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Research Article

Improvement Properties of Recycle Concrete using Clay Brick as a Coarse Aggregate

Mohamed R. Afify[Ȧ*] and Noha M. Soliman[Ȧ*]

[Ȧ]Civil Department, Faculty of Engineering, Menoufia University, Egypt

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Abstract

Recently, it has been taken into consideration the use of the recycle aggregate from old concrete, clay brick and waste materials, the recycle concrete is considered as one of the most important materials in the special concrete groups. It has extensive applications in the architect and insolation work. Many research studied the effect of this recycle aggregates on the properties of concrete. Chemical admixtures and cement content play an important role in the production of recycle concrete. This research is to establish the improvement properties of recycle concrete using clay brick as a coarse aggregate. Plan concrete specimens cast with concrete containing such recycle aggregate were cast and tested in the research. Using crushed clay brick was manufactured by local factories as an aggregate with replacement ratio as 100 % by volume of coarse aggregate. The main variable taken into consideration were the aggregate type, cement and water content as well as the chemical and mineralogical admixtures content. The mechanical properties as the compressive strength, the tensile strength and flexural strength of fifteen concrete mixes were measured in the experimental work at 7, 28, 90 and 180 days when they curing in salt solution and in the water. The results show that the hardened properties of recycled concrete improved by reducing the water/ cement, increasing admixture/ cement and using silica fume. Curing in salts decreased the compressive strength of recycled concrete compared to curing in water.

Keywords: *recycled concrete, clay brick, recycled aggregate, aggregate, curing conditions, durability, Polymer Matrix Composites, Injection Moulding, Flexural Strength, Hardness.*

1. Introduction

The failure and collapse is increasing and increasing the use of recycled materials worldwide in the past decades for purposes of environment protection and sustainable development. Concrete is a composite material that is often seen as a potential place for wastes, because of its composite nature (a binder, water and aggregates) and because it is widely used, which means that if a waste could be used in concrete, then certainly large quantities of it can be recycled. Since aggregates in concrete comprise about 60% to 75% of the total volume of concrete any reduction in natural aggregates consumption will have significant impacts in the environment. Environmental constrains of stone pits, such as noise, dust, vibrations, considerable impact on the countryside, besides the consumption of a non-renewable material tend to considerably limit their exploitation. In fact, a large number of researches have been conducted on employing recycled materials in construction field. [Chen HJ et al. (2003), Katz A. (2003), Khalaf FM. and Devenny AS(2004), Olorunsogo FT. and Padayachee N. (2002), Rao A. et al. (2007), Robinson GR, et al. (2004) and Tu TY et al. (2006)]

*Corresponding author: **Noha M. Soliman** and **Mohamed R. Afify** are working as Lecturers

The physical and mechanical properties of recycled concrete with high inclusion levels of recycled concrete aggregate (RCA) and crushed clay bricks (CCB) and to explore the potential or the limitation of this type of mixed recycled aggregate in primary concrete structures. And its results showed that crushed bricks can be used as natural aggregates substitutes in percentages up to 15% to 20% with very good strength. [Paulo B. Cachim (2009), Jian Yang, Qiang Du and Yiwang Bao (2011) and J. Hua, and K. Wangb, J.A. (2013)]

High temperature properties of partition wall concrete blocks prepared with recycled clay brick aggregate derived from construction and demolition (C&D) waste streams (e.g. collapsed masonry after an earthquake) were studied. An appropriate replacement for both coarse and fine clay brick aggregates can lead to better performance of the blocks at elevated temperatures. It is expected therefore that there will be significant advantages in terms of sustainability and fire safety by adopting this inherent fire-resistant material in concrete blocks especially for low rise residential developments. [Zhao Xiao et al. (2013) and Ivanka Netinger et al. (2011)]

Waste material from the brick and tile industry is the common **name** for waste material created by damaged brick and tile elements in the final phase of their production. As pre-fabricated bricks and tiles damaged over tolerance limits cannot be placed into the market, they get crushed at a location near to the factory. This type of waste material is often used as filling material for lower and upper layers of sports terrains. However, worldwide research [A.R.Khaloo (1995), F.M. Khalaf, and A.S.De Venny, (2004), F.M. Khalaf, (2006), F. Debieb and S. Kenai (2008), J.R.Correia, J.DeBritto and A.S.Pereira (2006), J.DeBritto et al. (2005), Yeong-Nain Sheen et al. (2013), and K.Jankovic (2002)] implies the possibility of using crushed brick as a concrete aggregate, which would be a valuable contribution to the solution of the ecological handling problem, as well as an attempt to preserve natural resources. Depending on the type of brick products used to make the aggregate and its strength, this kind of material might be used to produce concrete of comparable compressive strength to concrete made of natural aggregates [F.M. Khalaf, and A.S.De Venny, (2004) and F.M. Khalaf, (2006)]. The thermal conductivity coefficient of such concrete is lower than the thermal conductivity coefficient of concrete containing natural aggregate [K.Jankovic (2002)], which also explains the better fire resistance of concrete with crushed bricks and tiles as an aggregate [F.M.Khalaf and A.S.DeVenny (2004)].

The performance of Lightweight Foamed Concrete with Waste Clay Brick as Coarse Aggregate was studied. Lightweight concrete that were produced with 25% substitution of waste clay brick showed the compressive strength and workability of the lightweight concrete increases when the waste clay brick is applied in lightweight concrete mix. But decrease of the percentage of waste clay brick lightweight concrete will be making higher of compressive strength. Waste clay brick able to provide high permeability and absorption on the durability performance of lightweight concrete [Norlia Mohamad Ibrahim et al. (2013) and Shyh-Haur Chen et al. (2013)].

In recent considered the use of the recycled aggregate from old concrete, clay brick and waste materials, many research were studied the effect of this recycled aggregates on the properties of concrete. The production of lightweight concrete is a careful one of the important special concrete using in special buildings in the last years, this research is to establish performance of recycle clay brick as a coarse aggregate to produce recycle concrete.

