KUFA JOURNAL OF ENGINEERING
ISSN 2071-5528
PRINTED IN IRAQ

Volume 4, Number 1 pp.137- 156, 2012

Effect of Fine Materials on the Compressive Strength and Workability of Concrete

Asst. Prof. Dr. Hakim Saeed Muhammed
Najaf Technical Institute
Hakim_skursh@yahoo.com

Lect. Kadum Taha Kadum
Najaf Technical Institute

Asst. Lect. Muhammed Ali Ahmed
Najaf Technical Institute

B.Sc.Eng. Nabeel Getfan
Najaf Technical Institute

B.Sc.Eng. Asaad Abdul Zehra
Najaf Technical Institute

(Received:30/1/2012 ; Accepted :September/2012)

Abstract:

This paper studies the effect of different ratios of clay addition on the concrete properties. Most of the standards limit the ratio of the clay in aggregates due to its harmful effect on the concrete properties. For example, ASTM C33 limits the fine contents in fine aggregate to 5% whereas the ratio of clay lumps is limited to 0.5% as deleterious substances included in the fine materials as very fine substances .This study has considered many ratios of clay addition(0%,2%,3%,4% and 5%) of the total aggregate weight to the concrete mixes and observed the governed values of compressive strengths and workability. A series of cube groups were fabricated with different water-cement ratios (0.45,0.5 and 0.55) and different mix ratios(1:1:2,1:1.5:3 and 1:2:4).It is seen that as the ratio of clay increases, slump decreases; therefore, more water will be needed to reach a reasonable workability while the compressive strength is severely affected in high ratios of clay existence. There is no effect of age on the ratio of strength decrease when a high ratio of clay is added or existed. The strength will decrease by about 33% if a 5% of clay is available in fine material. This study has come as a result of investigating the reasons behind the continuous deterioration in concrete cubes that came to the laboratory for the aim of testing through local construction companies and contractors who are working in most of projects all over the middle region governorates in Iraq.

Key words: Micro-fines, clay, slump, compressive strength.

تأثير وجود المواد الناعمة على مقاومة الخرسانة وقابلية تشغيلها

ا.م.د. حاكم سعيد محمد
المعهد التقني- النجف

المدرس كاظم طه كاظم
المعهد التقني- النجف

المدرس المساعد محمد علي احمد
المعهد التقني- النجف

المهندس نبيل كطفان
المعهد التقني – النجف

المهندس أسعد عبد الزهرة
المعهد التقني – النجف

الخلاصة:

يدرس هذا البحث تأثير إضافة او وجود نسب مختلفة من الطين على صفات الخرسانة. إن معظم المداون تحد نسبة الطين في الركام بسبب تأثيرها المؤذي على مواصفات الخرسانة الناتجة. فعلى سبيل المثال، فأن الجمعية الأمريكية لفحص الموادASTM C33 قد حددت محتوى المواد الناعمة في الركام الناعم بنسبة٥% بينما تكون نسبة الكتل الطينية محددة عند٠,٥% كمواد ضارة من ضمن المواد الناعمة. تناول هذا البحث دراسة نسب من الطين مبتدئة بنسبة صفر ثم ٢% ،٣% ، ٤% و٥% في الخلطات الخرسانية ومراقبة نتائج مقاومة الخرسانة وقابليتها التشغيلية. تم صب سلسلة من مجاميع كبيرة من المكعبات بنسب ماء/سمنت (٤٥%،٥٠% و٥٥%) ونسب مختلفة من الخلطات (١ :١: ٢ ، ١ : ١,٥ : ٣ ، ١: ٢ :٤) .لقد لوحظ انه كلما زادت نسبة الطين فأن الهطول يقل ولذلك ستكون هنالك حاجة لمزيد من الماء للوصول إلى قابلية تشغيل معقولة بينما تتأثر مقاومة الانضغاط بشكل كبير وشديد بوجود نسب كبيرة من الطين .لم يلاحظ تأثير كبير لعمر الخرسانة على نسبة نقصان المقاومة حين إضافة نسبة كبيرة من الطين .إن المقاومة ستنقص حوالي ٣٣% إذا كانت نسبة ما موجود من طين بحدود ٥% في المواد الناعمة.إن هذه الدراسة جاءت كنتيجة لتقصي الأسباب المؤدية إلى تردي نتائج فحص المكعبات الواردة إلى المختبر من اجل فحصها من قبل الشركات الإنشائية والمقاولين في العراق .

Introduction

Many projects and buildings are constructed now in Iraqi governorates. Some of these projects are newly constructed and others are to be rehabilitated starting from their infrastructure. The major serious problem and difficulty facing engineers and contractors in Iraq nowadays is the failure of concrete cubes due to low compressive strengths gained. This phenomenon is really a very complicated matter due to the time delay in the project period and the money loss resulting from the maintenance of such failures. Therefore, a study must be done to know what factors can lead to such descending in compressive strength of concrete.

Concrete is a human-made rocky material industry. Its components are majorly aggregate, cement and water. Due to the fact that aggregates comprise between 60-80% of the total volume of concrete, and concrete failures have often been tied to the use of different aggregates, it would appear that one should characterize these aggregates in order to determine the role of these materials in the final performance of concrete(1).

Aggregates often contain a layer of small particles bound strongly or weakly to the aggregate surface (a surface coating).Previous researches associate the presence of some types of micro-fines on the surface of these aggregates with the deleterious properties of concrete. A large fraction of micro-fine gravel coatings consists of clay minerals. Due to their small size and large surface areas as well as differing chemistries, these minerals can likely be expected to be major components of reactivity in concrete systems. It has been widely reported that the presence of clays in aggregates reduces the compressive strength and increases shrinkage in the resulting concrete. However, the exact mechanism by which these clays affect these properties has not been established, yet.

To show how clays enter the reaction and participate in the whole process of the concrete manufacturing, the following hypothesis can be taken into consideration. In the course of mixing process , a fraction of the clay coating detaches from the aggregate surface and disperses into the aqueous phase. Thus, when the cement powder is added to this mixture, particles of clay will be incorporated into the matrix of the cement paste and affect hydration reactions. The other fraction of the coating will remain on the aggregate surface and influence the adhesion of the cement paste to the aggregates(1). The overall objective of this research project is to conclude how the existence of clay particles affects the compressive strength of concrete through increasing its ratio as one of the investigated reasons which reduce the concrete compressive strength and lead to troubles and suffering of so many people especially Iraqi companies and contractors.

Review of literature

In the last few years, the ability to design alternative methods of producing concrete has greatly expanded but at the same time the level of complexity in determining which set of parameters provide superior pavement performance has increased too. Several factors contribute to this complexity : the use of different sources of materials (multiple sources of rock, sand and cements), the replacement of cement by new cementitious materials (fly ash ,ground granulated blast furnace slag, etc.), and the production of many new chemical additives that are claimed to produce a superior product. As aggregates comprise between 60-80% of the total volume of concrete ,a special significance has been given to them. It has been documented that the presence of micro-fines in aggregate materials has a significant impact on the ultimate quality of resulting pavement. Defects such as spalling, D- cracking, longitudinal cracking, transverse cracking and corner breaks have occurred in large parts attributed to the presence of these micro-fines. Coarse Aggregates commonly contain small particles(surface coatings) that are bounded strongly or weakly to the aggregate surface, these fine particles may partially or completely cover the surface of the aggregate. The coating usually appears as layers, blends ,patches, or individual grains. The most known types of coatings are clays, calcium carbonates, and dust or silt. Clay coatings originate through the participation of water-soluble materials from sand or gravel deposits ; and are different from the rest of the coatings in that they strongly adhere to the aggregate. Clay minerals comprise a significant proportion of these finely divided materials, and as shall be demonstrated later in this investigation, they are already known to cause deleterious effects in concrete(1). .

ASTM C33 limits the amount of micro-fines that can be used in concrete based on the natural sand micro-fines, but previous researches show that good concrete can be made with highly manufactured fine aggregate (MFA) and micro-fine contents(2). The current ASTM C33 limits the material finer than 75 um (No.200) sieve to 3 percent for concrete subject to abrasion and 5% for all other concretes. As the research continues, it is observed that micro-fines can be successfully added to concrete at much higher percentages than those allowed in ASTM C33 (2). Some sands can be included and perform well in concrete with fines up to 20% passing the No. 200 mesh sieve. This is true for fines that are free of deleterious clays and minerals (3).

