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Full Length Research Paper

Developing a Green Concrete Using Recycled Material and Cement alternatives

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Abstract
Nowadays recycling of waste and industrial by-product materials is an environmental and economic necessity. Utilization of these materials to develop concrete contributes to their disposal and environment preservation; this concrete is defined as green concrete. This study performed to evaluate properties of green concrete developed using aggregate of crushed refractory brick, with different by-product materials as a cement replacement material. Evaluated properties were the workability of fresh concrete and compressive strength, tensile strength, and modulus of elasticity for hardened concrete. The results indicate that properties of green concrete with crushed refractory brick and by-product as cementitious material indicate the usability of developed green concrete in different applications. Also, it is found that concrete mixes containing aggregate of crushed refractory brick with industrial by-products of 10% silica fume or 10% metakaolin or 10% dealuminated kaolin as cement replacement materials appear to be the optimal concrete mixes.

Keywords: *Green Concrete, Crushed refractory bricks, Cement replacement, Strength*

Introduction

Green Concrete is a term that does not express the color of the concrete, but it refers to concrete made using recycled material or industrial waste material. Green concrete is eco friendly and saves the environment by using various by products such as dust, silica fume, fly ash, solid waste, marble granules, metakaolin, etc.

Previous studies have been conducted to investigate the potential of using demolished concrete and crushed clay brick as alternate aggregate and its influence on the properties of the fresh and hardened recycled concrete [1]. The physical and mechanical properties of solid cement brick manufactured with crushed clay brick as a recycled aggregate have been reported by [2]. Effect of clay brick powder on concrete mechanical properties has been reported by [3]. The statistical analysis showed that RCA derived from crushed concrete consists of 65–80 % of natural coarse and fine aggregates and 20–35 % of old cements paste [4]. It was reported that the mortar in RCA contributes to a lowered relative density and higher water absorption than virgin aggregate [5]. The higher portion of attached mortar and weaker interface between aggregate and mortar in RCA lead to lower concrete quality such as low Compressive strength and poor durability. The compressive strength in the recycled concrete with 25% and 50% replacement ratios was 8.7%–15.9% and 15.1%–18.4% lower than that of the controlled concrete with no recycled aggregate at 7 and 28 days of curing, respectively as reported in [6]. In this paper, an experimental investigation is presented to evaluate properties of green concrete produced using crushed refractory brick as aggregate with by-product material;silica fume,metakaolin,and dealuminated kaolin as cement replacement.

Research Objectives

This study aim to evaluate utilization of recycled and waste materials like the crushed refractory bricks and industrial by-product materials to produce eco-friendly green concretes and suitable for structural works.

Experimental Study

Materials

Aggregate: As shown in Fig.1, a crushed refractory brick of maximum size of 9.5 mm and fineness modulus of 5.41 was used herein as coarse and fine aggregate. Sieve analysis and physical properties of crushed refractory bricks, are shown in Fig. 2 and Table 1 respectively.

