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Recycled refractory brick and Kaolin in Green concrete production

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Abstract : *The paper presents results of three studies on concrete mixes containing calcined clay to produce green concrete. The first type (Type I) was Metakaolin (600° K Calcination), second type (Type II) was calcined kaolin in high temperature (1000°K) and (Type III) was a waste crushed refractory brick. The first study was to replace 20% of Portland cement by (Type I) and also with (Type II). In the second study fine aggregate was replaced by 20% (Type I) and (Type II). The last study was with crushed refractory brick. Fine and coarse aggregate were replaced by 20% (Type III). Normal grade of concretes containing calcined clay were prepared in six mixes. The Setting times and normal consistency of pastes were determined. Workability, Compressive strength, tensile splitting and flexural strength were checked against the control concrete mix. The study recommended calcined clay as a worthwhile alternative material instead of Portland cement with consideration of water requirement. The research recommends using recycled refractory crushed brick as a green aggregate for production of concrete with recycled materials*

Keywords - *Green concrete, Calcined Clay, kaolin, Meta kaolin, recycled refractory Clay brick.*

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I Introduction

It is now known that cement manufacturing process is one of the most effectual reasons that cause the problem of CO2 emission in atmosphere. Researchers are interested in Green Concrete as a suggested solution. Bambang Suhendro[1] summarized the definition of Green Concrete as a concrete which uses waste materials, or its production process does not lead to environmental impact, or it has high performance. Obla [2] noted that reuse / recycling of materials can help in CO2 emission reduction. Tarun R. Naik were agree with the previous results [3] M.Shahul &Sekar[4] showed an excellent result in them research about Quarry rock dust and marble sludge powder as fine aggregate. Also Micheal Berry [5] tried to produce green concrete with 100% fly ash instead of ordinary Portland cement and he examines its properties. C. Meyer [6] pointed out that the economic factors in using recycled materials in Green concrete production. Imbabi [7] reviewed some benefits of green alternatives of cement. Rajwala D.B [8] and others concluded that each of compressive, split tensile and flexural strength increases about 40% when use flies ash instead of ordinary Portland cement .Al Bakri. [9] Agreed with the previous conclusion. Amankwah and others [10] studied partial replacement of ordinary Portland cement with (0 -25) % calcined clay. It will be good if the developing countries can use the refractory brick which came out from rebuilding the furnaces in many factories. The paper represents an experimental work in green concrete production from waste refractory brick and also from kaolin calcined clay.

II Materials

Three calcined clay types were selected, the first and second were Metakaolin and kaolin respectively produced by " Asfour factory for mining and refractories" located in Helwan city in Egypt. Kaolin fired up to the temperature of 1000^o C and Metakaolin fired up to the temperature of 500^o C depending on Asfour factory datasheets. third type of calcined clay was waste crushed refractory brick obtained from" Helwan cement factory" for Portland cement production which located in Helwan city in Egypt . The samples of kaolin and Metakaolin were labeled as Type I and Type II and the sample of waste refractory brick was labeled as Type III. The physical and chemical properties of kaolin and Metakaolin were shown in table (1) to table (3). The admixtures used were super plasticizing named X-Mix GTA produced by NCC construction chemicals Egypt. Cement was (Type52.5 N) produced by the Sinai cement factory respecting the requirements of the Egyptian Standards [(ESS. 4657-1/2009)] [11]. Coarse aggregate was crushed dolomite from North Sinai quarry, has maximum size and specific gravity of 12.5 mm, and 2.70 respectively, which satisfies the Egyptian Standard

Specification (ESS. 1109\ 2010)][12]. Fine aggregate was siliceous sand from North Sinai quarry; it has specific gravity of 2.50.

