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Study Properties of Eco-Friendly Lightweight Concrete Made with Crushed Clay Bricks

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Abstract: Recycling crushed clay bricks (CCB) in concrete is a sustainable and cost-effective process. Huge quantities of crushed clay bricks waste cause many serious environmental problems around the world. To deal with this problem, crushed bricks were recycled in the concrete industry as an alternative to natural resources, and the brick powder was reused as a partial replacement for cement. The objective of this paper is to study the effect of crushed clay bricks on the characteristics of concrete. 7 concrete mixtures containing coarse crushed brick aggregate (CCBA) and fine crushed brick aggregate (FCBA) were prepared as a complete substitute for sand and dolomite, respectively. Clay brick powder (CBP) and silica fume were used as a partial substitute for cement by 5%, 10%, and 15% of its weight. The water-to-cement ratio was 0.35. For comparison, a control mixture was prepared. Various tests were conducted to evaluate the performance of concrete. The results showed that the workability of the different mixtures containing CCB decreased compared to that of the reference mixture. The compressive strength values of mixtures containing CCBA had a clear decrease compared to the reference mix at 7, 28, and 56 days of curing. The modulus of rupture results had the same path as compressive strength results. The thermal conductivity coefficient for mixtures including CCBA decreased compared to the control mix. Scanning Electron Microscope images indicated crystals of calcium silicate hydrate because of the pozzolanic interaction between the brick powder and the fine crushed clay bricks with calcium hydroxide.

1. Introduction

The incorporation of crushed clay bricks as a partial substitution of coarse aggregates in concrete mixtures has special importance in maintaining natural resources. Additionally, it decreases crushed bricks waste that is harmful to the environment. Kim et al. demonstrated that crushed bricks could substitute for coarse aggregates without affecting concrete

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durability if steel is not included [1]. However, the replacement of coarse aggregates with crushed clay bricks is not preferred if concrete involves steel. Kim et al. [2] made samples of concrete with different replacement ratios of normal aggregates, crushed clay bricks (CCB), and various ratios of water to cement. The results indicated that stiffness and modulus of elasticity decreased at high replacement ratios of CCB aggregates and high ratio of water to cement. The suggested model was used to measure the stress-strain curve and modulus of elasticity of the concrete samples, and they agreed well in many cases. Nevertheless, the precision of predictions was weak with a high ratio of water to cement greater than or equal to 0.65. Concrete samples of crushed clay bricks aggregates and fibers with different aspect ratios and shapes such as mono, double, and triple fibers were made. Six mixes were performed. Mixes containing the inclusions of fibers in high-performance lightweight aggregate concretes improved the maximum fracture and impact resistance at the first crack with respect to normal samples containing mono and hybrid fibers. Impact energy at fracture of samples with mono steel fiber rose by 1283%, 1042 %, 984, and 892%. In comparison to the normal samples, the increase in samples with single plastic was 917%, 908%, 766, and 753% at 7, 28, 60, and 90 days of curing. Impact resistance at the first crack of the mixes with double hybrid fibers reduced and achieved complete failure with respect to samples with mono steel fibers. Samples with triple hybrid fibers indicated the highest maximum fracture at the first crack [3].

Concrete mixtures of recycled concrete and crushed clay bricks aggregates were made. Scanning Electron Microscope and Energy Dispersive Spectrometer tests have been performed at the age of 9, 28, and 90 days of curing. Many tests were conducted such as compressive and splitting tensile strength tests on the specimens of different replacement ratios of recycled aggregates 0%, 25%, 50%, 75%, and 100% by weight. Three distinct ratios of recycled crushed bricks to recycled concrete aggregates 1:9, 3:7, and 5:5 have been studied in every ratio of recycled aggregates. Following that, the fuzzy approach was utilized to assess the mechanical characteristics of samples. The Mechanical stability properties of cement mixes were altered linearly at a ratio of 25%, and 50% of recycled aggregates and then dramatically reduced at a ratio of 75%. The influence of the recycled crushed bricks ratio on pavement behavior reduces slowly as the recycled aggregate level rises [4].