2. Research Significance

The main objective of this research is to establish the performance of recycle clay brick as a coarse aggregate to produce recycle concrete. The main variables of concrete mixes taken into considered in this study were the replacement ratio of clay brick to coarse aggregate, cement content, water cement ratios; chemical admixtures / cement ratio and silica fume / cement ratio on the properties and the durability of the recycle concrete. The properties of concrete made with crushed clay bricks replacing natural aggregates. The bricks were crushed in order to obtain a usable aggregate. The properties investigated were the density, the compressive strength, indirect tensile strength and flexural strength of hardened concrete, which it cured in salts and water maintained till the age of testing.

3. Experimental Program

The experimental program conducted in this study was performed in the laboratory of testing of building materials at the Faculty of Engineering, Menoufia University, Egypt. Cubes 10x 10 x10 cm, cylinders 10x20 cm and beams 10x10x40 cm. were cast and tested to determine the compressive strength, indirect tensile strength, flexural strength of concrete using crushed clay brick investigate as replacement of coarse aggregates with different ratios of water content, admixtures cement ratio and silica fume cement ratio on recycle concrete. The recycle concrete cured in water and salts maintained till the age of testing to measure the durability according to [ACI 201.2R-08], See table (1).

Table (1): Proportions of the Concrete Mixes Used.

Mixes	Cement kg/m^3	Sand	Course Aggregate		W/C	Add./C	S. F./C
			Dolomite	Clay Brick			
MC	350	1	2	0	0.5	0	0
M1	350	1	0	2	0.58	0	0
M2	350	2	0	3	0.55	0	0
M3	400	1	0	2	0.58	0	0
M4	400	1	0	2	0.53	1	0
M5	400	2	0	3	0.55	0	0
M6	450	2	0	3	0.55	0	0
M7	450	2	0	3	0.47	1	0
M8	450	2	0	3	0.46	1.5	0
M9	450	2	0	3	0.41	1.5	0
M10	450	2	0	3	0.39	1.5	0
M11	450	2	0	3	0.39	2	0
M12	450	2	0	3	0.43	1.5	10
M13	450	2	0	3	0.43	1.5	15
M14	450	2	0	3	0.39	2	15
M15	450	2	0	3	0.33	2.5	15

W/C = Water /Cement. Add./C= Admixture/Cement.
S.F./C= Silica Fume/Cement.

3.1. Materials

The fine aggregate used in the experimental program was of natural siliceous sand. Its characteristics satisfy the [E.C.P. 203/2007], [E.S.S. 1109/2008] and [ASTM C 33, 2003]. It was clean and nearly free from impurities with specific gravity 2.65 t/m^3 and modulus fineness 2.7.

The coarse aggregate used was of crushed dolomite, which satisfies the [E.C.P. 203/2007], [E.S.S. No. 1109\ 2008] and [ASTM C 33, 2003], Its specific gravity is 2.67 t/m^3 and modulus fineness 6.64. The shape of these particles was irregular and angular with a very low percentage of flat particles. The delivered crushed dolomite size 1 had a maximum nominal size of 9.5 mm.

The clay brick used was crushed from demolition of building and out of transfer. Clay brick is brought from factories of Egyptian Brick Companies. It was used as a coarse aggregate with a maximum nominal size of 9.5 mm. which satisfies the Egyptian Standard Specification [E.S.S. No. 1109\ 2008] and the American Society for Testing and Materials [ASTM C 33, 2003]. Its physical properties and Chemical analysis were obtained from the tests as in table (2).

Table (2): The Physical Properties and Chemical Analysis of clay brick

The properties	Results
Specific weight (gm./cm^3)	1.66
Unit weight (ton/m^3)	1.16 gm./cm^3
M.N.S.	9.5 mm
Absorption	8.2 %

The cement used was the Ordinary Portland cement, type (CEM (I) 42.5 N) produced by the Suez cement factory. Its chemical and physical characteristics satisfied the Egyptian Standard Specification [E.S.S. 4657-1/2009].

The water used was clean drinking fresh water free from impurities used for concrete mixing and curing the plain concrete specimens and the R.C. beams and slabs. It was tested according to the [E.C.P. 203/2007].

Super plasticizer used was a high rang water reducer HRWA. It was used to improve the workability of the mix. The admixture used was produced by CMB GROUP under the commercial name of Addicrete BVF. It meets the requirements of [ASTM C494 (type A and F]. The admixture is a brown liquid having a density of 1.18 kg/liter at room temperature. The amount of HRWA was 1.0 % of the cement weight.

Extra Marine Salt; Coarse white crystals with variable matters size extracted from sea water by solar evaporation with a small amount of insoluble matters. It produced by El-Max Salines Company. It produced according to the international specifications, and contains the following components (sodium chloride on dry basis 98:98.5% by weight, insoluble matters 0.15:0.25% by weight, soluble matters 1.35:1.75% by weight and moisture 3.5:4.5% by weight). The salt solution consisted of 30% salt (NaCl) and 70% water for curing the concrete mixes. It meets the requirements of [ACI 201.2R-08].

3.2. Concrete Investigation

Sixteen concrete mixes were cast and cured in this study to investigate the effect of using crushed clay brick as 100% replacement of coarse aggregate on the hardened properties of concrete mixes. The effect of using clay brick on the density and mechanical properties of the concrete as compressive strength, indirect tensile strength and flexural strength at different ages (7, 28, 90 and 180 days) was studied. The effect of curing conditions on the properties of recycle concrete was determined by curing the mixes in water and in salt solution (30% NaCl and 70% water). The main variables taken in to consideration were different cement content (350, 400 and 450 kg/m3), different water cement ratio (0.58 to 0.33), admixtures to cement ratio (0, 1, 1.5, 2 and 2.5%) and silica fume (0, 10 and 15%) of cement.

Preparation and Casting of Test Specimens: The samples were mixed and cast in steel cubes (100 x100 x100mm) cylinders (100 x 200 mm) and beams (500 x100 x 100 mm) after oiling its surface. The molds were placed on the vibration table at a low speed. After casting the specimens were covered with wet burlap in the laboratory at 24^{o}C and 68% relative humidity. The specimens were demolded after 24 hours and the concrete mixes cured in water and salt solution maintained till they were tested. The properties of the concrete mixes used are shown in table (1).