Fig 1. Crushed refractory brick

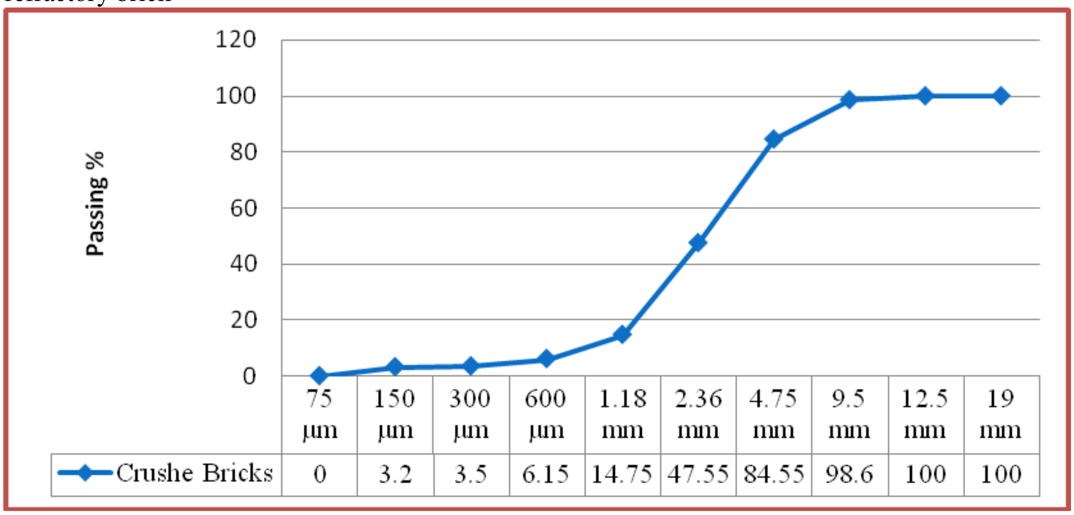

Fig 2. Grading of Aggregate

Table 1. Physical Properties of crushed refractory brick

Physical Property	Value
Specific Gravity of oven dry	2.75
Dry rodded weight (kg / m^3)	2048
Nominal max.Size (mm)	9.5
Absorption by weight %	1.93

Cementitious materials

-Cement: Ordinary Portland cement (OPC) CEMI-42.5N that meets the ASTM C150 requirements was used [7]. Composition of (OPC) presented in Table 2.

- Silica fume (SF): is a by-product during manufacture of ferrosilicon alloys in The Egyptian Chemical Industries - Kima, Aswan – Egypt. The chemical composition of silica fume shown in Table2.

-Metakaolin (MK) and de-aluminated kaolin (DK): are by-products of alum industry by Egyptian Aluminum Sulphate Company, their chemical composition presented in Table 2.

Chemical admixture

- Super plasticizer: Sikament-163M high range water reducer (HRWR) complies with ASTM C494 type F was used as a super plasticizer additive [8].

Water: Potable tap water complies with ASTM C 94 has been used in mixing and curing concrete.

Table 2. Composition of (OPC), silica fume, metakolin and de-aluminated kaolin.

Main Components	Percentage by weight %			
	OPC	SF	K	DK
SiO2	21.36	91.50	65.92	83.00
Al2O3	5.57	0.65	22.56	5.00
Fe2O3	3.35	0.30	0.90	0.50
CaO	62.50	0.90	0.36	0.08

Concrete Mix Design

Mix proportioning of concrete is based on the ACI Manual of Concrete Practice (ACI 211.1, 2004) [9]. Employing the sequence outlined in that standard practice, the quantities of ingredients per cubic meter of concrete given in Table 3.

Mixing, casting, Test Specimens and Instrumentations

Mixing was carried out in a 60 kg revolving electric mixer of pan drum type. Then concrete was cast into steel moulds immediately after mixing. Vibrating table has been used in consolidating concrete. Specimens were removed from moulds after 24 hours and cured in clean water for 28 days**.** Specimens of 15x15x15 cm were used for compressive Strength tests, while cylindrical specimens of 15x30 cm were used in both of splitting tensile strength and elastic modulus tests.

Table 3..Concrete Mix Proportions (kg / 1 m^3 Concrete)

Mix designation	Crushed R.Brick	Cement	SF	MK	DK	Water	HRWR (1.5%)
Control mix (CM)	1857	450	0	0	0	181	6.75
S5	1857	427.5	22.5	0	0	181	6.75
S10	1857	405	45	0	0	181	6.75
S15	1857	382.5	67.5	0	0	181	6.75
M5	1857	427.5	0	22.5	0	181	6.75
M10	1857	405	0	45	0	181	6.75
M15	1857	382.5	0	67.5	0	181	6.75
D 5	1857	427.5	0	0	22.5	181	6.75
D10	1857	405	0	0	45	181	6.75
D15	1857	382.5	0	0	67.5	181	6.75

Results and Discussion

Workability

Figure 3 shows the compacting factor values of concrete mixes. It indicates that use of silica fume or metakaolin or dealuminated kaolin as cement replacement with percentages of 5%, 10%, and 15%, results in lower workability than control mix. Also, the results show that the minimum compacting factor of concrete mix containing 15% SF is 0.78 lower than compacting factor of control mix by 18%. For the same water cement ration and amount of super plasticizer, as the specific surface area of cementitious materials increase, as the workability of concrete mix decrease.