Xiong et al. [5] prepared concrete mixtures with recycled aggregate and recycled clay bricks. Samples were classified into nine categories based on replacement ratios and coarse aggregate kinds that varied from 0% natural aggregates to 100% complete replacement with recycled broken concrete or crushed clay bricks. Tests have been conducted up to a strain level of about 100 s^{-1}. According to the findings, recycled aggregate and recycled clay bricks concrete are more affected by strain rate than natural aggregate concrete. In recycled aggregate concrete, the dynamic increase factor is highly dependent on the ratio of replacement, whereas in recycled clay bricks concrete, has a less pronounced reliance.

To make the crushed brick aggregates, two kinds of clay bricks were used: solid and hollow crushed bricks. 50% of the crushed brick aggregates have been substituted with natural aggregates. Thirty-two concrete circular columns have been prepared and subjected to testing under axial compressive load. Concrete strength and glass FRP layers number were parameters of the investigation. The findings showed that utilization of glass FRP is a great option for altering the maximum capacity for carrying loads and concrete column's stiffness constructed with crushed bricks as a partial replacement of coarse aggregates. Glass FRP confinement impacts on concrete columns were observed to be greater in concrete constructed with hollow crushed bricks than in concrete constructed with solid crushed bricks [6].

Younis et al. [7] used Polyethylene glycol (PEG) 6000 in concrete mixtures as an interior cure agent. Crushed bricks and crushed ceramic were utilized as a partial substitution for dolomite by 25 %, 50 %, and 75 %. Various tests were performed to evaluate mechanical characteristics such as compressive and flexural strength and elastic modulus. Durability was determined by numerous tests like the rate of water absorption and drying shrinkage. The results indicated that Polyethylene glycol 6000 with 1.5 % of cement weight was the optimum dosage. Leading to a 48.9% increase in compressive strength after 28 days of curing, also, the rate of water absorption, sorptivity, and shrinking during drying reduced by 37.5%, 27%, and 44%, respectively at a percentage of 2% PEG. The ideal protection against chloride penetration occurred at 4% PEG. Depth of penetration reduced almost 78.7% with respect to the mix cured with air. The structural reactions of concrete stub columns filled steel tubes and recycled brick aggregate under axial compressive load were measured experimentally. The crushed clay bricks substitution level ranged from 0% to 50%, whereas the recycled concrete aggregate substitution level varied from 100% to 50%. Various tests were performed on 18 recycled brick aggregate concrete-filled steel tube columns and 36 specimens of concrete. Due to the lower stiffness and higher porous nature of the crushed clay bricks, the compressive strength and elastic modulus of concrete reduced as the crushed clay bricks content increased. With the rising ratio of crushed clay bricks, the strain of concrete during compressive strength rises greatly, and the addition of crushed clay bricks further enhances concrete lateral deformation [8].

Tahwia et al. [9] utilized fly ash and granulated blast furnace slag as a partial replacement of ordinary Portland cement by 30% and 50%. Also, type III cement (CEM III) was used as a partial substitution for ordinary Portland cement by 30%, 50%, and 100%. Findings indicated that a replacement ratio up to 50% of fly ash gave higher compressive strength and elastic modulus. Concrete continues to attain ultra-high performance over a long length of time with fly ash substitution of up to 50% and an elevated level of sulphate attack. Nevertheless, for CEM III or granulated blast furnace slag, the attack duration, sulphate content, or substitution ratio should be reduced to keep the concrete performing at an ultra-high level. Images of Scanning Electron Microscope (SEM) and Energy-dispersive X-ray (EDX) examination of the improved ultra-high performance concrete structure revealed an intensive microstructure with a thin Interfacial Transition Zone (ITZ) layer and confirmed the findings tests of the permeability and compressive strength of concrete.

The behavior of concrete was investigated when integrating polypropylene (PP) plastic produced from plastic waste as a partial substitution of stone aggregate (SA) and crushed brick aggregate (CBA). The ratio of PP aggregate was (0%, 10%, 20%, and 30%), water to cement ratio was (0.45 and 0.55), and the kinds of aggregate (SA and CBA) are the primary variables. The findings showed that raising the proportion of polypropylene aggregate (PPA) improved the slump value. Concrete containing 10% PPA had greater compressive, flexural, and indirect tensile strengths than the control mixture with stone aggregate and crushed brick aggregate. The ultrasonic pulse velocity values ranged depending on the kinds of aggregate and ratio of polypropylene aggregate. With higher ratios of polypropylene aggregate from 10 to 30, compressive strength and ultrasonic pulse velocity values reduced [10].