According to a study done by Teychenne (4) ,the majority of concrete mixes including 10 to 25 percent dust of fracture needed more water where one of the major differences in adding micro-fines to a concrete mix is the change in the water demand of the mix. For the most part, concrete mixes with micro-fines need additional water to achieve the same workability as mixes with no micro-fines, but in some cases less water is needed.

Previous studies(3,5) have shown that a mixture with no micro-fines needs water-to- cement ratio (w/c) equal to 0.49 ,and when 3.2% (of the total weight of aggregate) micro-fines are added, w/c increases to 0.62. In the same study, when admixtures are also used, the w/c with micro-fines increases from 0.41 to 0.53 to achieve a similar slump. The study indicates that the increase in water demand is proportional to the fines content (5).Fillers such as micro-fines can have a positive effect on concretes, influencing both particle packing and physiochemical reactions in the interface zone. Some effects of including fine fillers in mixtures are: smaller water requirement due to improved particle packing ; increased strength due to smaller requirement and improved interaction between paste and aggregate; decreased porosity, and better workability (6).

A study by Ahmed and Al-Kourd (7) indicated that the addition of micro-fines, called "dust" in their study, increases the shrinkage of concrete. Seven concrete mixes are made and measured for over one year. The final shrinkage measured at 330 days reaches in its higher value to 0.07%. Therefore , increasing the amount of micro-fines increases the drying shrinkage. The effect of addition of fines to normal-strength concrete at levels of up to 270 kg/m^3 was studied in concrete mixtures prepared with constant workability. It was found that as long as workability can be controlled by reasonable amounts of admixture, the addition of fines improves concrete strength by as much as 30%, somewhat reduces the carbonation rate, and slightly increases the volume changes of fresh and hardened concrete.(8).

Effect of clay addition in concrete properties

The presence of some types of clays in the cement mixture causes a decrease in strength and an increase in shrinkage. Unikowski has found that the water demand, for making a workable cement mixture is related to the specific surface area of the clays present in the cement. He had noted that a 3% replacement of sand for monmorillonite(a one of clay types) decreases the compressive strength by 4% and doubles the amount of shrinkage. The work which is done by Pike concluded that the loss of strength in clay mortars is caused by clays adsorbing part of the water used for the cement forming "impermeable envelopes" around the cement grains slowing the rate of the pozzalanic reactions(1).

Moukwa M. et al. have attributed the loss of strength in clay mortars to a higher porosity in the hardened mixtures. Changling H. et al.,(9) studied the water demand, compressive strength, size distribution and pozzalanic activity in six clays. He concluded that since absorbed water has different physical properties than the free water, it should not be available for hydrating the reactive components of the cement. Most of the authors believe that a significant amount of clay in a cement mixture reduces the amount of water available for the hydration reactions and thereby decreases its workability and also alters the course of the pozzalanic reactions. As a result, hardened cement containing clay minerals is expected to have different physical properties from that of cement fabricated without clays(1) . It has been widely reported that the presence of clays in cement reduces the compressive strength and increases shrinkage in the resulting concrete.

Alkiss R.M. and Alzeyoori M.A.K., (10) studied the effect of clays on the workability and compressive strength of concrete through so many tests. They concluded that the effect is behind the ratio of clay available in sand and the clay mineral composition. Their main recommendations focus on the following:

(1) A ratio of fines in sand can be increased to 10% instead of 5% ratio which Iraqi specifications recommends. But care must be taken here that the ratio of clays must not exceed 1% of the sand weight and when the ratio of the fines in the tested sand exceeds 3%.

(2) Water/cement ratio can be decreased to get the required workability in concrete using sands containing fines and clays by using chemical admixtures. .

The difference between what is studied in (10) and the current study is that the researchers were focusing on what is available of fines in the sand in Baghdad soil while in this study the source of sand tested was Najaf region. The aim of the study of Alkiss R.M. and Alzeyoori M.A.K. was to find a new ratio of the acceptable fines available in Baghdad sands. Here the study is to know the effect of fines besides clay on the properties of concrete through addition of clay by different ratios. The ratio of clay added to the fines was compared to the total weight of fines while this study takes this ratio compared to the total weight of aggregates which is more easy for the workers to take any decision.

Aim of the study

The objectives and aims of this study are to investigate the effects (whether harmful or beneficial) of the existence of clay on the workability and compression strength of concrete . The effect will include the following:

A – Clay content: 2%, 3% , 4% and 5%.

B – W/C ratios : 0.45,0.5 and 0.55.

C - Mix proportions: 1:1:2, 1:1.5:3 and 1:2:4.

Experimental work

Materials:

Coarse aggregate:

The coarse aggregate used is natural crushed type having nominal maximum sizes from 9.5 to 20 mm. Its grading conformed to I.O.S. No. 45/1984. This material is washed very well several times by water to have it without any fines or clays. The unit weight of the coarse aggregate is found to be 2620 kg/m^3.

Fine aggregate:

A natural sand brought from Najaf quarries conforming to I.O.S. No. 45/1984 zone 3 is used in this work having a density of 2630 kg/m^3 . This material has been washed several times on the No.200 sieve to collect materials finer than this size. One of the components of this soluble or suspended matter is the clay coming from sand to be used in the concrete mix. This clay which represents the main problem of the study will be collected from the suspension by normal and oven drying .

Cement:

The used cement used is Ordinary Portland cement(Type I).Its specific gravity is 3.15,physical and chemical properties are listed in Tables(1) and (2) respectively. Test results indicated that the adopted cement conformed to the to I.O.S. No.5/1984.

Table(1) :Chemical composition of cement used.

Oxides	Test results %	Limits of I.O.S. No.5/1984
CaO	63.15	--------------------------------
SiO_2	21.52	--------------------------------
Al_2O_3	5.71	--------------------------------
Fe_2O_3	2.64	--------------------------------
MgO	2.54	Not more than 5.0%
SO_3	2.13	Not more than 2.8%
L.O.I.	2.16	Not more than 4.0%
I.R.T.	0.12	Not more than 1.5%
L.S.F.	------------------------	--------------------------------
C_3S	45.32	--------------------------------
C_2S	27.70	--------------------------------
C_3A	10.66	--------------------------------
C_4AF	8.03	--------------------------------

Table(2) :Physical properties of cement used.

Property	Test results %	Limits of I.O.S. No.5/1984
Fineness(Blain's method)-(cm^2/gm)	3000	Not less than2300 cm^2/gm
Setting time: Initial(min.) Final(hour)	72 7.5	Not less than 45 min. Not less than 10 hr.
Compressive strength of cement mortar(N/mm^2): 3 days age: 7days age:	 ٢٠ ٢٧	 Not less than15 N/mm^2 Not less than23 N/mm^2

Clay used as an additional material to concrete

The source of the clay used in this study is natural sand. This clay is obtained from washing sand on the No.200 sieve. The mixture of water and clay has been naturally dried followed by an oven drying. The ratios of clay used are 0%,2%,3%,4% and 5% by weight of the total aggregate weight . The particle size properties of this clay are as shown in Fig.(1). The fraction of clay added to the mixes contains fine materials of silt that are part of the materials existed on the pan during grading. The clay is a part of the fines content. Particle size distribution of the fines was done in the lab. using hydrometer settling according to (ASTM D422)