4. Analysis and Discussion of the Test Results

4.1. The Mechanical Properties of the Concrete Mixes

Feasibility was obtained the recycle concrete with replacement the clay brick as a coarse aggregate. The clay brick replacement ratio was 100% by volume of the total course aggregate (dolomite). The compressive strength, the indirect tensile strength and the flexural strength of all the recycle concrete mixes under investigated with different curing and different ages of tests were discussed in this section. The properties of different hardened concrete mixes are shown in table (3).

Table (3): The Properties of Different Hardened Concrete Mixes

Mixes	Density (gm/cm^3)	Compressive Strength (kg/cm^2)		Specific Compressive Strength * (kg/mm^2/g)	Indirect Tensile Strength (kg/cm^2)	Specific Indirect Tensile Strength * (kg/mm^2/g)	Flexural Strength (kg/cm^2)	Specific Flexural Strength * (kg/mm^2/g)
		7 days	28 days					
MC	2.34	170	250	106.8	25.2	10.8	50.4	21.54
M1	1.95	124	197	101	20	10.3	40	20.52
M2	1.97	132	205	104	20.8	10.6	41.6	21.1
M3	2	139	212	106	21.6	10.8	43	21.5
M4	2.04	156	229	112.3	23.2	11.4	46.4	22.74
M5	2.06	164	237	115	24	11.7	48	23.3
M6	2.07	172	245	118.4	24.8	12	49.6	24
M7	2.09	187	260	124.4	26.4	12.6	52.6	25.2
M8	2.11	204	277	131.3	28	13.2	56	26.6
M9	2.13	220	293	137.6	29.6	13.9	59.2	27.8
M10	2.15	235	308	143.3	30	13.6	60	28
M11	2.18	254	327	150	33	15.2	66	30
M12	2.19	472	345	157.5	34.8	11.75	69.6	31.8
M13	2.21	291	364	164.7	36.8	16.6	73.4	33.2
M14	2.23	311	384	172.2	38.8	17.4	77.4	34.78
M15	2.25	331	404	179.6	40.8	18.1	81.7	36.2

*Specific Compressive Strength28 = Compressive Strength28 / Density
*Specific Tensile Strength28 = Indirect Tensile Strength28/ Density,
*Specific Flexural Strength28 = Flexural Strength28 / Density

4.1.1 The Compressive Strength of Concrete

Figures (1 , 2 and 3) show that recycled concrete with density between 1.95 gm./cm^3 and 2.25 gm./cm^3 (83.3% and 96 %) of the control mix (normal concrete), and the compressive strength was between 197 kg/cm^2 and 404 kg/cm^2 (78.8% and 161.6%) of the control mix were obtained at 28 days ages. Increasing the cement content from 350 to 400 and 450 kg/m^3 improved the compressive strength of the recycled concrete. The mixes (M2, M5 and M15 give variable ratios of the compressive strength 82%, 94.8% and 161.6% compared to the control mix with different cement content 350, 400 and 450 kg/m^3 with curing in water. Improving the compressive strength was improved the specific compressive strength improved, the maximum specific compressive strength was M15 with the maximum compressive strength.

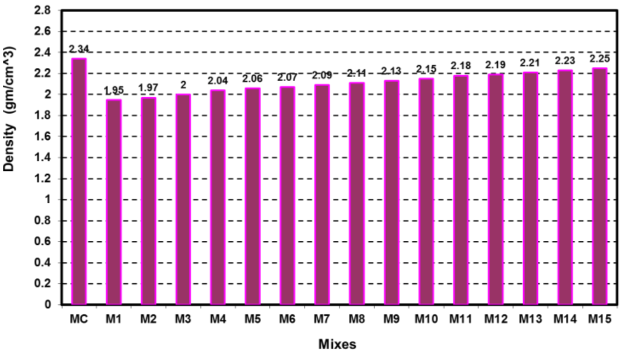

Figure (1): Density for all Mixes

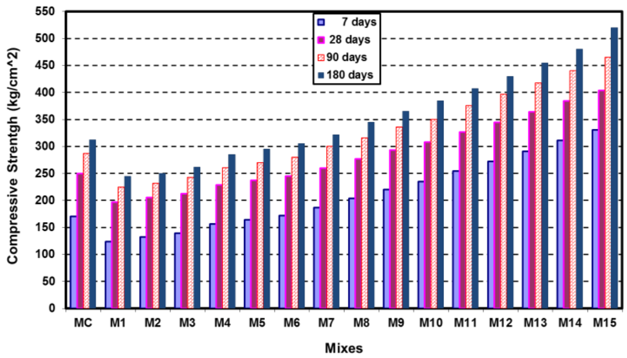

Figure (2): The Compressive Strength for all Mixes

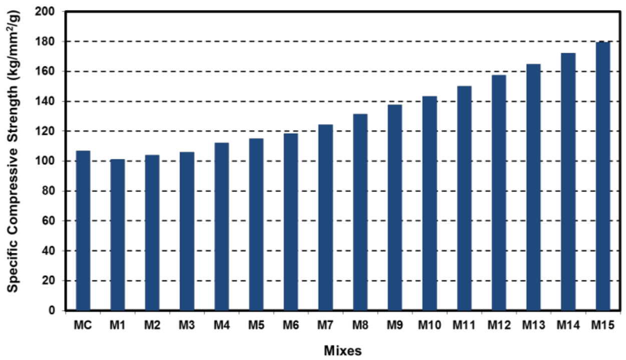

Figure (3): Specific Compressive Strength for all Mixes

At 90 days ages the compressive strength of the mixes (M2, M5 and M15 increased by about (13.17%, 13.9 and 15.1%) compared this mixes at 28 days age with different cement content 350, 400 and 450 kg/m^3. When the concrete mixes give variable ratios of the compressive strength by about (22 %, 24.5 % and 29 %) at 180 days compared to this mixes at 28 days ages with different cement content 350, 400 and 450 kg/m^3 with curing in water see figure (2).

Increasing the fine to coarse aggregates ratio increased the compressive strength by 4% for mix (M2) compared to the mix (M1) with cement content 350 kg/m^3, and the increasing of compressive strength was 11.8% for mix (M5) compared to the mix (M3) with cement content 400 kg/m^3. Then, the fine to coarse aggregates ratio 0.667 was used with cement content 450 kg/m^3 because this ratio is the best ratio for the strength of mixes with curing in water see figure (4).