M.M. Atyia et al. [11] proposed that crushed clay bricks can be reused as a partial substitution of natural aggregates to produce lightweight concrete having the desirable characteristics. Furthermore, it has been demonstrated that grinded crushed clay bricks have a pozzolanic effect and may be utilized as additional cementitious material to decrease the amount of cement without noticeably degrading the concrete characteristics. The viability of utilizing fine brick aggregate produced from the construction demolition and its impact on concrete characteristics such as apparent density and compressive strength was investigated. The findings showed that increasing the substitution volume of sand particles in recycled brick aggregate concrete sequentially affects the compressive strength of concrete. When fine brick aggregate was used as a substitute for sand, the apparent density and the compressive strength reduced by 150 kg/m^3 and 17%, respectively [12].

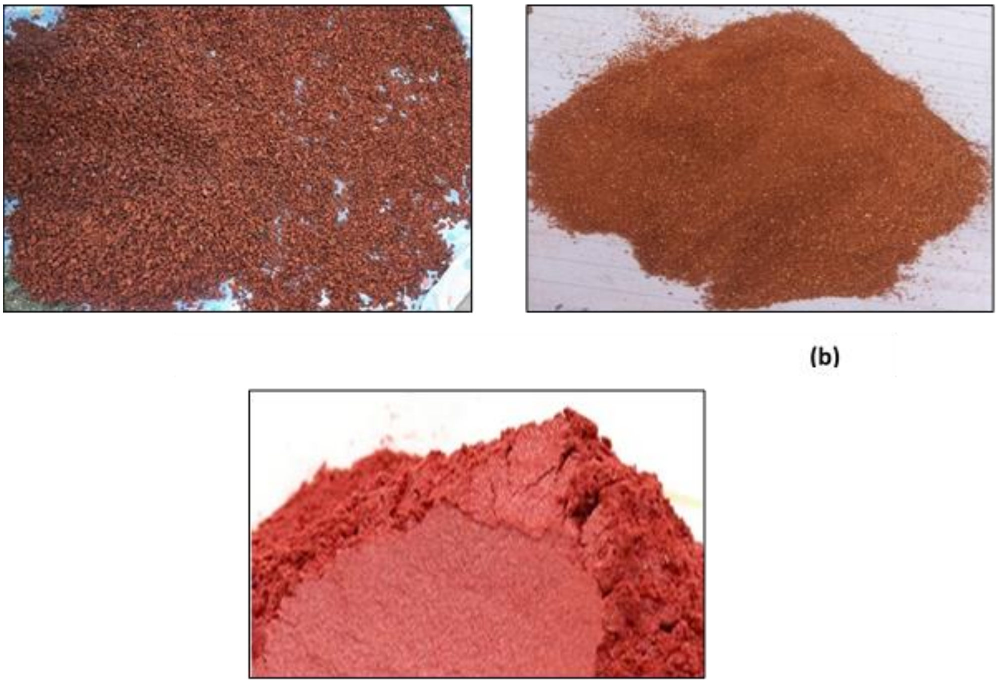
2. Research significance

A lot of previous research have investigated the influence of crushed bricks on the behavior of concrete, but their results were not satisfactory. It was essential to enhance the properties of concrete using CCBA and FCBA as a complete replacement for sand and dolomite, respectively. Also, CBP and silica fume were used as a partial substitute for cement. Many tests were performed to assess the behavior of concrete such as compressive strength, modulus of rupture, water absorption. Scanning Electron Microscopy (SEM) was used to determine the properties of concrete microstructure. The thermal conductivity test was conducted to find out the thermal properties of concrete.