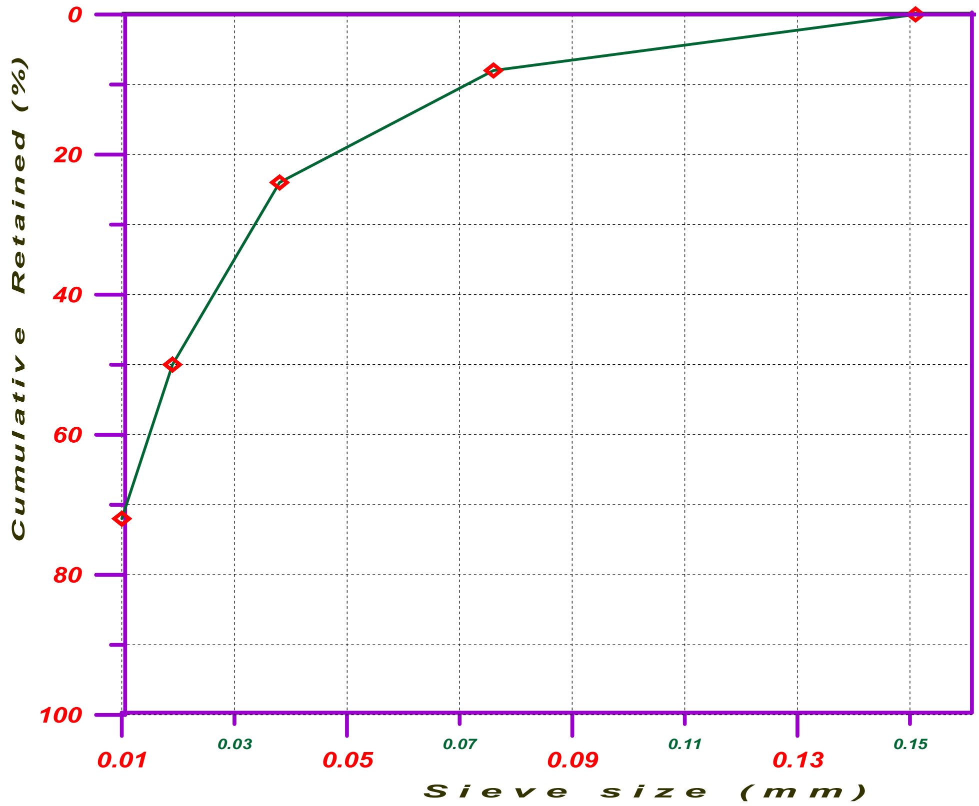

Fig.(1): Particle size distribution of fines

Preparation of concrete mixtures

Three mixes have been prepared using three mixing ratios of 1:1:2,1:1.5:3 and 1:2:4, respectively as common ratios used in major structural members. A water/ cement ratio of 0.45 is used at the first time and the water is added to each mix. After mixing the concrete components, 24 cubes are taken to be tested at 3,7,14 and 28 days age, then the clay is added to the mix by a ratio of 2% of the total aggregate weight as a first time of clay addition. Also twenty four cubes are taken to be tested according to B.S. 1881 Part 116. After that, the ratios of clay addition increase to 3%,4% and 5%

and for each ratio the same number of cubes are taken as mentioned previously. For each mix, the slump of the fresh concrete is taken and measured according to ASTM C 143.

The second series of tests are done exactly as mentioned before except that the water cement ratio is increased to 50% and 120 cubes of 150x150x150 mm have been prepared. And finally the third phase of tests is with a water cement ratio of 55%. The slumps of fresh concrete with different ratios of clay addition are drawn on the same graph for three different mix ratios and three different water cement ratios as shown in Fig.(2).

Results and discussion

The graphs starting from Fig.(3) to Fig.(14) clearly show that the compressive strength gives maximum recorded values when there is no clay existed in the sand (i.e. sand is washed).As clay is added, the compressive strength starts to decrease. Many parameters are studied and discussed separately here, such as the effect of water/ cement ratio, effect of mix proportions ,the ratio of clay added and the workability is studied by measuring the slump of the mix.

(1)Workability

Fig.(2) shows the relationship between slump and ratio of clay added. The graph contains three groups of curves. Each group is for a constant water/cement ratio. The first group represents a 45% water/cement ratio and a maximum slump recorded for this group is 32mm when there is no clay. For 5% clay ratio, the maximum value of slump is 20mm and according to the standard specifications, this slump represents a low workability. Therefore, it is not advised to use this water/cement ratio or an admixtures must be used to improve this low slump and workability. For water/cement ratio equal to 50%, the maximum slump is 50mm for 5% clay ratio and this slump value does also not really give good workability. The related graph shows that the best ratio of W/C used is 55% when maximum ratio of clay added is 5%, and the slump recorded is 70mm.

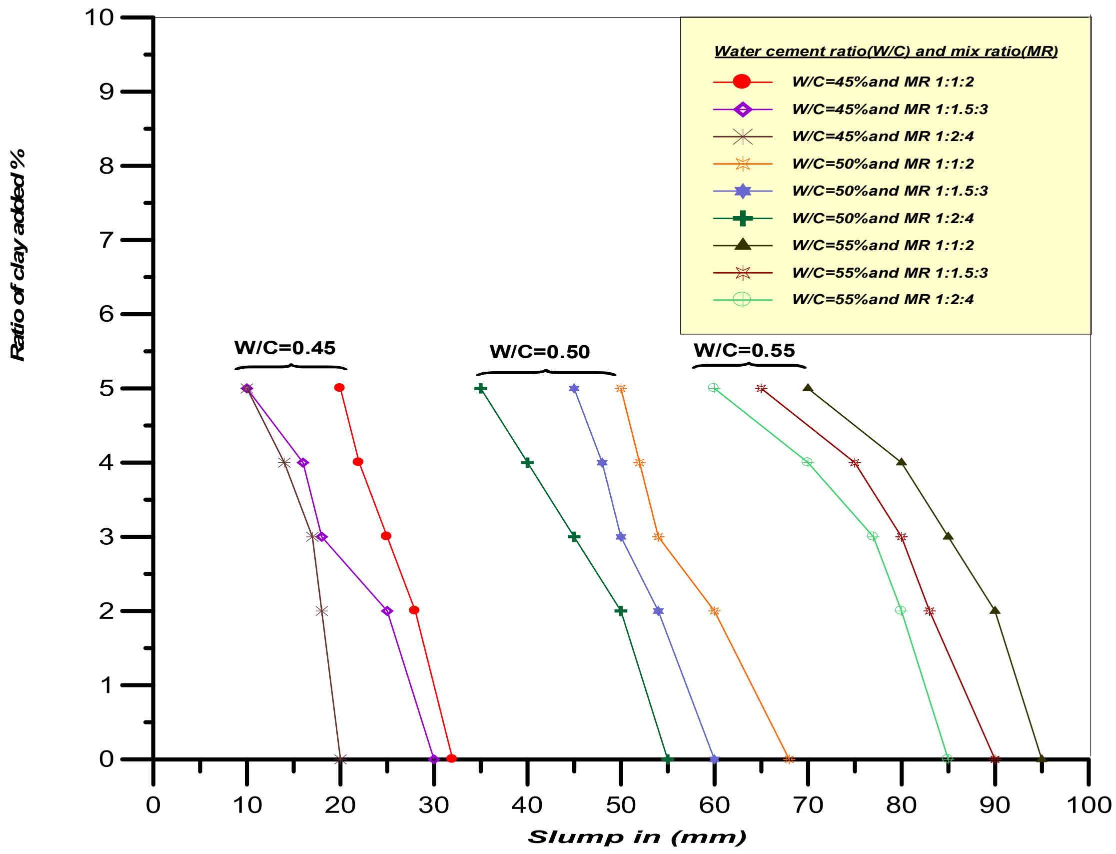

Fig.(2) Effect of clay addition on the concrete workability.

(2) Water -Cement ratio

It is a known engineering fact that as water increases, the compressive strength decreases and concrete will be more workable. Table(3) shows the classified results of rate of decrease in compressive strength with age of concrete . Here, if the mix ratio is for example 1:1:2 ,then the rate of decrease for 3 days age and 45% water/cement ratio is 0%,12%,19%,27% and 37% for a ratios of clay addition 0%,2%,3%,4% and5% respectively. That phenomenon is very clear in Fig.(3).This rate of decrease dropped down as ratio of mix increased or W/C ratio increased. When the water-cement ratio increases to 55%, the rate of compressive strength decreases returned to decrease. This means when there are high quantities of clay content, an experimental mixes design must be done and there are no guidelines or recommendations to be set up here. One of the sources of water loss during hydration is the surfaces of the clay fine materials. This leads to the phenomenon that as the ratio of clay increases more water is needed.

(3) Effect of mix ratios

Mix ratio increase means an increase in cement content and this will increase the compressive strength of concrete. But when the water/ cement ratio is fixed, high decrements in compressive strength of concrete appear as the clay ratio is increased because hydration will not be completed due to the lack of water. To get a reasonable value of the strength, trial mixes must be done to reach the required compressive strength and slump needed. These trial mixes will solve one problem only because the effect of clays not only on the compressive strength of concrete but it will affect on the following parameters :

*The bond between aggregate and cement mortar besides the bond between concrete and steel reinforcement.

*Permeability and durability of concrete.

*Expansion and contraction in concrete which lead to cracks.

Table (3) shows statistical data of the parameters affecting the compressive strength of concrete.

Table (3): Rate of decrease in compressive strength compared to ratios of clay addition.

