of loose sand samples. Furthermore, trying to use different sizes of artificial loose sandy soil.

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