3. Experiments

3.1. Material properties

The used coarse aggregate was crushed stones (dolomite). It was passed through a sieve size 10 mm and reserved on a sieve size 4.75 mm. The sand was utilized as a fine aggregate with a fineness modulus of 2.86 and was passed from a sieve size of 4.75 mm. coarse crushed brick aggregate (CCBA) was used as an alternative to coarse aggregate. It was passed through a sieve size 10 mm and reserved on a sieve size 4.75 mm. Fine crushed brick aggregate (FCBA) was utilized as a substitute for sand, it was passed through a sieve size of 4.75 mm. Table 1 and 2. Show the physical characteristics and sieve analysis of used aggregates. Clay brick powder (CBP) was used passing through a sieve size of 180μm. Ordinary Portland cement CEM I-42.5N was used conforming to BS EN 197-1/2011. Silica fume (SF) was utilized as a partial replacement of cement with a specific gravity of 2.21 and a specific area of 200000 cm^2/gm. Superplasticizer (SP) (Sikament 163 M) was used by 0.5%, and 1% of cement weight according to BS EN 934-2/2001. It has a density of 1.2 kg/l. Table 3. Illustrates the chemical characteristics of cement, CBP, and SF.



(b)

(c)

Fig. 1: a: Coarse crushed brick aggregate, b: Fine crushed brick aggregate, and c: Clay brick powder

Table 1. Physical characteristics of used aggregates

Properties	Dolomite	Sand	CCBA	FCBA
Absorption ratio%	0.9	1.75	12.5	16
Density (kg/m^3)	1562	1735	1035	1240
Specific gravity	2.63	2.56	2.17	2.17

Table 2. Sieve analysis of used aggregates

Sieve size (mm)	% Passing					
	Dolomite	Code Limits of C.A.	Sand	Code Limits of F.A.	CCBA	FCBA
37.5	100	-	100	-	100	100
19	95	100	100	-	96	100
9.5	75	50-85	100	-	75	100
4.75	0.5	0-10	100	-	4	100
2.36	0	0	92	60-100	0	93
1.18	0	0	75	30-90	0	78
0.6	0	0	30	15-45	0	34
0.3	0	0	16	5-40	0	20
0.15	0	0	1	-	0	2

Table 3. Chemical characteristics of cement I -42.5N, CBP, and SF

Components	% By weight		
	CEM	CBP	SF
SiO_2	20.2	52	90.3
AL_2O_3	5.6	15	0.52
CaO	62.4	7.4	0.63
Fe_2O_3	3.4	10.55	0.39
MgO	2.62	1.72	4.52
SO_3	2.75	7.8	0.31
K_2O	0.8	0.72	0.84
Na_2O	0.85	0.78	0.88

3.2. Mixture proportions

In this study, crushed clay bricks from demolished structures were utilized. It was manually washed, broken into fractions, and a part of it was grinded. Then it was sieved to produce fine and coarse crushed brick aggregate and clay brick powder. Seven concrete mixtures containing CCBA and FBCA were prepared as a complete substitute for sand and dolomite, respectively. CBP and silica fume were used as a partial substitute for cement by 5%, 10%, and 15% of its weight. The water-to-cement ratio was 0.35. For comparison, a control mixture was prepared. The concrete mixture was designed according to the modern British method. Table 4. Indicates the mix proportion for concrete mixtures. Fine and coarse crushed bricks and brick powder were soaked in a water container for 24 hours before mixing for pre-saturation of crushed bricks (saturated, surface dry).

Table 4. Mix proportion (Kg/m^3) for concrete mixtures.

Mix	C	CBP	Silica fume	F.A		C.A		SP	W
				Sand	FCBA	Dol	CCBA		
NC	450	-	-	793	-	1031	-	2.25	157.5
M1	450	-	-	-	672	-	851	4.5	157.5
M2	427.5	-	22.5	-	672	-	851	4.5	157.5
M3	405	-	45	-	672	-	851	4.5	157.5
M4	382.5	-	67.5	-	672	-	851	4.5	157.5
M5	427.5	22.5	-	-	672	-	851	4.5	157.5
M6	405	45	-	-	672	-	851	4.5	157.5
M7	382.5	67.5	-	-	672	-	851	4.5	157.5

4. Results and discussion

4.1. Properties of fresh concrete

A slump test was carried out for different mixtures according to ASTM C143. The slump values indicate the workability of the fresh concrete. Superplasticizer was used by 0.5% and