Table (1) Chemical composition of kaolin

Chemical composition	Percentage %
AL2 O3	36 – 40
Fe2 O3	1.3 -1.8
SiO2	54 – 58
TiO2	1.5 – 2.5
CaO	0.3 – 0.4
MgO	0.1 – 0.2
K2O+ NaO	0.2 - 0.4

Table (2) Physical properties of kaolin

Grain size distribution	Percentage %
> 100 µ	0.5 – 2
>63µ	17 – 22
<63µ	75 -82

Table (3) physical composition of Metakaolin

Element	*Result %*
L.O.I	*6 -7 %*
Al2O3	*28 - 31 %*
SiO2	*57 -60 %*
Fe2O3	*1.5 -1.7 %*
TiO2	*1.5- 2.5 %*
CaO	*1% Max*
Mg O	*0.2 %Max*
Na2O+K2O	*0.3% Max*
Sieve Analysis	*max>500µ =3 %*

Fig (1) Recycled refractory brick after crushing and grading

Fig (2) Recycled refractory brick

III Experimental program

3.1 Mix Proportions and Specimen

In the study Ordinary Portland cement was partially replaced with 20% of (Type I) and 20% of (Type II). Then fine aggregate was partially replaced with 20% of (Type I) and (Type II). Then fine and coarse aggregate were replaced with 20% crushed graded waste refractory brick (Type III).Table (4) presents the mix definition , table (5) presents mixtures proportions of the designed calcined clay concretes. The standard consistency and setting times of the cement and kaolin paste mixtures were determined with the Vicat apparatus. The workability of the fresh formulated concrete mixes was measured using the slump flow procedure.

Table (4) Mix definition

Mix name	Mix definition
Ref. Mix	Control mix without any calcined clay
20% MK, 80% C	20% metakaoline instead of Portland cement
20% K ,80% C	20% kaoline instead of Portland cement
20% MK,80% F.A	20% metakaoline instead of fine aggregate
20% R , 80% A	20 % recycled refractory crushed brick instead of fine and coarse aggregate.
20% k , 80% F.A	20% kaoline instead of fine aggregate

Table (5) Mix proportions of concrete for one cubic meter

Mix Name		Ref. mix	20% MK, 80% C	20% K ,80% C	20%MK,80% F.A	20% R , 80% A	20% k , 80% F.A
Cement kg		450	360	360	450	450	450
Meta kaolin kg		---	90	---	120	---	---
Kaolin kg		---	---	90	---	---	120
Fine agg. kg		600	600	600	480	540	480
Coarse agg.kg		1200	1200	1200	1200	1080	1200
Water litter		170	170	170	170	170	170
Admixture lt		10	10	10	10	10	10
Recycle agg. kg	Fine	---	---	---	---	60	---
	coarse	---	---	---	---	120	---

3.2 Testing of Concrete Cubes and Prisms

The concrete prisms cured by putting in water. The specimens attain a saturated dry state before the test. The concrete cubes were tested by compressive machine at different ages to determine compressive strength .Tensile splitting test was on the cylinders and flexural strength test was done on the prisms. Average result of three concrete specimens was determined and represents the values of the compressive, tensile splitting and flexural strengths. Abrasion test was carried out on 70 mm cubes by 500 cycles.

IV Results and Discussions

4.1 Standard Consistency and Setting Time

The effect of calcined clay types on standard consistency and setting times of Portland cement were shown in Tables (6) by Vicat apparatus. The table shows that the amount of water required for the desired consistency for Type I and Type II pastes increased ranging from 17% and 35% respectively as compared to the control paste. The initial and final setting times of both types of calcined clay (Type I & II) paste were increased. The increases in initial and final setting times for the Type II were 22% & 8% respectively, Type I was 44% &12% respectively.