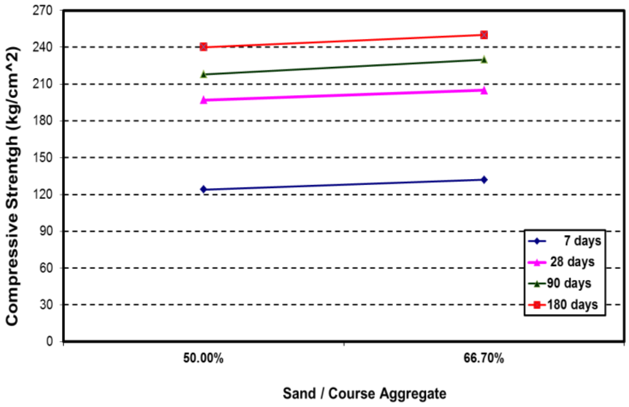

Figure (4): Effect of Sand / Coarse Aggregate Using Cement = 400 kg

The increasing of cement content of the recycled concrete improved the compressive strength by (7.6 and 24.4%) for mixes (M3 and M6) using cement content 400 and 450 kg/m3 compared to M1 with cement 350 kg/m^3 at the nearly W/C, but the improvement was 105% by reduction the water and using chemical admixtures compared to M1 with curing in water see figure (5).

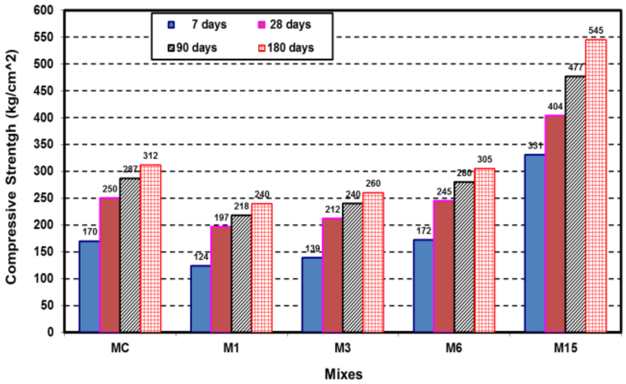

Figure (5): Effect of Cement Content on the Compressive Strength

Reduction of water cement ratio (W/C) in concrete mix improved the compressive strength as (4%) for mix (M2) with w/c as (0.55) compared to the mix M1 containing w/c ratio by 0.58, and 350 kg/m^3 of cement, where using cement content 400 kg/m3 and reduce w/c ratio from (0.58 to 0.53) increase the compressive strength by (8 %) for mixes M4 compared to the mix M3 with w/c ratio 0.58. however using cement content 450 kg/m^3 and reduce w/c ratio by (0.47, 0.46, 0.41, 0.39 and 0.33) increase the compressive strength by (6.1, 13, 19.6, 33.5 and 65%) for mixes M7, M8, M9, M11 and M15 compared to the mix M6 with w/c ratio 0.55. And when using cement content 450 kg/m^3 and silica fume /cement ratio 15% and reduce w/c ratio by (0.39 and 0.33) increase the compressive strength by (5.5 and 11%) for mixes M14 and M15 compared to the mix M13 with w/c ratio 0.43 and with curing in water see table (4) and figures (6 and 7)

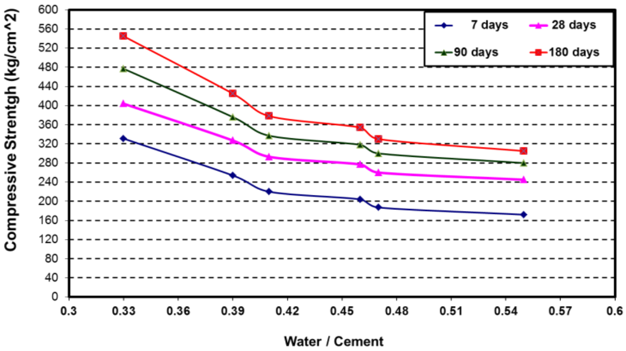

Figure (6): Effect of Water/Cement Ratio on the Compressive Strength Using Cement Content 450 kg/m^3

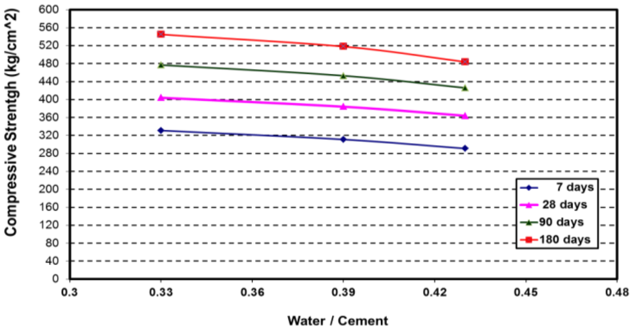

Figure (7): Effect of Water/Cement Ratio on the Compressive Strength Using Cement Content 450 kg/m^3 and 15% Silica Fume

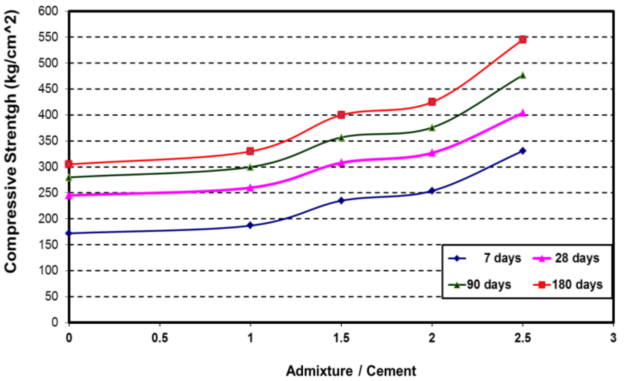

Figure (8): Effect of Admixtures on the Compressive Strength at Different Ages

Using Super plasticizer admixtures by 1% improve the workability of the mixes (M4) and enhancing the compressive strength by (8 %) compared to the mix M3(0% Admixtures) containing 400 kg/m^3 cement content however using cement content 450 kg/m^3 and the admixtures increasing by (1, 1.5, 2 and 2.5%) the compressive strength were enhancing by (6.1, 25.7, 33.5 and 65%) of the control mixes for the mixes (M7, M10, M11 and M15) compared to the mix M6 (0% Admixtures) with curing in water . as shown in figure (8).