1% of cement weight to achieve proper slump. Fig 2. Shows slump values of mixtures with CCBA, FBCA, CBP, and control mix. It was noticed that the slump values of the different mixtures containing CCB decreased compared to that of the reference mixture (NC) however utilizing crushed clay bricks in a saturated, surface dry (SSD). This is because the crushed brick particles have an irregular shape and rough surface. The slump value of M2 is lower than that of M1 due to the presence of silica fume which is distinguished by its fineness, this leads to absorption of mixing water. The higher the ratio of silica fume, the lower the slump value as in mixtures M3 and M4. A clear decrease appears in the value of the slump of M5, M6, and M7 mixtures, this is due to the high absorption rate of brick powder. The higher the percentage of replacing cement with brick powder, the lower the slump value. When comparing M3 with M6, it was found that M6 gives a lower slump value than that of M3, this is because of the high porosity and irregular shape particles of the clay brick powder [10, 11].

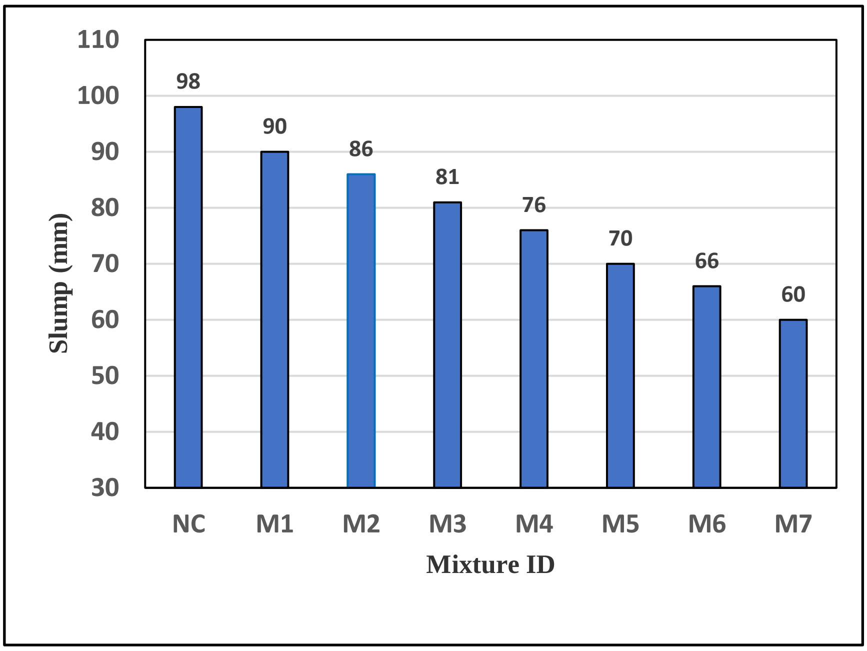
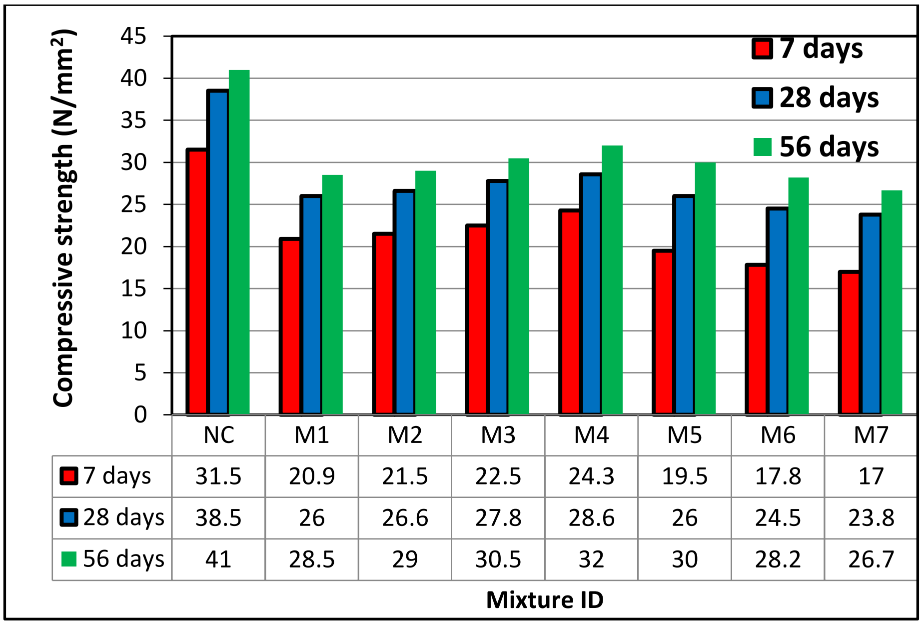