W/C	Mix Ratio	Reference compressive strength in (MPa) without clay addition				Ratio of clay added%	Rate of decrease in compressive strength%			
		3days	7days	14days	28days		3days	7days	14days	28days
٤٥	1:1:2	15.96	24.60	26.68	29.66	٢	١٢	١٧	٢٤	١٥
						٣	١٩	٣٦	٢٨	٢٧
						٤	٢٧	٤١	٣٢	٣٢
						٥	٣٧	٤٤	٣٤	٣٤
	1:1.5:3	14.82	23.54	24.55	28.22	٢	١٨	٣٠	١٥	١٥
						٣	٢٤	٣٧	٢٤	٢٧
						٤	٢٣	٤١	٢٦	٣٤
						٥	٣٦	٤٥	٣٠	٣٦
	1:2:4	12.56	22.62	21.12	27.71	٢	١١	٣٠	٦	١٥
						٣	١٣	٤٠	١٢	٢٨
						٤	٢٣	٤٤	١٥	٣٥
						٥	٢٨	٤٦	٢٠	٣٧
٥٠	1:1:2	15.12	21.21	23.69	28.15	٢	٨	٢١	١٥	١٤
						٣	١٦	٣٣	٢٥	٢٨
						٤	٣٣	٣٨	٢٦	٣٢
						٥	٣٣	٣٨	٢٩	٣٣
	1:1.5:3	14.10	21.00	22.93	27.65	٢	١٦	٢٣	١٦	٢٠
						٣	٢٨	٣٥	٢٦	٢٨
						٤	٣٢	٣٧	٢٨	٣١
						٥	٣٤	٤٠	٢٩	٣٣
	1:2:4	12.00	20.90	21.22	27.10	٢	٢٢	٢٩	١١	٢٠
						٣	١٨	٣٦	٢١	٢٨
						٤	٢٦	٤٣	٢٢	٣٠
						٥	٣٠	٤٥	٢٥	٣٤
٥٥	1:1:2	14.51	20.88	20.56	27.77	٢	١٠	٢٦	٩	١٥
						٣	٢٤	٣٨	٢٠	٢٩
						٤	٣٢	٤٧	٢٥	٣٣
						٥	٣٤	٤٧	٢٧	٣٤
	1:1.5:3	13.60	19.49	20.11	27.00	٢	١٨	٢٨	٩	١٦
						٣	٣٢	٤٠	١٩	٢٩
						٤	٣٨	٤٧	٢٦	٣٣
						٥	٤١	٤٩	٢٧	٣٥
	1:2:4	11.90	19.12	20.00	26.66	٢	١٤	٢٦	١٠	١٧
						٣	١٠	٤١	١٨	٣٠
						٤	٣٣	٤٧	٢٨	٣٤
						٥	٣٩	٤٩	٣٠	٣٦

(4) Effect of clay added

Clay is a harmful substance to construction materials and structures. Although it is very fine ,and the addition of fine materials sometimes increases the compressive strength, but clay is a very seriously dangerous material. From Table(3) and from all the graphs drawn, it is clear and without any doubt that as this ratio increases, the rate of strength decreases for all ages of concrete tested (3,7,14 and 28 days age).

Higher ratio values of clay have been considered because there is a statistical study for all the sand samples reaching the laboratory of the Civil Engineering Department in Najaf Technical Institute. This study explores the huge quantities of clay available in this material. The ratio of clay is about 2% as minimum up to 5%. Therefore the present study limits the ratios from 2% to 5% to investigate their effect .

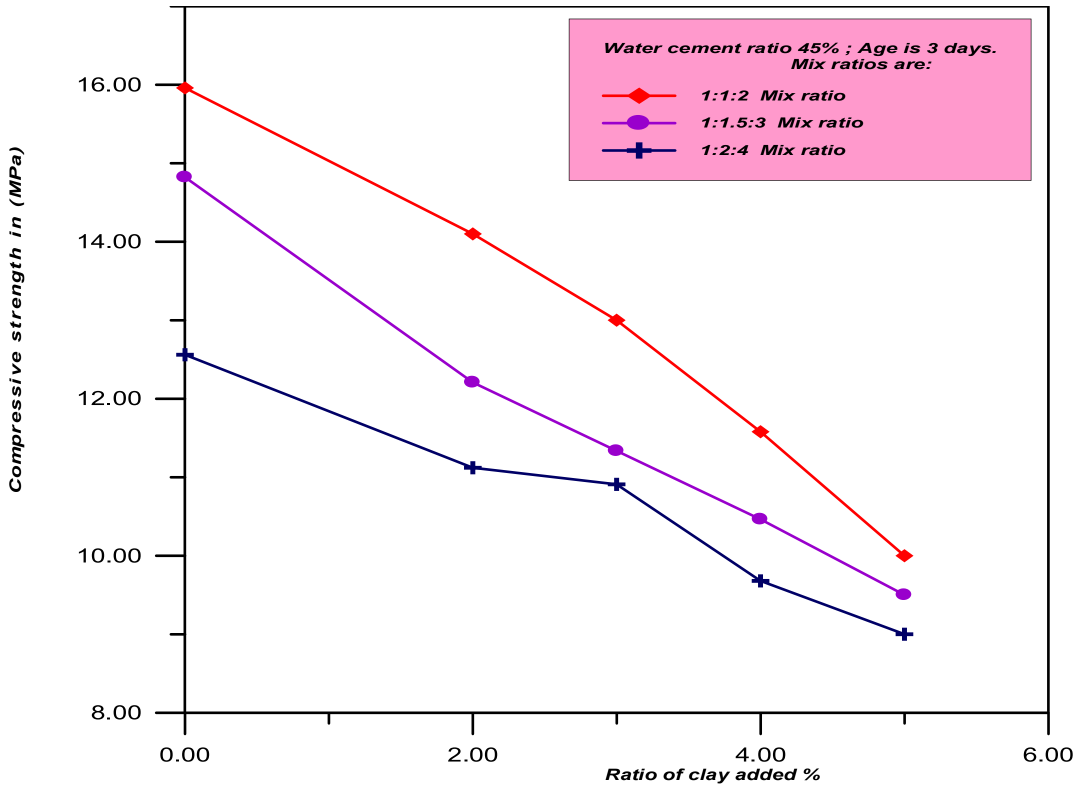

Fig.(3): Effect of clay addition on concrete compressive strength W/C=45%; Age of concrete is 3 days

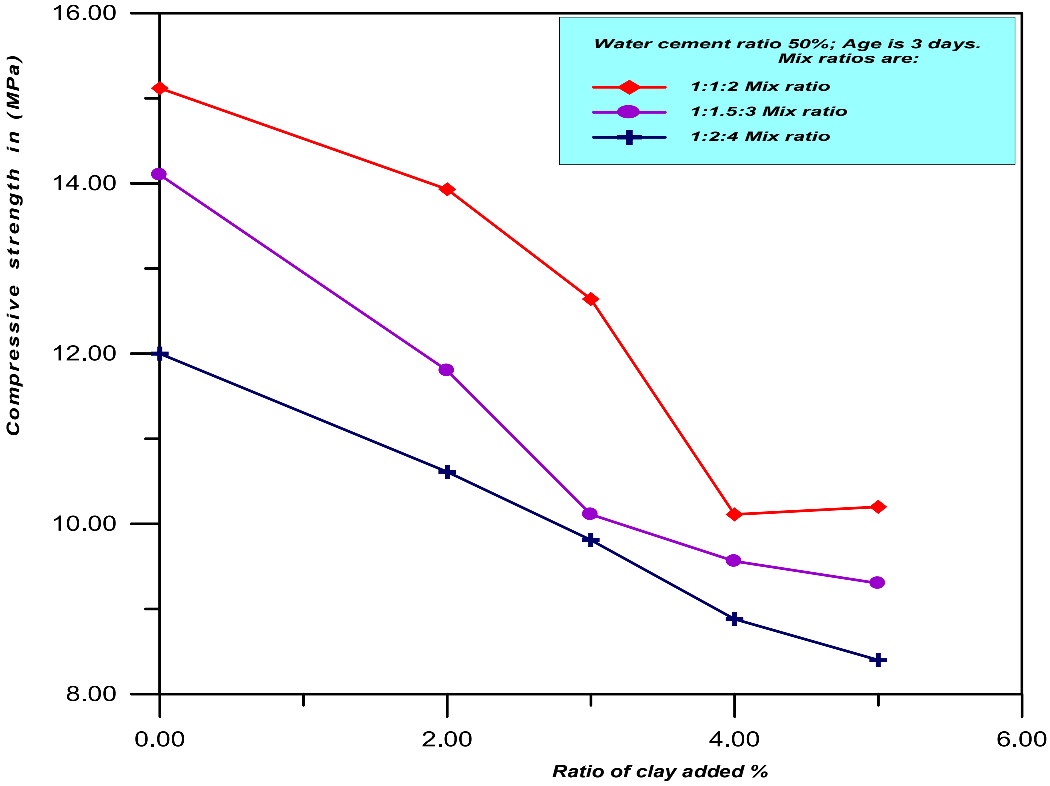

Fig.(4): Effect of clay addition on concrete compressive strength. W/C=50% ; Age of concrete is 3 days.