Using silica fume (S.F.) as a replacement of cement by 10% and 15% for (M12 and M13) improves the compressive strength by (17.7 and 24.2%) respectively compared to M9 without (S.F.= 0%) for cement content 450 kg/m^3 with curing in water as shown in figure (9).

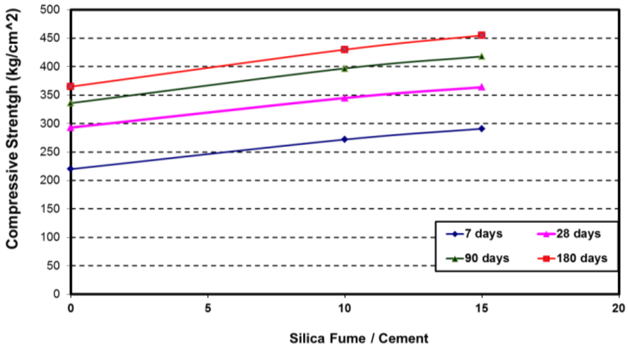

Figure (9): Effect of Using Silica Fume on the Compressive Strength at Different Ages

The compressive strength of recycle concrete mixes was improved by increasing cement content, decreasing w/c ratio, using admixtures and using silica fume because these lead to decrease the volume of voids in the mixes. The specific compressive strength of recycle concrete was improved because the density decreased compared to the control mix and the compressive strength was increasing with using chemical admixtures and reduction of W/C. The best recycle concrete mix using in the construction building was M15 for (cement content 450 kg/m^3, 0.33W/C, 15% Silica Fume/C and 2.5% Admixture/C) respectively with time in the range of this study.

However the curing in salt solution decreased the compressive strength by about (5% to 3.5%) at 28 days age. When the decreasing ratio of the compressive strength were by about (25% to 10%) at 90 days age and the compressive strength decreased by about (45% to 30%) at 180 days age. This means the improvement in the performance of recycle concrete increase the compressive strength ratio because the small volume of voids decreased the effect of salt solution and increased the durability of recycle concrete see figure (10).

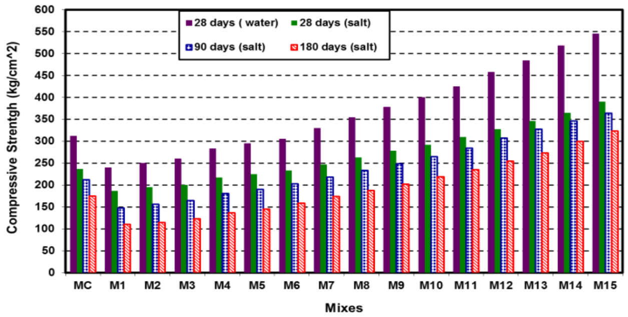

Figure (10): Effect of Curing in Salt Solution on the Compressive Strength at Different Ages for all Mixes

4.1.2 The Indirect Tensile Strength of Concrete

Figures (11 to 18) show that the indirect tensile strength of recycle concrete was improved by increasing cement content, reduction of water cement ratio (w/c), using admixtures and silica fume. Increasing cement content from 350 to 400 and 450 kg/m^3 improved the indirect tensile strength of recycle concrete. The mixes (M2, M5 and M15 give variable ratios of the indirect tensile strength 79%, 95.2% and 161.6% compared to the control mix with different cement content 350, 400 and 450 kg/m^3, then the maximum increasing of the indirect tensile strength of recycle concrete was at the mix M15 by 61.9 % with cement content 450 kg/m^3 compared to the control mix with curing in water. Improving the indirect tensile strength was improved the specific indirect tensile strength improved, the maximum specific indirect tensile strength was M15 with the maximum indirect tensile strength see figures (11 and12).

At 90 days and 180 days ages the indirect tensile strength of the mixes increased by about (5% and 5.5%) respectively compared this mixes at 28 days age with different cement content 350, 400 and 450 kg/m^3 with curing in water see figure (11).

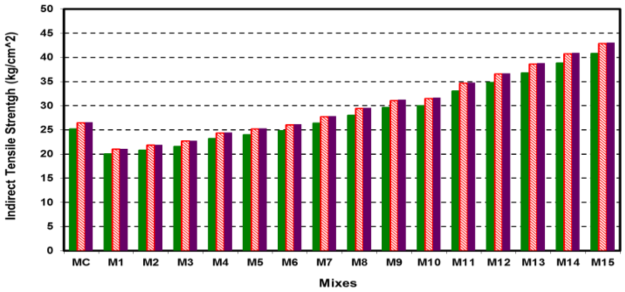

Figure (11): Indirect Tensile Strength for all Mixes at Different Ages

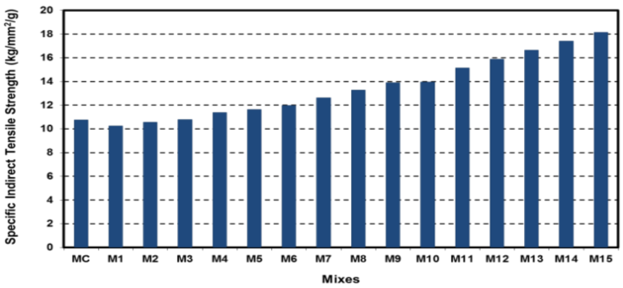

Figure (12): Specific Indirect Tensile Strength for all Mixes

Increasing the percentage of fine to course aggregates increased the indirect tensile strength by 4% for mix (M2) compared to the mix (M1) with cement content 350 kg/m^3, and the increasing of indirect tensile strength was 11.1% for mix (M5) compared to the mix (M3) with cement content 400 kg/m^3. The increasing of cement content of the recycle concrete improved the indirect tensile strength by (8 and 24%) for mixes (M3 and M6) using cement content 400 and 450 kg/m^3 compared to M1 with cement 350 kg/m^3 see figure (13).