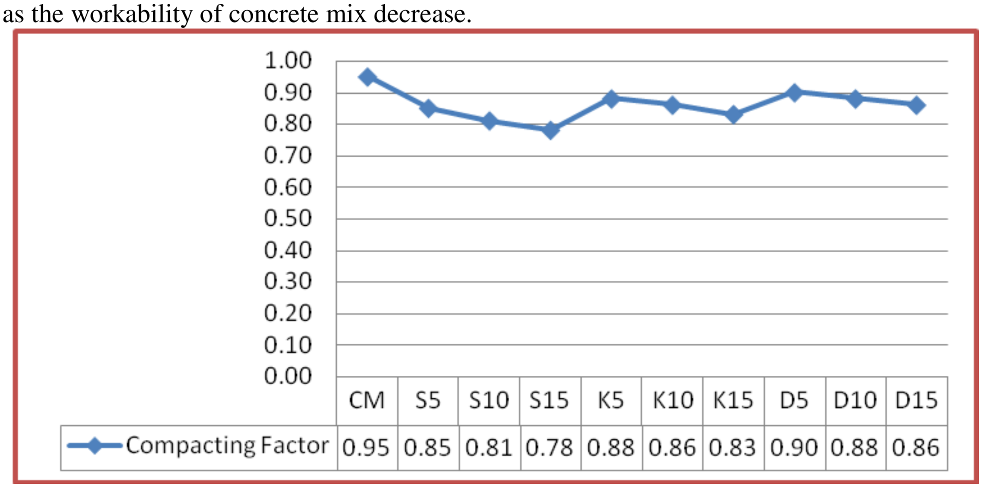

Fig 3. Compacting Factor (Workability) of Concrete Mixes

Compressive Strength

Figures 4 and 5 show the test results of concrete compressive strength after 7 and 28 day. It was found that use of 10% SF or 10% MK or 10% Dk individually and respectively result in increase in compressive strength than that of control mix, while compressive strength of concrete mix contains 5% DK are less than compressive strength of other mixes except CM either after 7 days or 28 day. Also, the results indicate that the concrete mix containing 5%, 10%, and 15% of silica fume or metakaolin or dealuminated kaolin have higher compressive strength than control mix.

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Figure 6 represents the relative compressive strength for concrete mixes with respect to compressive strength of control mix after 7 and 28 days. Relative Compressive strength of concrete mixes at age of 7 days higher than that after 28 days. Also Fig.6 indicates that the higher relative compressive strength exceeds 73% and 53% at age of 7 and 28 days respectively, and these values for 10% silica fume.