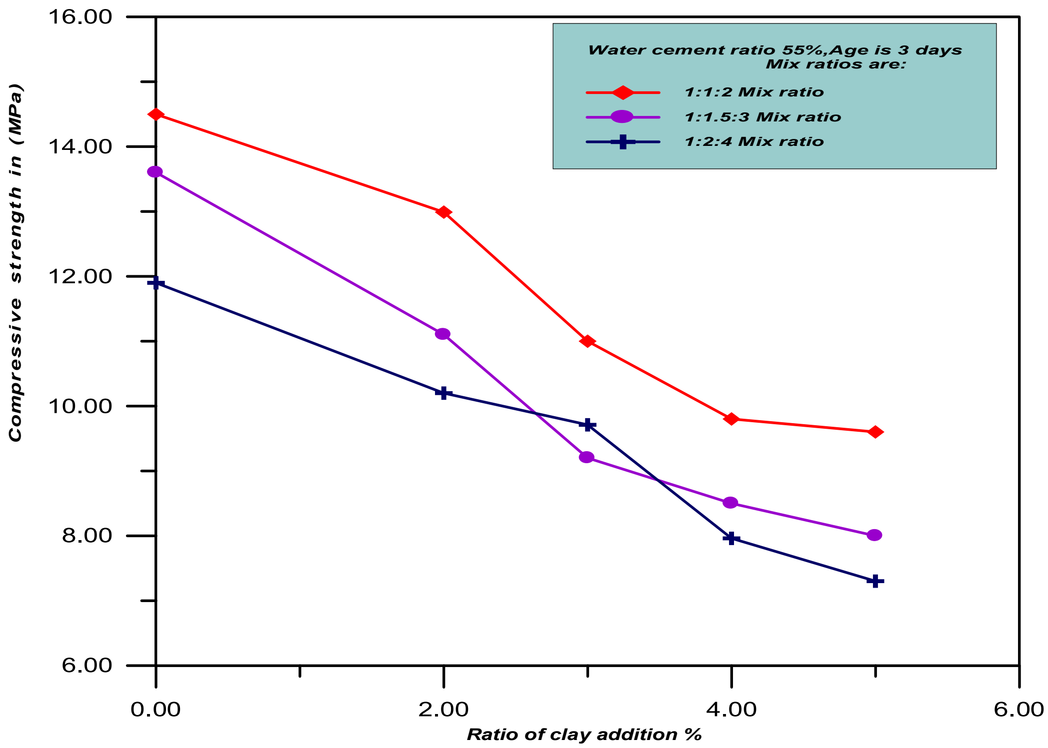

Fig.(5): Effect of clay addition on concrete compressive strength W/C=55%; Age of concrete is 3 days

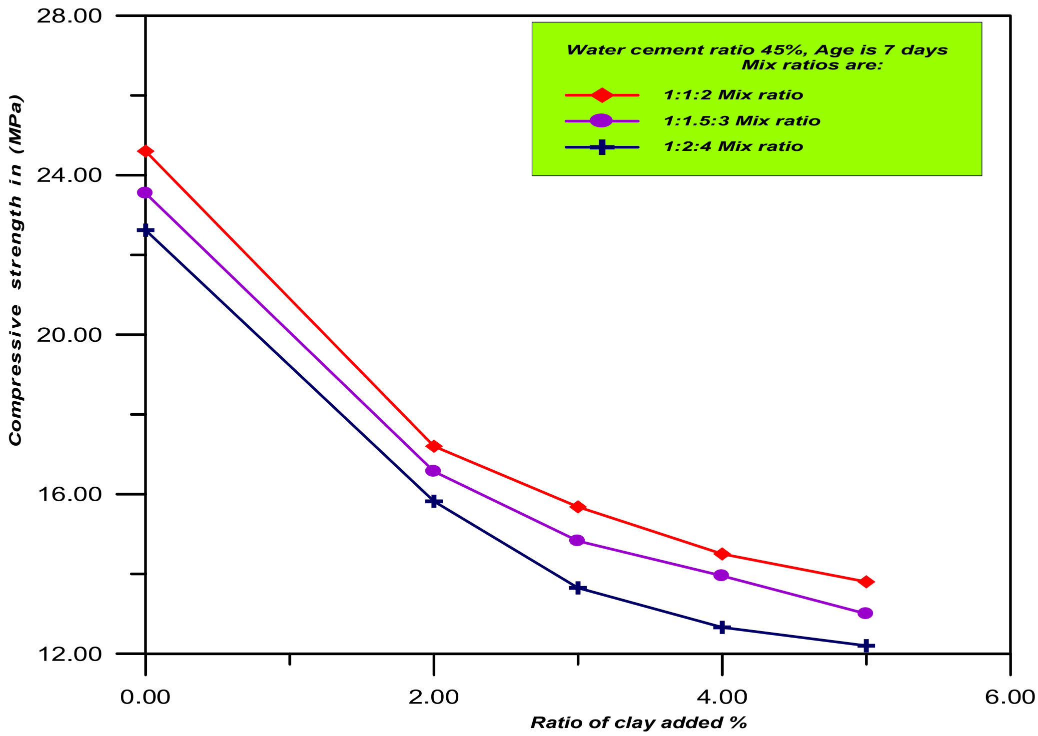

Fig.(6): Effect of clay addition on concrete compressive strength. W/C=45%; Age of concrete is 7 days

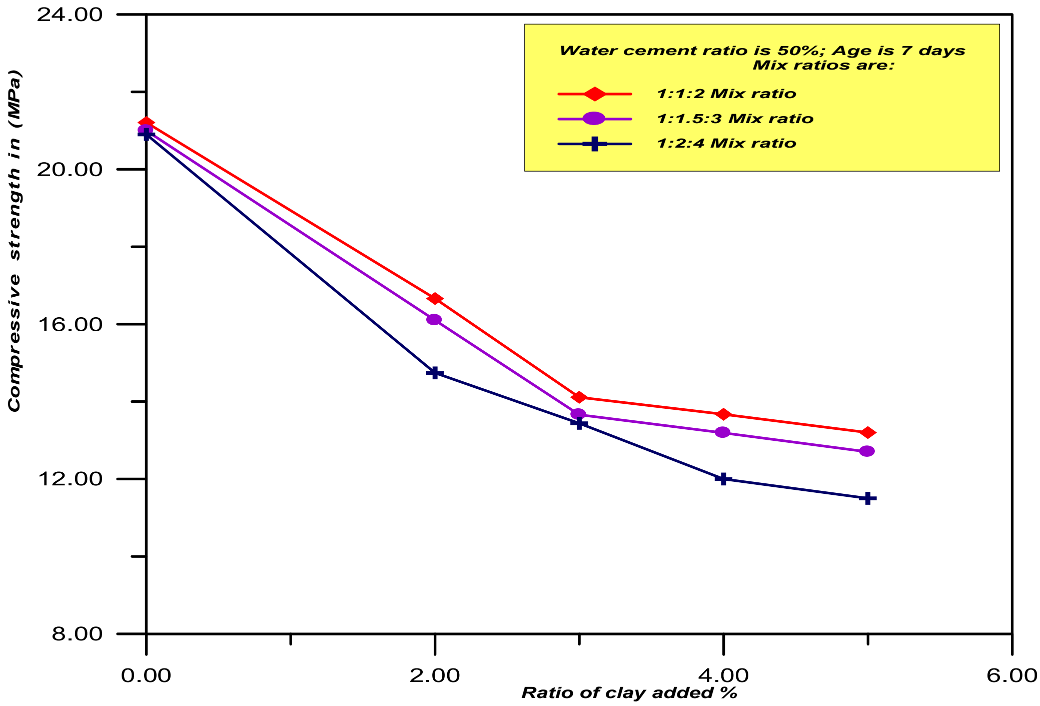

Fig.(7) :Effect of clay addition on concrete compressive strength. W/C=50%; Age of concrete is 7 days.