Fig. 2: Slump values of different fresh mixes

4.2. Properties of hardened concrete

4.2.1. Compressive strength

Concrete cubic samples with dimensions of 150×150×150 mm for different mixes were subjected to compression load at the age of 7, 28, and 56 days of curing. Three cubic specimens were used for each age and the average of compressive strength values were calculated considering the exclusion of values of compressive strength that had a deviation= ±25%. Statistical analysis (t-test) was calculated between groups of data to conclude whether the differences in the average properties are of statistical significance or not. Findings are shown in Fig. 3. It was observed that mixtures containing CCB had a clear decrease in compressive strength compared to the reference mix at all ages. This is due to the high percentage of CCB voids compared with natural aggregate. Also, it was noticed that the compressive strength of the M1, M4, and M5 reduced by 30.5%, 22%, and 26.8%, respectively at the age of 56 days with respect to the control mixture. The compressive strength of the M2 is higher than that of M1 at all ages, due to the formation of calcium silicate hydrate (CSH) produced from the interaction of silica (SiO_2) in silica fume with calcium hydroxide resulting from the hydration of cement. The compressive strength of M5 reduced at the age of 7, 28 days compared to the M2 mixture. This is because silica fume is softer than brick powder which fills the voids and improves the compressive strength. However, at the age of 56 days, the compressive strength of M5 is slightly greater than that of M2 because of the pozzolanic effect of brick powder, as it has great content of silica, aluminum oxide, iron oxide, and therefore it was considered a pozzolanic substance [11, 13].



	NC	M1	M2	M3	M4	M5	M6	M7
7 days	31.5	20.9	21.5	22.5	24.3	19.5	17.8	17
28 days	38.5	26	26.6	27.8	28.6	26	24.5	23.8
56 days	41	28.5	29	30.5	32	30	28.2	26.7

Fig. 3: Compressive strength at 7, 28, and 56 days of curing for various mixes

4.2.2. Modulus of rupture

A modulus of rupture test was conducted on concrete beams of size 100×100×500 mm at 7, 28, and 56 days of curing for all mixtures following (ISO 1920 and ISO 4013) standards [14,15]. Three concrete beams were utilized for each age and the mean value of the modulus of rupture was determined. Fig. 4 illustrates that the modulus of rupture had the same path as compressive strength. The modulus of rupture values for CCB mixtures reduced with respect to that of the control mix at all ages. The modulus of rupture of M1, M4, and M5 decreased by 38.3%, 23.3%, and 18%, respectively, at the age of 56 days compared to the reference mixture. The modulus of rupture of M2 is higher than that of M1 at all ages, due to the formation of calcium silicate hydrate (CSH). It was also observed a reduction in the modulus of rupture of M5 at the age of 7, 28 days compared to the M2, but at the age of 56 days, the modulus of rupture of M5 increased slightly compared to that of M2 [19].

4.2.3. Water absorption

The water absorption rate test was performed for each mix. Three concrete cubic samples of size 100×100×100 mm were tested at 28 days and the average of values was calculated conforming to ASTM C642. The results of the water absorption test were indicated in Fig. 5.

It was observed that the water absorption rate increased for all the mixtures containing CCB with respect to that of the control mixture, because the replacement of normal weight aggregate with CCB provides more voids and the presence of large pores in CCB [11, 16, and 17]. With increasing CBP, the water absorption rate increases slightly in the case of using CBP as a partial substitution for cement. The water absorption rate of mixtures M2, M3, and M4, which contain silica fume, is less than that of mixtures M5, M6, and M7, which contain brick powder, due to the fineness of the silica fume particles, which fill the voids inside the concrete. The water absorption rate decreased with increasing the ratio of silica fume in M2, M3, and M4 mixtures. The great water absorption rate is the proof of durability reduction of concrete mixtures [7].