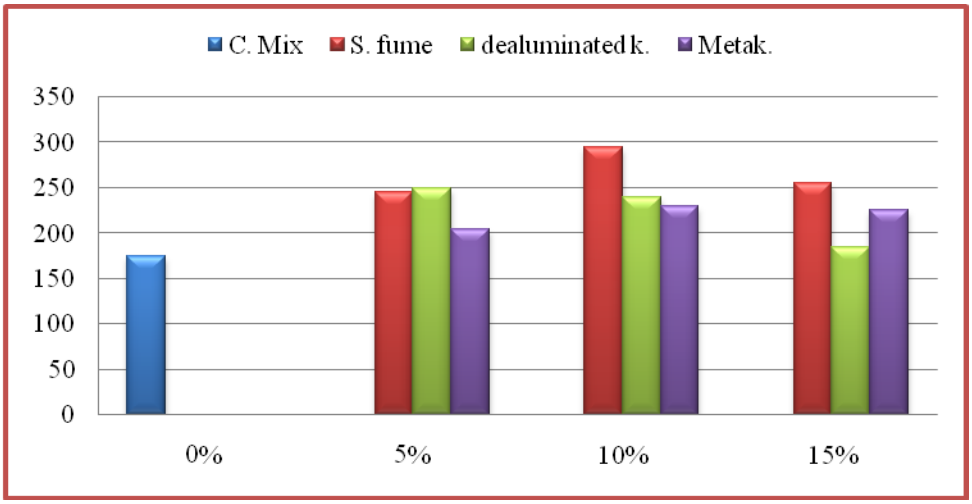


Fig 4.Compressive Strength of Concrete Mixes after 7 days

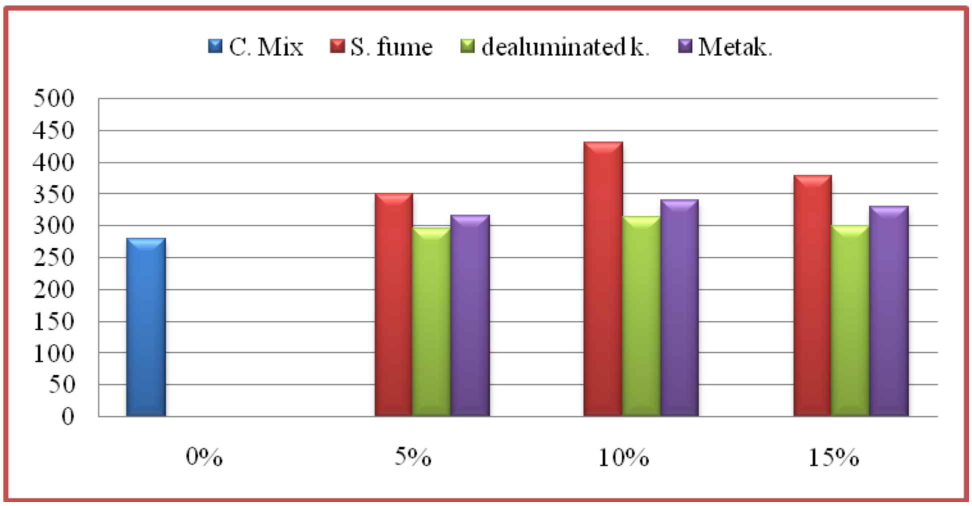
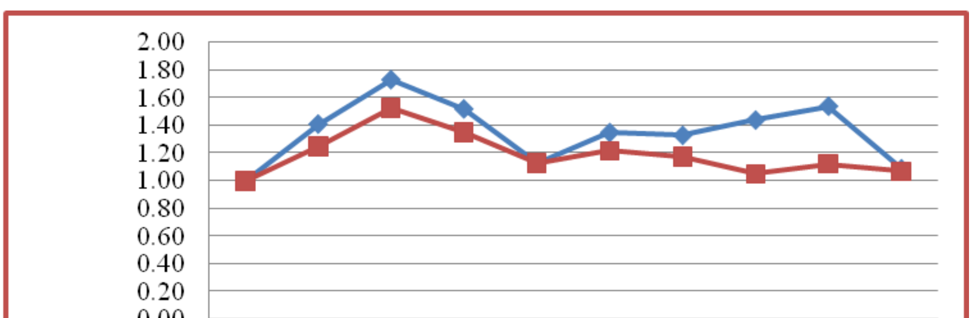


Fig 5. Compressive Strength of Concrete Mixes after 28 days



	CM	S5	S10	S15	K5	K10	K15	D5	D10	D15
7 days	1.00	1.41	1.73	1.52	1.13	1.35	1.33	1.44	1.54	1.09
28 day	1.00	1.25	1.53	1.35	1.13	1.22	1.18	1.05	1.13	1.07

Fig 6. Relative Compressive Strength of Concrete Mixes to Control Mix

Tensile Strength

Figures 7 and 8 show the test results of tensile strength of the developed concrete mixes after 7 and 28 day. This results indicate that use of silica fume or metakaoline or dealuminated kaoline with percentage of 10% result in increase in tensile strength than tensile strength of control mix, while tensile strength of concrete mix contains 5% DK are less than tensile strength of other mixes except control mix either after 7 days or 28 day. Also, the results indicate that the concrete mix containing 5%, 10%, and 15% of silica fume or metakaolin or dealuminated kaolin have higher tensile strength than control mix.