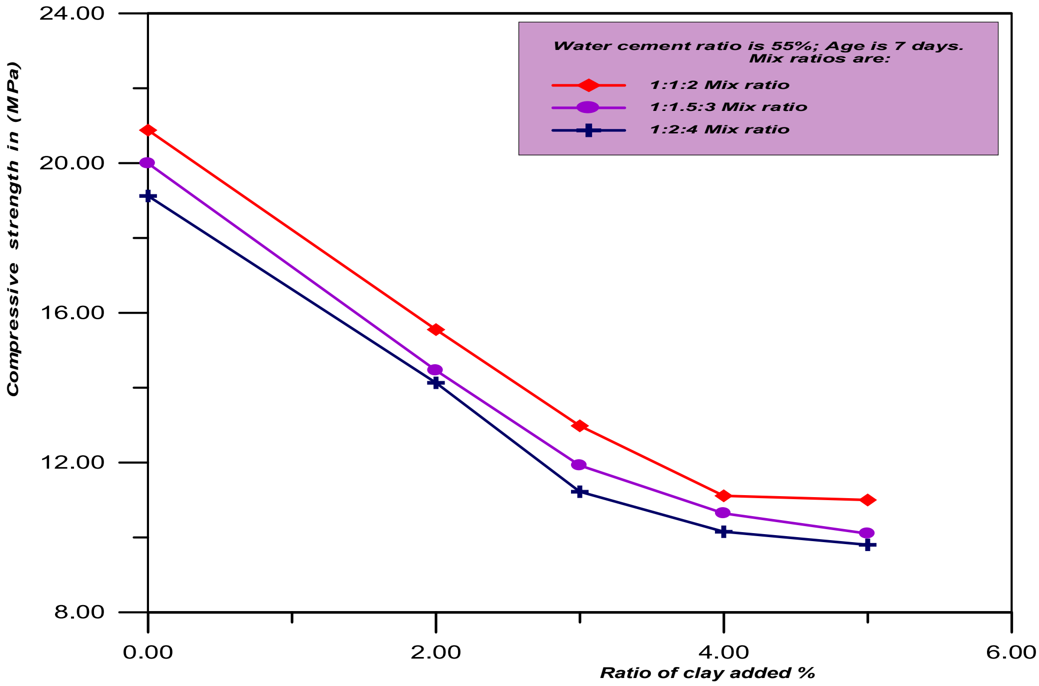

Fig.(8): Effect of clay addition on concrete compressive strength. W/C=55%; Age of concrete is 7 days.

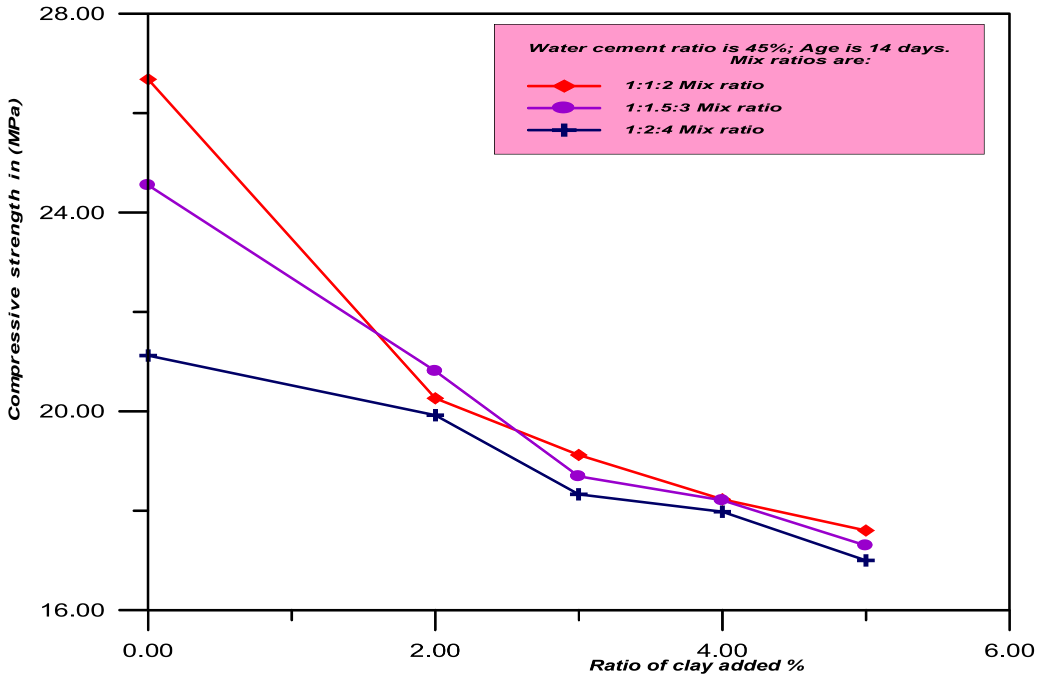

Fig.(9): Effect of clay addition on concrete compressive strength. W/C=45%; Age of concrete is 14 days.

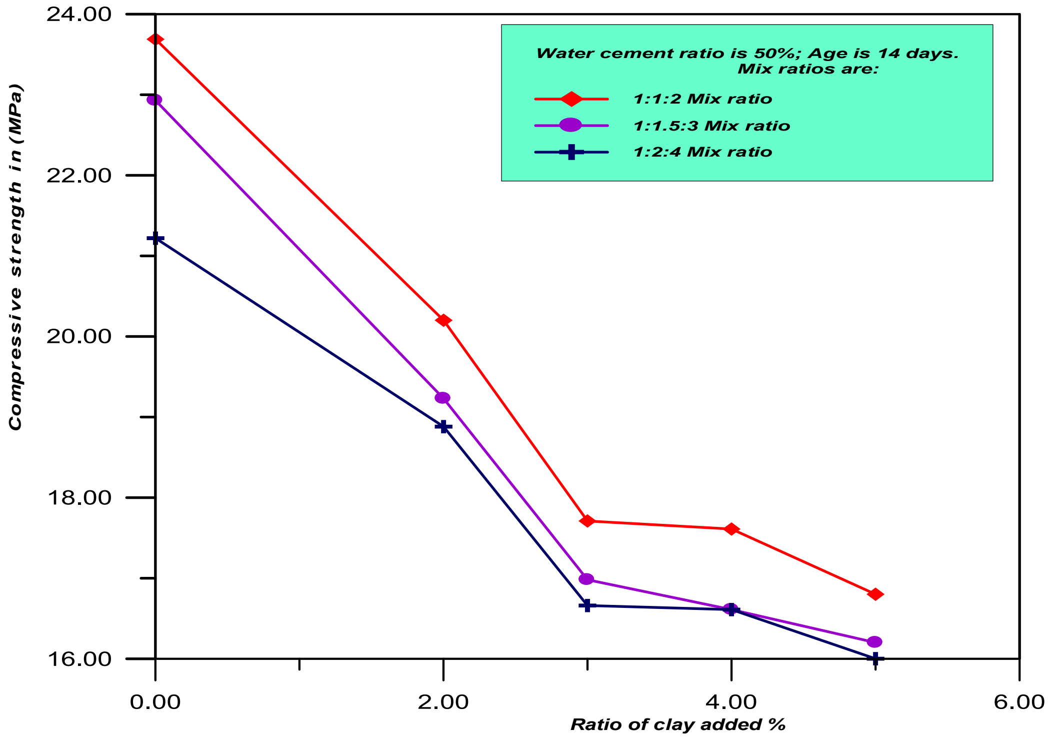

Fig.(10):Effect of clay addition on concrete compressive strength.
W/C=50%; Age of concrete is 14 days.