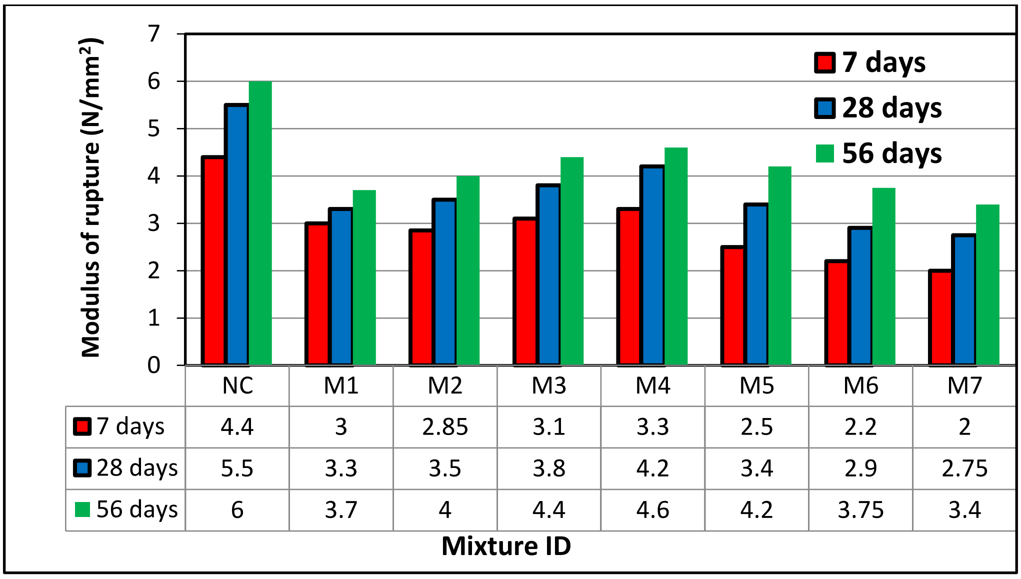


Fig. 4: Modulus of rupture at 7, 28, and 56 days of curing for various mixes

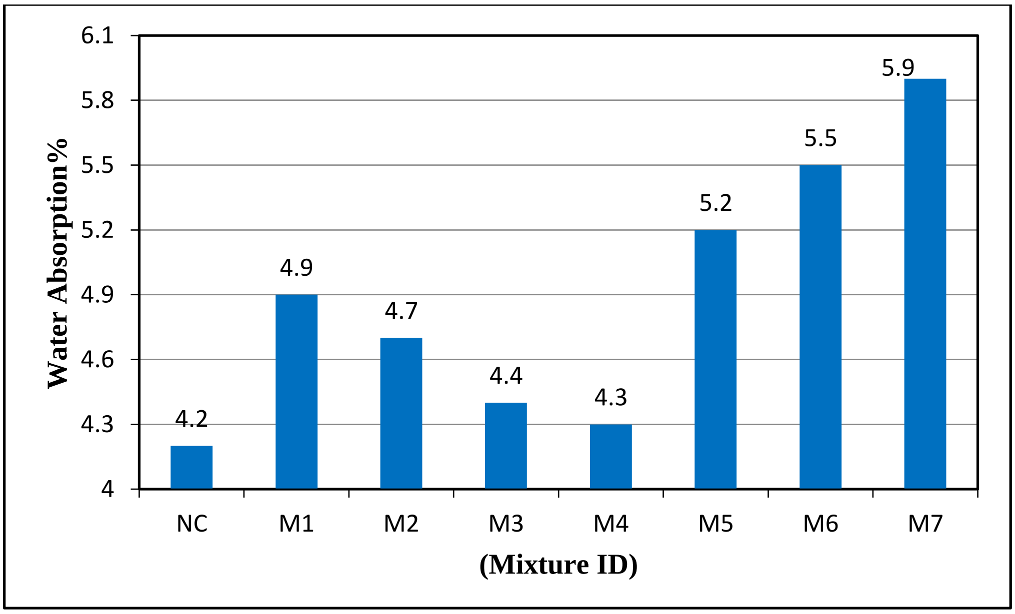


Fig.5: Water absorption variations of different mixes at 28 days of curing

4.2.4. Dry density

Dry density was measured for different mixtures after 28 days using three concrete cubic samples for each mix with dimensions of 150×150×150 mm and the average value was taken according to BS 1881 [18]. It was observed that the dry density of the mixtures containing CCB is lower than that of the reference mixture as presented in Fig. 6. This is due to the lower dry density of the crushed bricks with respect to that of fine and coarse aggregate. The dry density of the mixtures containing brick powder is less than that of the mixtures containing silica fume because of the high porosity of the brick powder compared to silica fume. Increasing brick powder as a partial replacement of cement did not have a clear effect on the dry density, where the mixtures containing brick powder have close densities. The control mixture achieved a density of about 2437 kg/m^3, while the M1 which contains CCB as a complete substitute for sand and dolomite, had