Table (6) Setting times & water required for standard consistency

Paste type	Control cement paste with 400 gm cement	320 gm Cement &80 gm Type II paste (20% replacement)	320 gm Cement &80 gm Type I paste (20% replacement)
Water required for standard consistency (Litter)	0.125	0.170	0.145
Initial setting. Time(mins)	90	110	130
Final setting. Time (mins)	230	250	280

4.2 Workability of Fresh Concrete

Table (7) and fig (3) show slump flow results. Control result was 120 mm. The control mix (with ordinary Portland cement only) had better slump result than the cement calcined mixtures generally. Concretes that contained any of the calcined clay either Type I or Type II had a lower slump than the control. This could be attributed to the fact that the high surface area of the kaolin increased the water demand for the cement-kaolin system and therefore for a given water-cement ratio and cement content, the workability of the mixtures which contain koaline and metakoaline were lower. This observation was so clear in result of mix (20%K 80%F.A) which has 20% fine aggregate replacement by kaolin**.** It is a logic observation because of the surface area of the particles.

Table (7) slump result of mixtures

MIX Name	Ref. mix (1)	20%MK 80%C (2)	20%K 80%C (3)	20%MK 80% FA (4)	20%R 80% A (5)	20%K 80%FA(6)
Slump (mm)	120	30	17	24	50	5

Fig (3) different mixtures slump flow results

4.3 Compressive Strength

Compressive strength results of Type I, II and III and cement concretes are shown in table (8) and Figures from (4) to (8) the figures show that the concrete strength of all mixtures increased with curing time. The improvement of calcined clay concretes types I and II was more pronounced after 28 days and 56 day of moist curing. Virtually all mixes at 28 day were less than the reference mix except mix (20%recycle/ 80% agg) the mix having recycled refractory brick aggregate. Mix no (20%R/ 80% A) has compressive strength up to 2 % of the control mix at 28 day. For mix (20%MK 80%C) the compressive strength was less than the reference mix at age of 7 and 28 days by an average of 36 , 28 % respectively. The decrease in strength was observed for mix (20%K.80%C) which has 20% kaolin instead of cement. For mix (20%MK 80% F.A) which have 20 % Metakaolin instead of fine aggregate the reduction in compressive strength at 7, 28 and 56 day were so small. For mix (20%R 80% A) which has 20 % crushed recycled refractory brick instead of fine and coarse aggregate the observation was different. Compressive strength of mix no (20%R 80% A) are similar to those of control mix at different ages.

Table (8) compressive strengths test result of mixtures

Mix . NAME	7 day compressive strength Kg/cm2	28 day compressive strength Kg/cm2	56 day compressive strength Kg/cm2
1	425	525	600
2	275	385	615
3	330	430	465
4	430	505	555
5	425	540	615
6	250	350	550

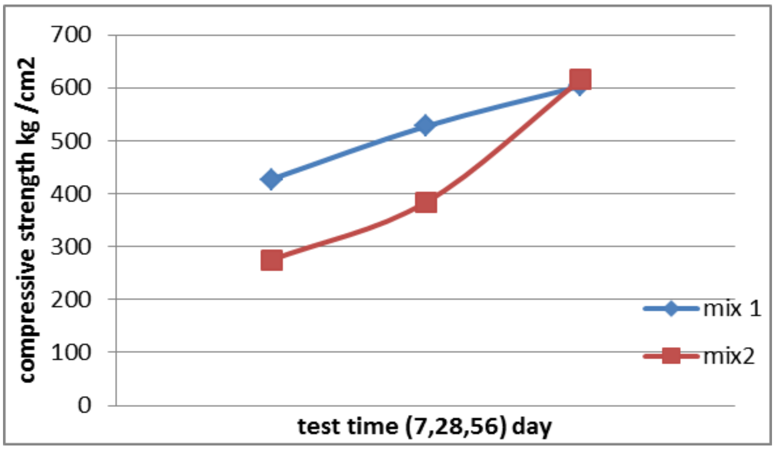

Fig (4) age of concrete with compressive strength for mix 2 (20% MK/ 80% C)