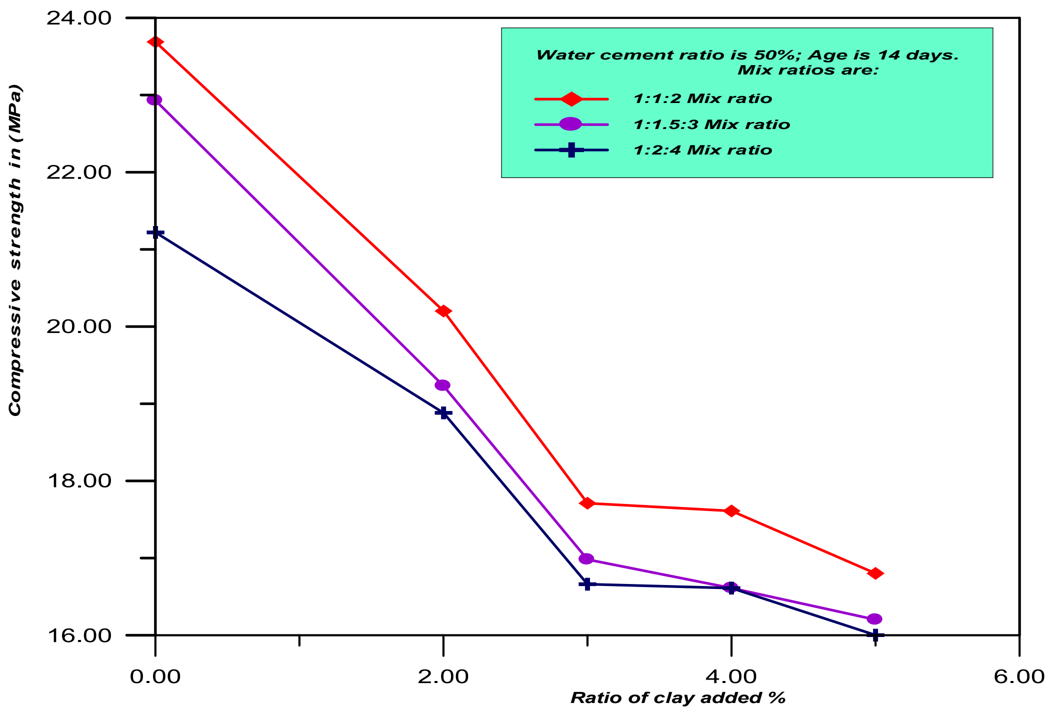
Fig.(10):Effect of clay addition on concrete compressive strength.
W/C=50%; Age of concrete is 14 days.

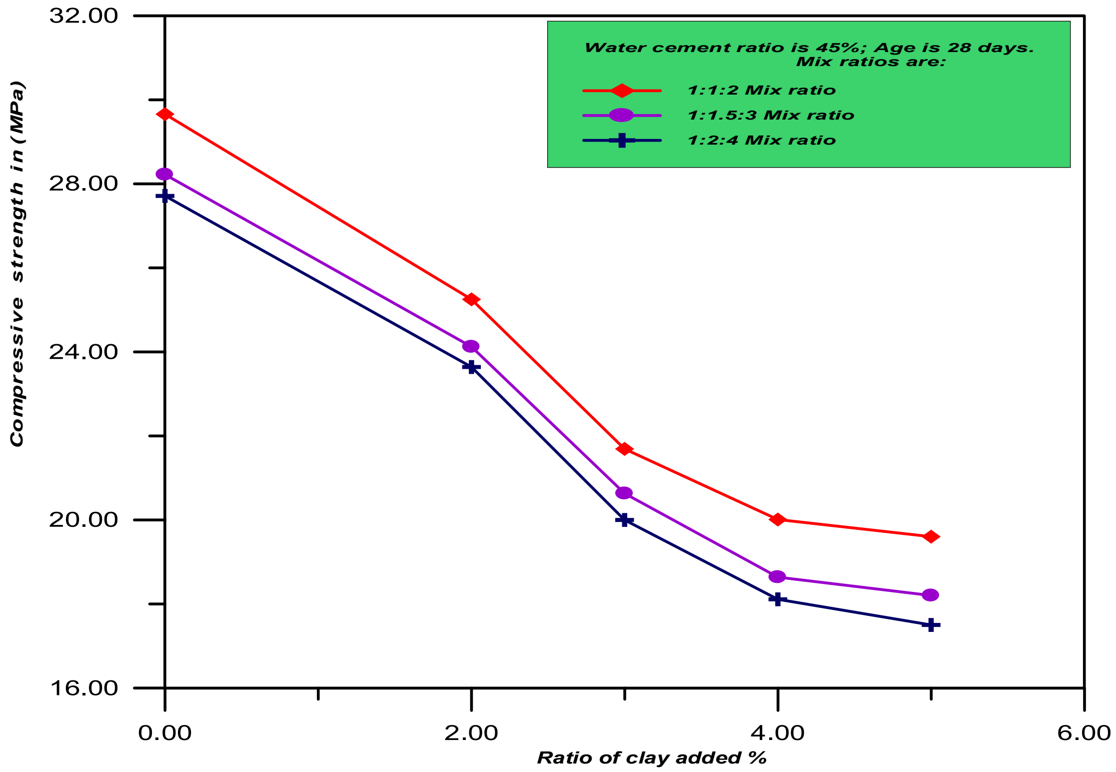

Fig.(11): Effect of clay addition on concrete compressive strength. W/C=45%; Age of concrete is 28 days.

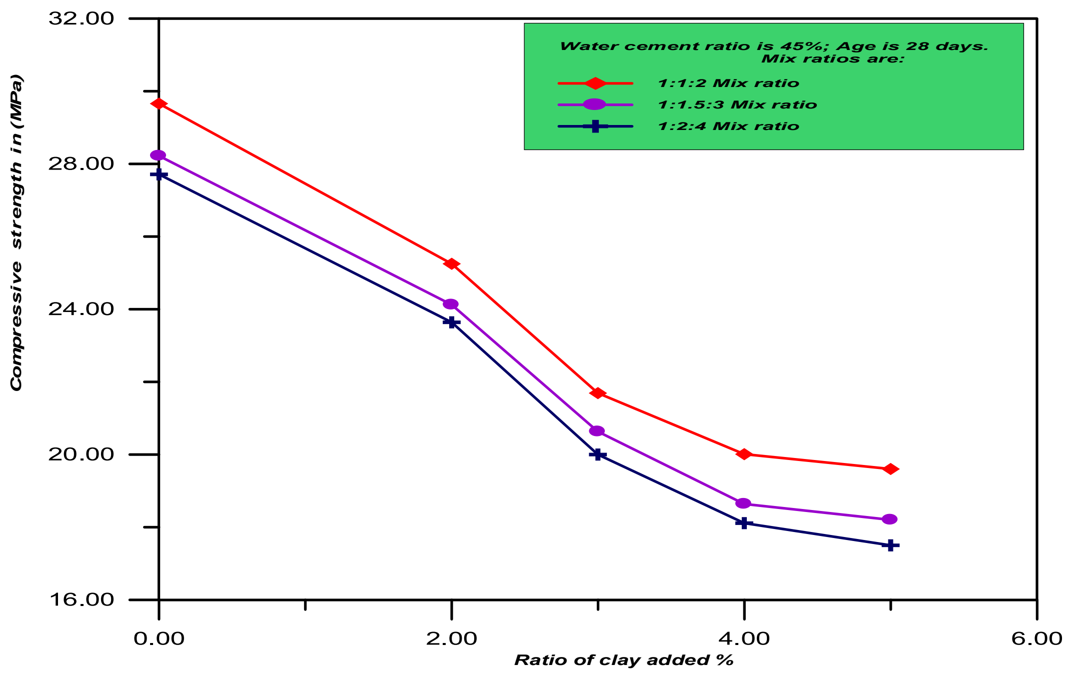

Fig.(12): Effect of clay addition on concrete compressive strength. W/C=45%; Age of concrete is 28 days.