Figure 9 represents the relative tensile strength for concrete mixes with respect to tensile strength of control mix after 7 and 28 days. Almost, relative tensile strength of concrete mixes at age of 7 days higher than that after 28 days except for 15% SF. Also, the results indicate that the higher relative compressive strength exceeds 73% for mix with 10% SF and 88% at age of 28 days for mix with 15% SF respectively,

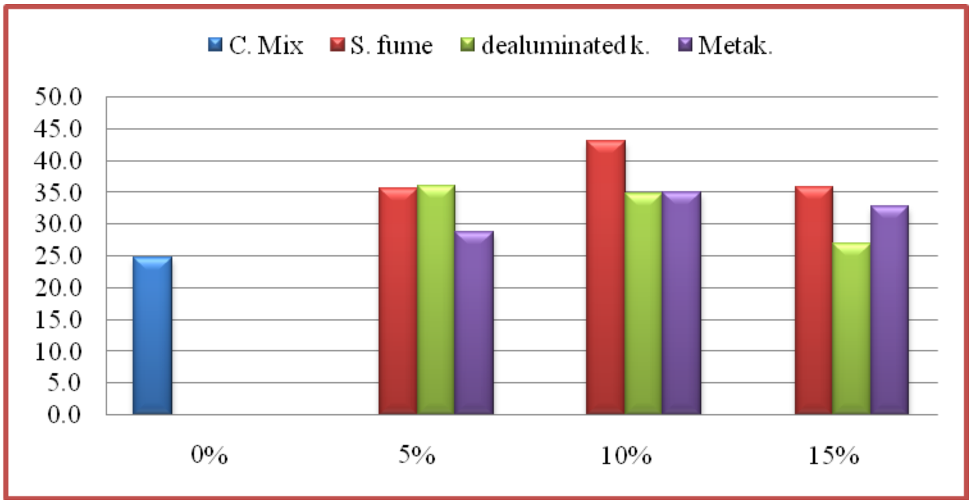


Fig 7. Tensile Strength of Concrete Mixes after 7 days

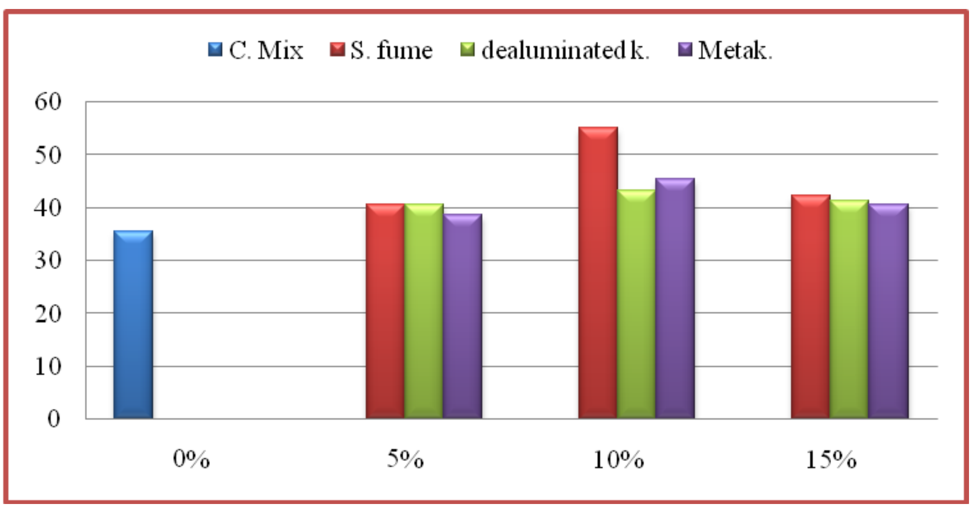
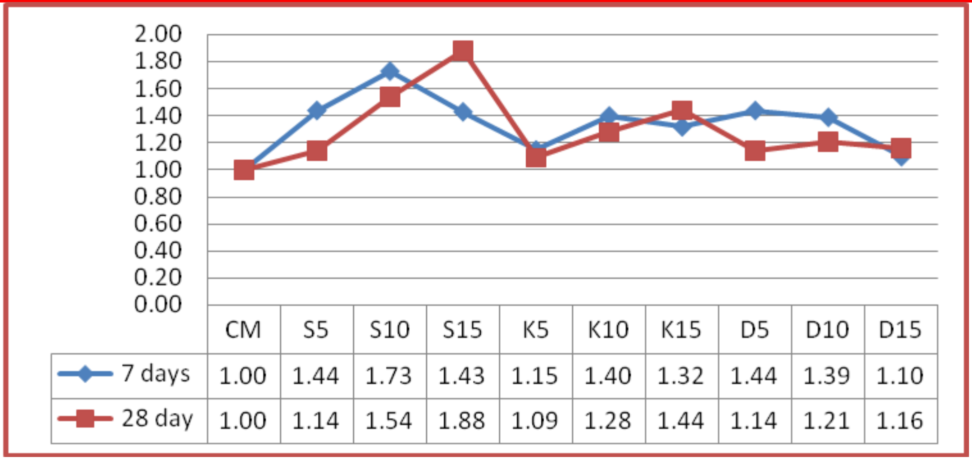