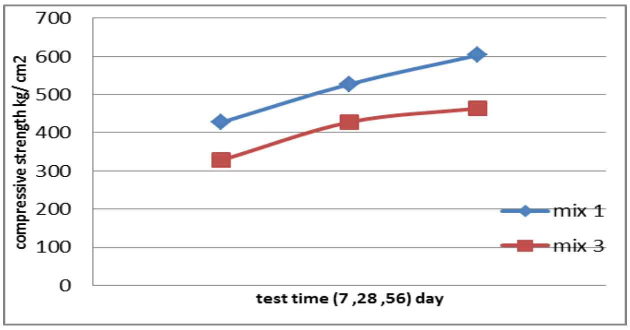

Fig (5) age of concrete with compressive strength for mix 3 (20%K,80%C)

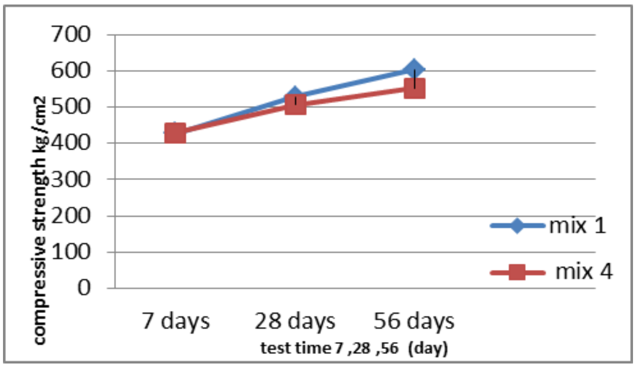

Fig (6) age of concrete with compressive strength for mix 4 (20%MK,80% F.A)

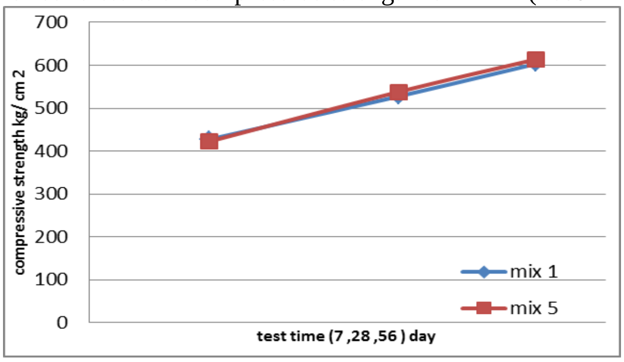

Fig (7) age of concrete with compressive strength for mix 5(20%R /80% A)

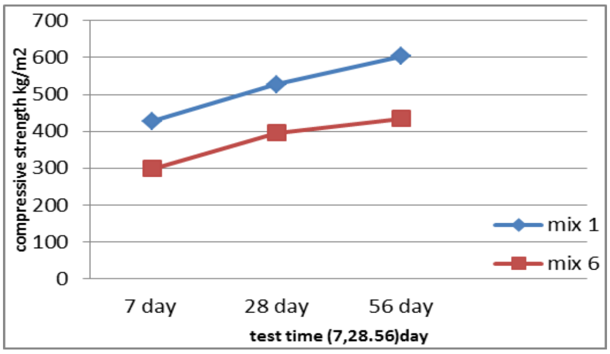

Fig (8) age of concrete with compressive strength for mix 6 (20% K, 80%F.A)

4.4 Flexural Strength

Figure (9) and table (9) present the flexural strength results at age 28 days of Type I, II and III concrete mixes. Flexural strength results decreased with using kaolin, Metakaolin and recycled calcined clay aggregate also. . Mix (20%R , 80% A) has the highest result of the Flexural strength.