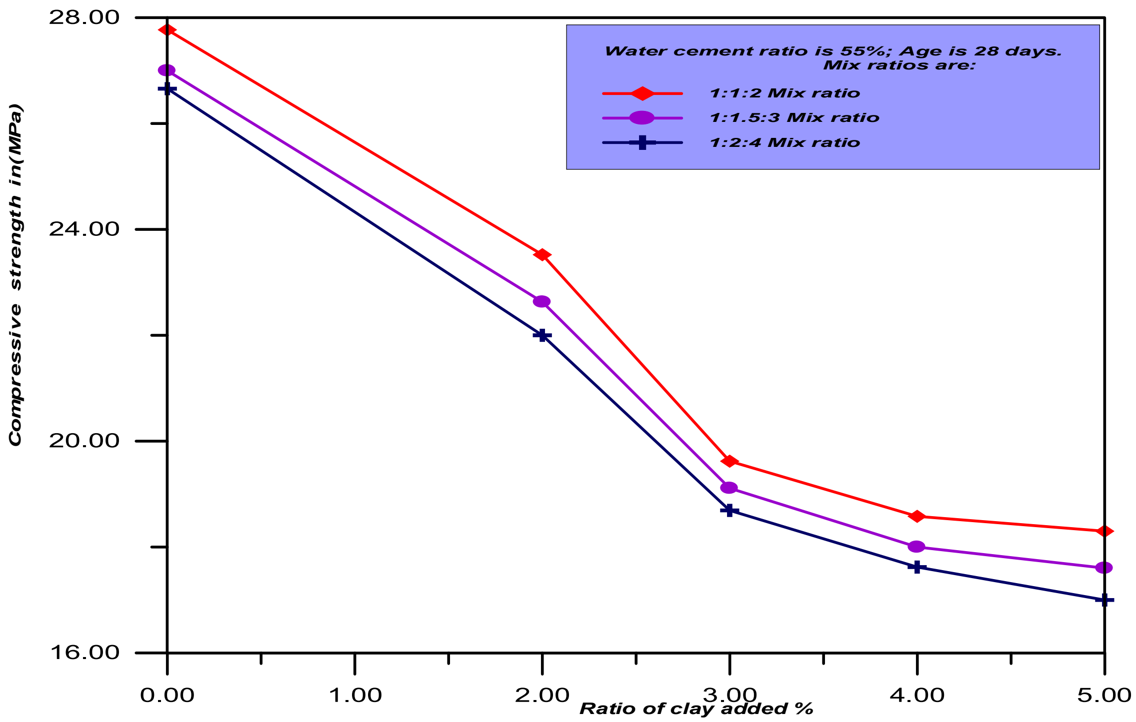

Fig.(13):Effect of clay addition on concrete compressive strength. W/C=55%; Age of concrete is 28 days.

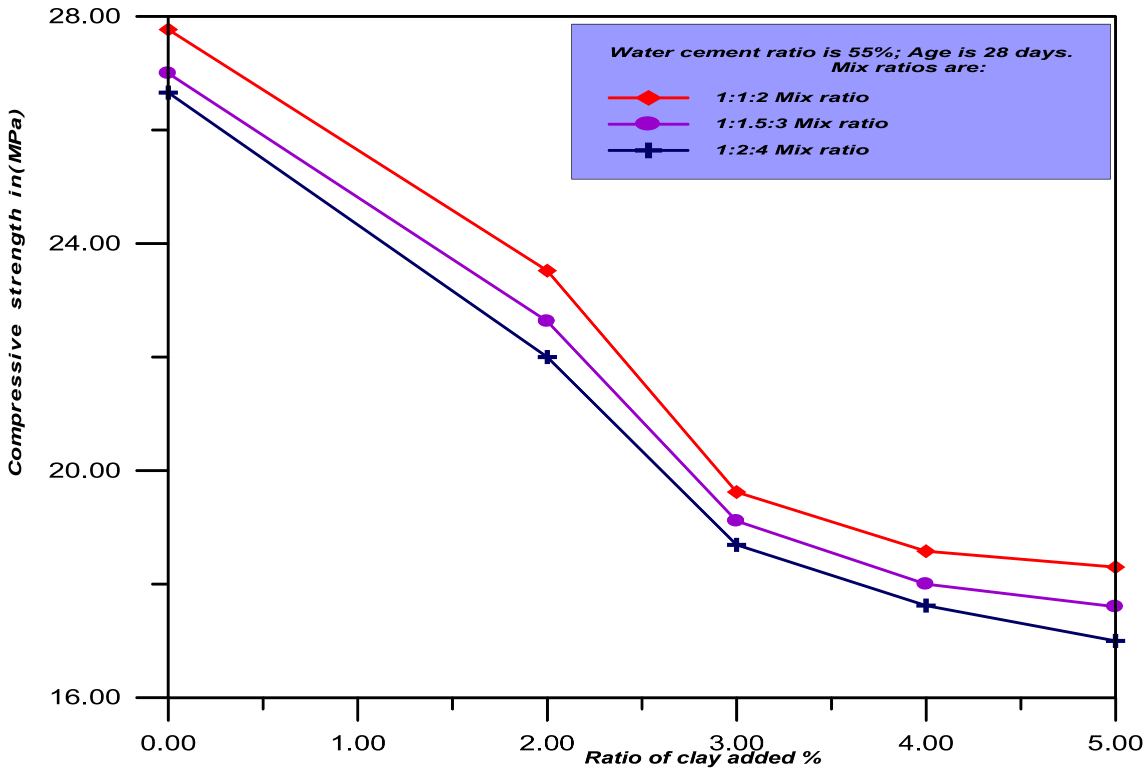

Fig.(14):Effect of clay addition on concrete compressive strength. W/C=55%; Age of concrete is 28 days.

Conclusions and Recommendations

The results and remarks obtained through this study concludes the following recommendations:

(1) As ratios of clay added, or existed in the sand increases, the compressive strength decreases as given in many references.

(2) It was noted that the average value of decrease in compressive strength starts with 20% for 2% clay ratio and this is increased to about 33% when the clay ratio is 5%. This ratio is really serious or critical; therefore, caution must be taken.

(3) Trial mixes must be attempted and tested to reach the most convenient mix ratio and water/cement ratio when there are high quantities of clay; otherwise the sand material must be rejected.

(4) This study shows clearly why all standards limit the ratio of fines to about 5% due to the harmful effect of clay on concrete properties.

(5) A study must be done to the volume change phenomena because clay particles, which are smaller than a few microns, undergo significant volume changes when they absorb water and dry out thereafter.

(6) The shrinkage of concrete must be studied under these high ratios of clay. Wet clay particles, which expand in the fresh state of concrete, later shrink and, as a result, their presence may lead to large volume changes of the hardened concrete and strength reduction.

Acknowledgements

The researchers wish to acknowledge the Ministry of Higher Education and Scientific Research - Development and Research Office for their continuous help and financial support to complete this research throughout its period.

References

(1) Munos J.F.,Tejedor I.,Anderson M. and Cramer S.(2005). "Effects of Coarse Aggregate Clay-Coatings on Concrete performance", An IPRF Research Report ,University of Wisconsin-Madison ,October 2005 .

(2) Ahn, N.(2000)." An Experimental Study on the Guidelines for using Higher Contents of Aggregate Micro-fines in Portland Cement Concrete", PhD Dissertation, University of Texas at Austin.www.robo.co.in/intro.pdf.

(3) Hudson B. (2003) "Discovering the Lost Aggregate Opportunity", Parts 1 to 9, Pit and Quarry, V.95, No.7, Jan.2003.

(4) Teychenne D.C.(1978). "Crushed rock aggregates in concrete", Quarry Management and Products.

(5) Abou-Zeid, M.N., and Fakhry, M.M.(2003)."Short-Term Impact of High Aggregates Fines Content on Concrete Incorporating Water-Reducing Admixture", ACI Materials Journal,V.100,No.4, July-Augest 2003 pp.280-285.

(6) Kronlof, A.(1994). "Effect of Very Fine Aggregate on Concrete Strength" ,Materials and Structures , Vol.27, 1994,pp. 15-25.

(7) Ahmed,E.,and EL-Kourd,A.(1989). "Properties of Concrete Incorporating Natural and Crushed Stone Very Fine Sand", Materials Journal , American Concrete Institute , Vol. 86 , No.4 , July 1989 , pp 119-128.

(8) Amon Katz and Hadassa Baum, "Effect of High Levels of Fines Content on Concrete Properties", ACI Materials Journal / November-December 2006.

(9) Changling H.,Makovicky E. and Osbaeck B. (1995), "Pozzolanic Reaction of six Principal Clay Minerals: Activation Reactivity Assessments and Technological Effects .Cement and Concrete Research,25 (8), 1691-1702.

(١٠) القس رائد متي والزيوري مقدام عبد الكريم(١٩٨٦). " تأثير الأطيان المتواجدة في المواد الناعمة على قابلية تشغيل ومقاومة انضغاط الخرسانة" ،مجلة بحوث البناء ،المجلد ٥ ،العدد ٢، تشرين الثاني ١٩٨٦، ص ١٥-٣٣.