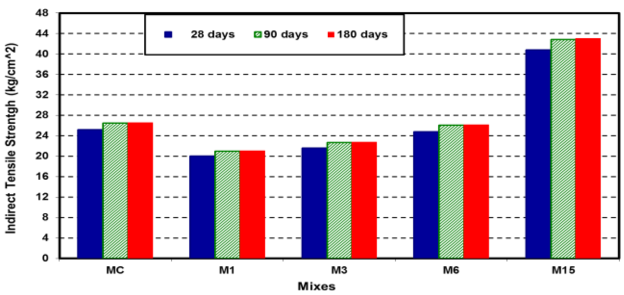

Figure (13): Effect of Cement Content on the Indirect Tensile Strength

Decreasing of water cement ratio (w/c) in concrete mix from (0.58 to 0.55) improved the indirect tensile strength as (4.1 %) for mix (M2) compared the mix M1with 350 kg/m^3, and for 400 kg/m^3 of cement the decreasing of W/C in concrete mix from (0.58 to 0.53) improved the indirect tensile strength as (7 %) for mix (M4) compared the mix M3. Decreasing W/C in concrete mix from (0.55, 0.47, 0.46, 0.41, 0.39 and 0.33) improved the indirect tensile strength as (13.8, 20.7, 27.6, 42.2 and 75.9 %) for mixes (M7, M8, M9, M11 and M15) compared the mix M6 with 450 kg/m^3 see figures (14 and 15).

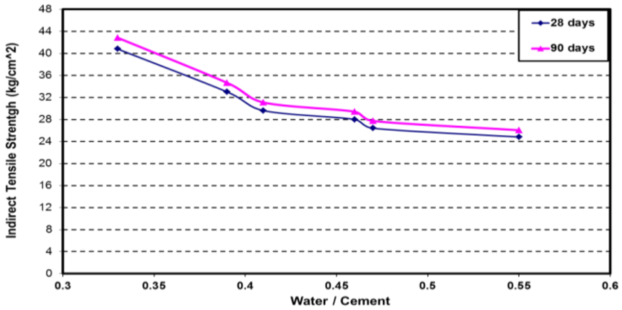

Figure (14): Effect of Water / Cement on the Indirect Tensile Strength Using Cement Content = 450 kg/m^3

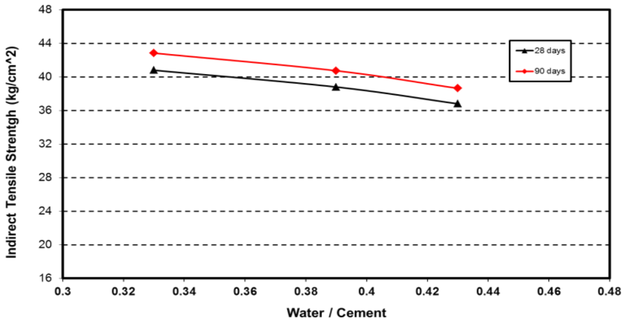

Figure (15): Effect of Water / Cement on the Indirect Tensile Strength Using Cement Content = 450 kg/m^3 with 15% Silica Fume

Increasing of super plasticizer admixtures to cement by 1% of mix (M4) enhance the indirect tensile strength by (7.4%) compared the mix M3 with (0% Admixtures) and cement content 400 kg/m3, however the increasing of super plasticizer admixtures to cement by (1, 1.5, 2 and 2.5) of mixes (M7, M10, M11and M15) enhance the indirect tensile strength by (6.4, 21, 33 and 64.5%) compared the mix M6 with (0% Admixtures) and cement content 450 kg/m^3 see figure (16).

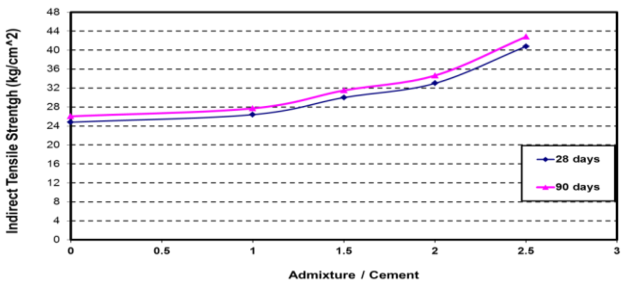

Figure (16): Effect of Admixtures on the Indirect Tensile Strength

Increase of using silica fume (S.F.) as a replacement of cement to 10% and 15% (M12 and M13) improve the indirect tensile strength by (17.6% and 24.3%) for cement 450 kg/m^3 see figure (17).

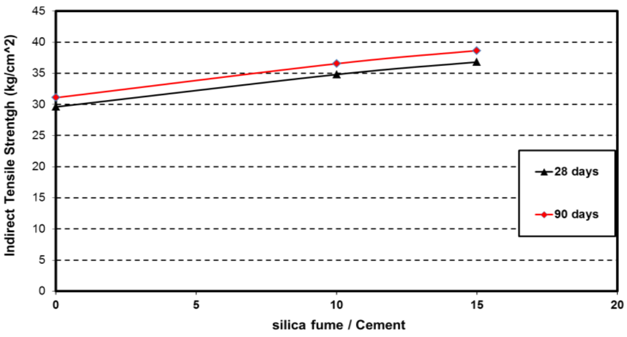

Figure (17): Effect of Silica Fume on the Indirect Tensile Strength

Increasing cement content, decreasing w/c ratio, using admixtures and using silica fume improved the indirect tensile strength of recycle concrete mixes because these lead to decrease the volume of voids in the mixes. The specific indirect tensile strength of recycle concrete was improved because the density decreased compared to the control mix and the indirect tensile was increasing with using chemical admixtures and reduction of W/C.

However the curing in salt solution decreased the indirect tensile strength by about (5% to 2.9%) at 28 days age. When the decreasing ratio of the indirect tensile strength were by about (25% to 10%) at 90 days age and the indirect tensile strength decreased by about (43% to 20%) at 180 days age. This means the improvement in the performance of recycle concrete increase the indirect tensile strength ratio because the small volume of voids decreased the effect of salt solution and increased the durability of recycle concrete with time in the range of this study, see figure (18).