Fig 8. Tensile Strength of Concrete Mixes after 28 days

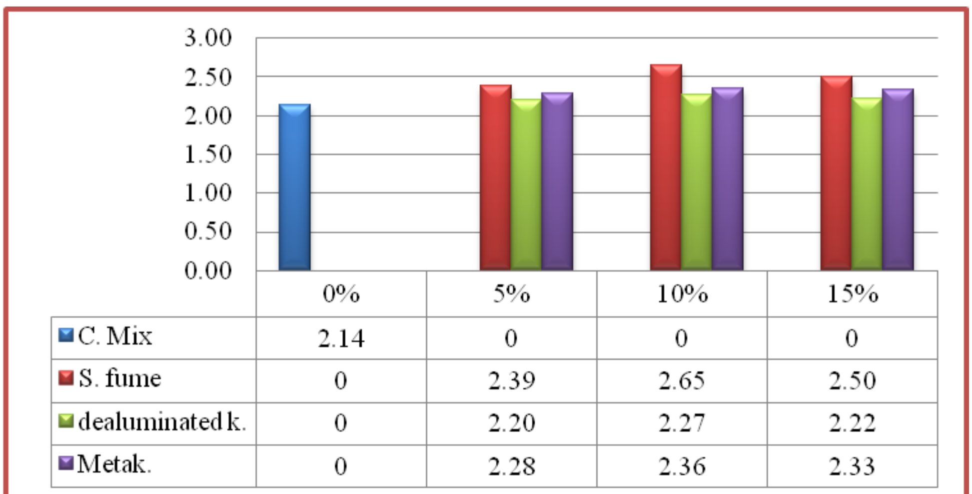
Modulus of Elasticity

Figure 10 indicate that concrete mix containing crushed refractory bricks as aggregate with 10% SF as a cement replacement has elastic modulus higher than that of all other concrete mixes followed by concrete mix containing 15% and 5% SF and 10% ,15% MK. Furthermore, concrete mixes containing 5%, 10%, and15% DK have elastic modulus less than elastic modulus of the other concrete mixes except the control mix.



	CM	S5	S10	S15	K5	K10	K15	D5	D10	D15
7 days	1.00	1.44	1.73	1.43	1.15	1.40	1.32	1.44	1.39	1.10
28 day	1.00	1.14	1.54	1.88	1.09	1.28	1.44	1.14	1.21	1.16

Fig 9. Tensile Strength of concrete Mixes Relative to Control Mix



	0%	5%	10%	15%
C. Mix	2.14	0	0	0
S. fume	0	2.39	2.65	2.50
dealuminated k.	0	2.20	2.27	2.22
Metak.	0	2.28	2.36	2.33

Fig 10. Elastic Modulus of Concrete Mixes (x10^5 kg/cm^2)

Conclusions

The results obtained from the tests considered in this study, refer to the following conclusions:

1. Utilization aggregate of recycled crushed refractory bricks with industrial by-products as cement replacement, give concrete mixes suitable for structural works.
2. Concrete containing 10% silica fume gave the optimal mechanical properties followed by concrete mix containing 10% metakaolin and concrete mix containing 10% dealuminated kaolin respectively.
3. Concrete mixes with 5%, 10%, and 15% dealuminated kaolin have values of compressive strength, tensile strength, and elastic modulus lower than that of concrete mixes containing silica fume or metakaolin ,but higher than that of control mix.
4. Concrete mixes produced using crushed refractory bricks with industrial by-products as cementitious materials have workability less than workability of control mix.

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