Table (9) Flexural strength results

Mix no.	Flexural strength kg/cm2	Ratio to control mix (%)
Ref. mix	70	100
20%MK ,80%C	65	92.8
20%K ,80%C	60	85.7
20%MK ,80% F.A	65	92.8
20%R ,80% A	75	107
20%K ,80%F.A	60	85.7

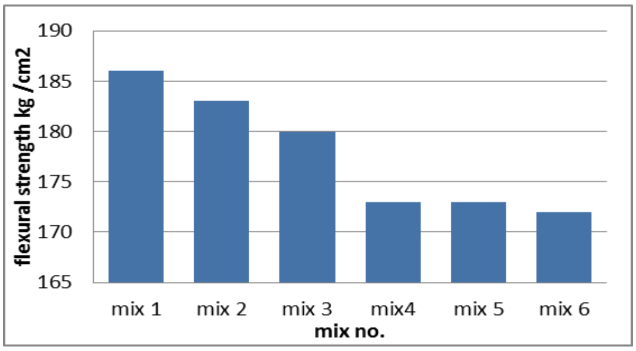

Fig (9) flexural strength Mixes bar chart

4.5 Splitting tensile strength

Figure (10) and table (10) present splitting tensile strength results at age 28 days. Mix (20%R,80% A) has the highest result of the tensile splitting strength as shown in table (10). On the other hand the decreases in splitting strength in the other mixes were not so high.

Table (10) tensile splitting strength results

Mix no.	Tensile splitting strength kg/cm2	Ratio to control mix (%)
Ref. mix	37.2	100
20%MK ,80%C	32.2	87
20%K ,80%C	30.0	80
20%MK ,80% F.A	33.6	90
20%R ,80% A	38.7	104
20%K ,80%F.A	25.4	68

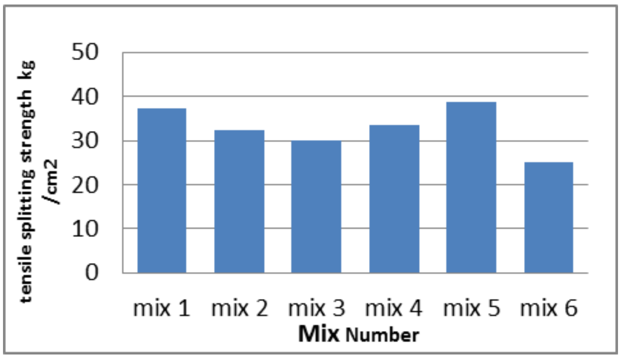

Fig (10) tensile splitting strengths bar chart

4.6 Abrasion test

Table (11) shows the percentage between weight loss of reference mix and other mixes after abrasion test with 500 cycles. The differences of weight loss in studied mixes were not so high.

Table (11) weight loss due to Abrasion test for different mixes

Mix no	Ref. mix	20%MK 80%C	20%K 80%C	20%MK 80% F.A	20%R 80% A	20%k 80%F A
Percentage of weight loss (%)	0.57%	0.46%	0.57%	0.64%	0.47%	0.48%
Ratio of weight loss to that of Control mix (%)	100%	80.7%	100%	112.3%	82.4%	84.2%

V. Conclusion

Based on the results obtained from the investigations, the following conclusions are drawn:

1) The addition of calcined clay (Kaolin and Metakaolin) to Portland cement increases the water demand need to standard consistency of the blended Portland cement mixtures.

2) The addition of calcined clay (Kaolin and Metakaolin) to Portland cement increases the initial and final setting time of paste.

3) The addition of calcined clay (Kaolin and Metakaolin) to concrete mixtures increases the need of water to reach the suitable workability.

4) The compressive strengths of calcined clay (Kaolin and Metakaolin) concrete mixes were less than that of control concrete mix at early age of 7days.

5) The reduction of compressive strengths of calcined clay (Kaolin and Metakaolin) concretes decreased by time.

6) The addition of calcined clay (recycled refractory brick) increases the compressive strength at age of 28 and 56 days.

7) The addition of Kaolin and Metakaolin decrease flexural and splitting tensile strengths by very small value. However, the addition of recycled refractory brick may increase splitting tensile strength.

9) The addition of Metakaolin does not effect on abrasion resistance of concrete. However, the addition of refractory brick and kaolin reduce the abrasion resistance of concrete by small value.

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