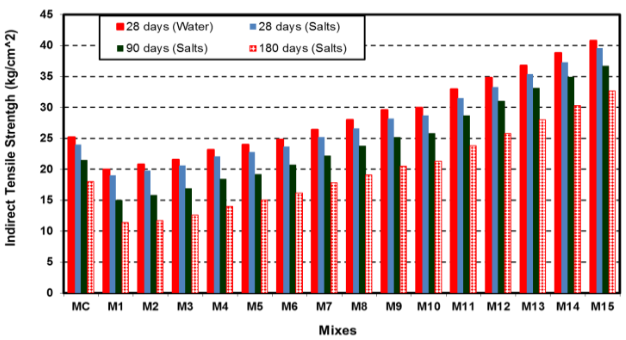

Figure (18): Effect of Curing in Salt Solution on the Indirect Tensile Strength at different ages

4.1.3 The Flexural Strength of Concrete

Figures (19 to 26) show that the flexural strength of the recycle concrete was increased by increasing cement content, reduction of water cement ratio (w/c), using admixtures and silica fume. Increasing cement content from 350 to 400 and 450 kg/m^3 improved the flexural strength of the recycled concrete. The mixes (M2, M5 and M15 give variable ratios of the flexural strength 82.5%, 95.2% and 161.5% compared to the control mix with different cement content 350, 400 and 450 kg/m^3, then the maximum increasing of the flexural strength of recycle concrete was at the mix M15 by 61.5 % with cement content 450 kg/m^3 compared to the control mix with curing in water. Improving the flexural strength was improved the specific flexural strength improved, the maximum specific flexural strength was M15 with the maximum flexural strength. At 90 days and 180 days ages the flexural strength of the mixes increased by about (5% and 5.5%) respectively compared this mixes at 28 days age with different cement content 350, 400 and 450 kg/m^3 with curing in water see figures (19 to 21).

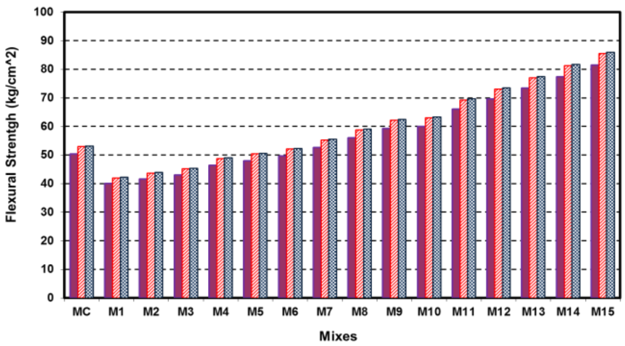

Figure (19): Flexural Strength of all Mixes

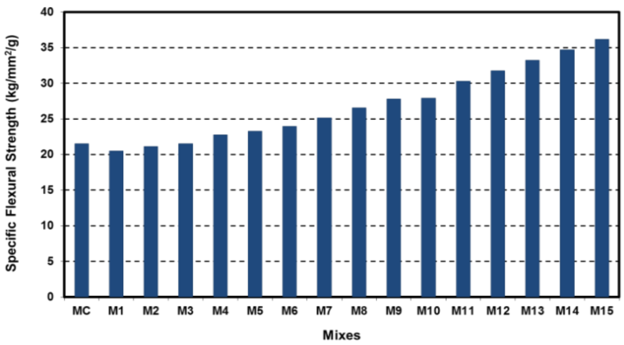

Figure (20): Specific Flexural Strength of all Mixes

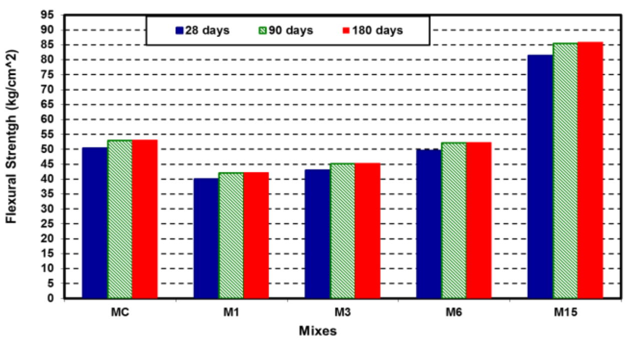

Figure (21): Effect of Cement Content on Flexural Strength

Increasing the percentage of fine to course aggregates increased the flexural strength by 4 % for mix (M2) compared to the mix (M1) with cement content 350 kg/m^3, and the increasing of flexural strength was 11.6 %

for mix (M4) compared to the mix (M3) with cement content 400 kg/m^3. However the increasing of cement content of the recycled concrete improved the flexural strength by (7.5 and 24%) for mixes (M3 and M6) using cement content 400 and 450 kg/m^3 compared to M1 with cement 350 kg/m^3.

Decreasing of water cement ratio (w/c) in concrete mix from (0.58 to 0.55) improved the flexural strength as (4%) for mix (M2) compared the mix M1with 350 kg/m^3, and for 400 kg/m^3 of cement the decreasing of W/C in concrete mix from (0.58 to 0.53) improved the flexural strength as (7.7 %) for mix (M4) compared the mix M3. Decreasing W/C in concrete mix from (0.55, 0.47, 0.46, 0.41, 0.39 and 0.33) improved the flexural strength as (6, 12.9, 19, 33 and 64 %) for mixes (M7, M8, M9, M11 and M15) compared the mix M6 for cement content 450 kg/m^3 see figures (22 and 23).

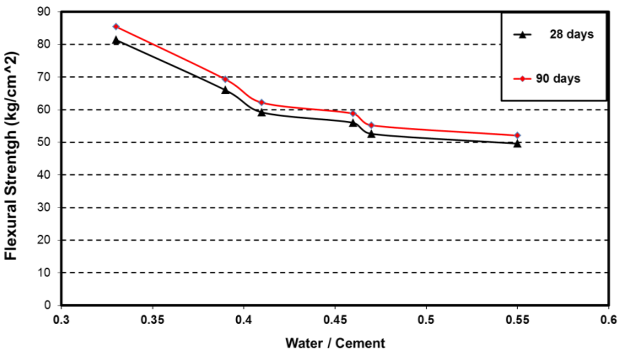

Figure (22): Effect of Water / Cement on the Flexural Strength Using Cement = 450 kg

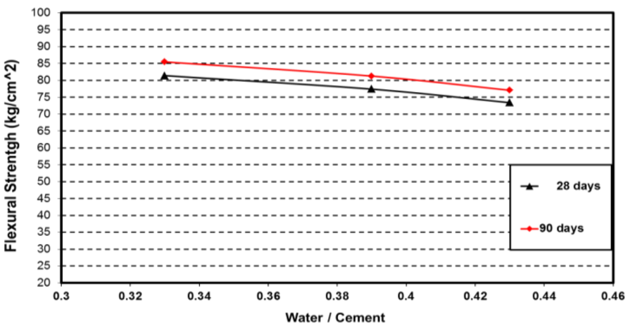

Figure (23): Effect of Water / Cement on the Flexural Strength Using Cement = 450 kg and 15% Silica Fume

Increasing of super plasticizer admixtures to cement by 1% of mix (M4) enhance the flexural strength by (8%) compared the mix M3 with (0% Admixtures) and cement content 400 kg/m^3, however the increasing of super plasticizer admixtures to cement by (1, 1.5, 2 and 2.5) of mixes (M7, M10, M11and M15) enhance the flexural strength by (6, 21, 33 and 64%) compared the mix M6 with (0% Admixtures) and cement content 450 kg/m^3. Increase of silica fume (S.F./ C) as a replacement of cement to 10% and 15% (M12 and M13) improve the flexural strength by (17.6% and 24 %) for cement 450 kg/m^3, see figures (24 and 25).

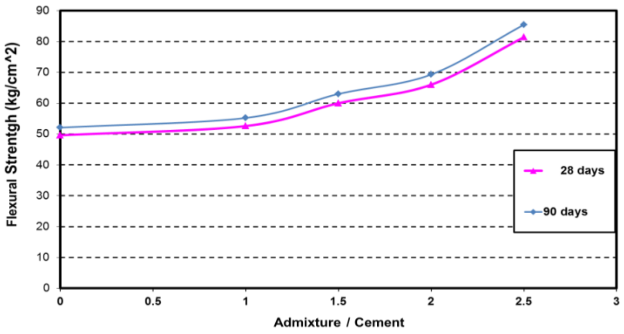

Figure (24): Effect of Admixtures on the Flexural Strength

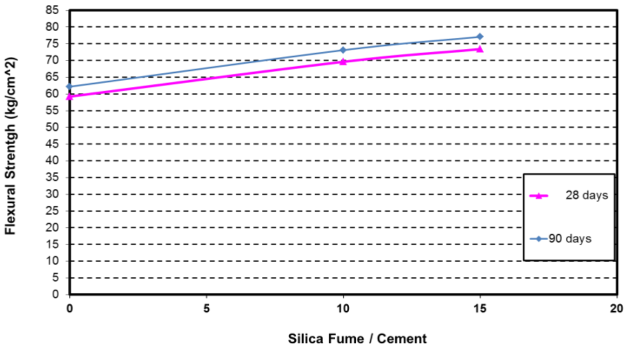

Figure (25): Effect of Silica Fume on the Flexural Strength

Increasing cement content, decreasing w/c ratio, using admixtures and using silica fume improved the flexural strength of recycle concrete mixes because these lead to decrease the volume of voids in the mixes. The specific flexural strength of recycle concrete was improved because the density decreased compared to the control mix and the indirect tensile was increasing with using chemical admixtures and reduction of W/C.

However the curing in salt solution decreased the flexural strength by about (5% to 2.9%) at 28 days age. When the decreasing ratio of the flexural strength were by about (25% to 10%) at 90 days age and the flexural strength decreased by about (43% to 20%) at 180 days age. This means the improvement in the performance of recycle concrete increase the flexural strength ratio because the small volume of voids decreased the effect of salt solution and increased the durability of recycle concrete with time in the range of this study see figure (26).

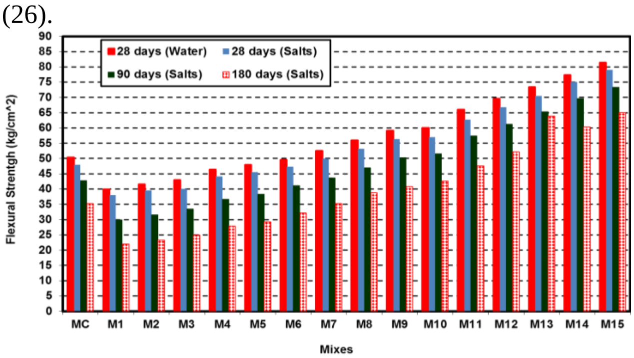

Figure (26): Effect of Curing in Salt Solution on the Flexural Strength for all Mixes at Different ages

Conclusion

The following conclusions are derived based on the conducted experiments

1) A recycle concrete has been successfully produced and improved its properties by using crushed clay brick and different of other components.
2) Production of recycle concrete and could be achieved to be applied for super structural works not the foundations as well as density of artificial applications.
3) The hardened properties of recycle concrete have been successfully improved better than ordinary concrete by using chemical admixtures, silica fume and reducing water cement ratio.
4) The recycled concrete with clay brick was low density compared to control (normal concrete)
5) Can be obtained in the compressive strength 404 kg/cm^2, indirect tensile strength of 40.8 kg/cm^2 and flexural strength of 81.4 kg/cm^2 by using cement content 450 kg/m^3 in recycle concrete mix.
6) Different amounts of cement, silica fume, and super plasticizer with 100% replacement of the dolomite aggregate by clay brick aggregate led to concrete mixes with wide span of different physical and mechanical properties.
7) Clay brick as replacement of coarse aggregate in concrete mixes without any admixtures, at the same of cement and water cement ratio decreased the compressive strength, the indirect tensile strength and the flexural strength compared to the normal concrete.
8) Increasing water cement ratio decreases the compressive strength, indirect tensile strength and flexural strength.
9) Increases cement content than 350 kg with different W/C increases the compressive strength, indirect tensile strength and flexural strength.
10) The optimum replacement ratio of S.F. to cement was 15% with cement content 450 kg.
11) The specific compressive, tensile and flexural strength increased by a larger increase in the control mix because the weight of concrete became lighter.
12) The less density of recycle concrete lead to higher isolation sound and heat.

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