a dry density of about 2250 kg/m^3, this is approximately 7.7% less than the control mix. M7 had the lowest dry density compared to other mixtures, as it achieved a dry density of about 2184 kg/m^3 which is about 10.4% less than that of the control mix [10, 11, and 19].

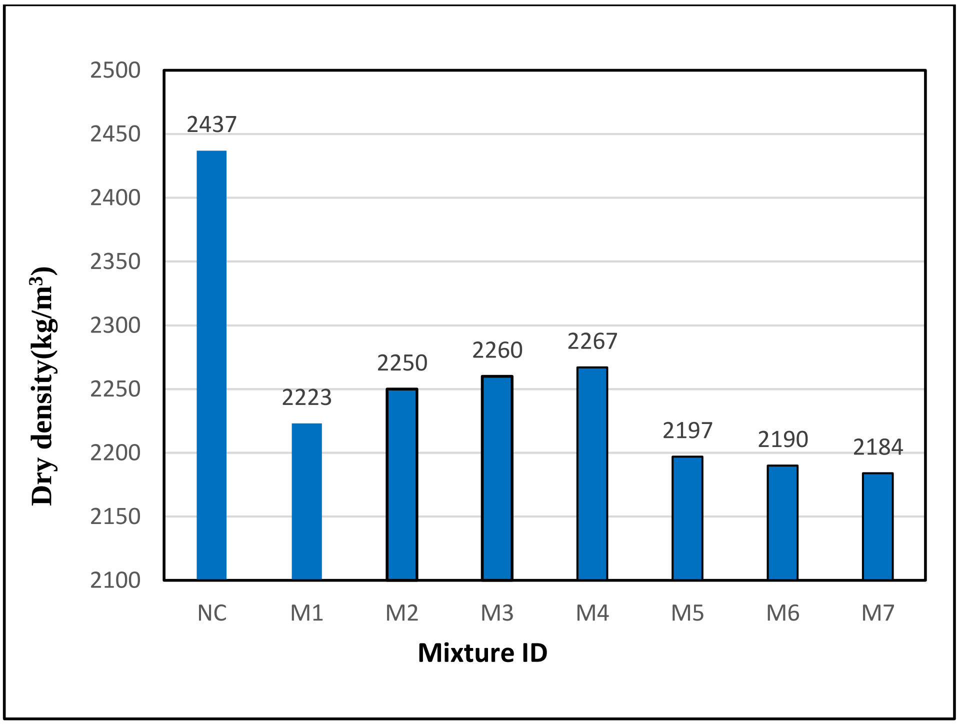


Fig.6: Dry density variations of various mixtures after 28 days of curing

4.2.5. Thermal conductivity coefficient

Concrete slides with dimensions of 100×100×30 mm were utilized to calculate the thermal conductivity coefficient (K) at 28 days of curing for different mixtures. Three concrete slides were tested for each mix, and the mean value was calculated. Fourier's equation was used to determine K-values for all mixtures. It was observed that K-values for mixtures including CCB decreased compared to the reference mix as shown in Fig. 7. This is due to high voids of crushed clay bricks with respect to natural aggregate. K-values of M1, M3, and M6 reduced by 54.3%, 48.6%, and 52.1%, respectively with respect to the control mix. The k value of M3 increased by 4.5% more than that of M6 because of the great porosity of brick powder. Also, the K-values of M5, M6, and M7 are close [20].

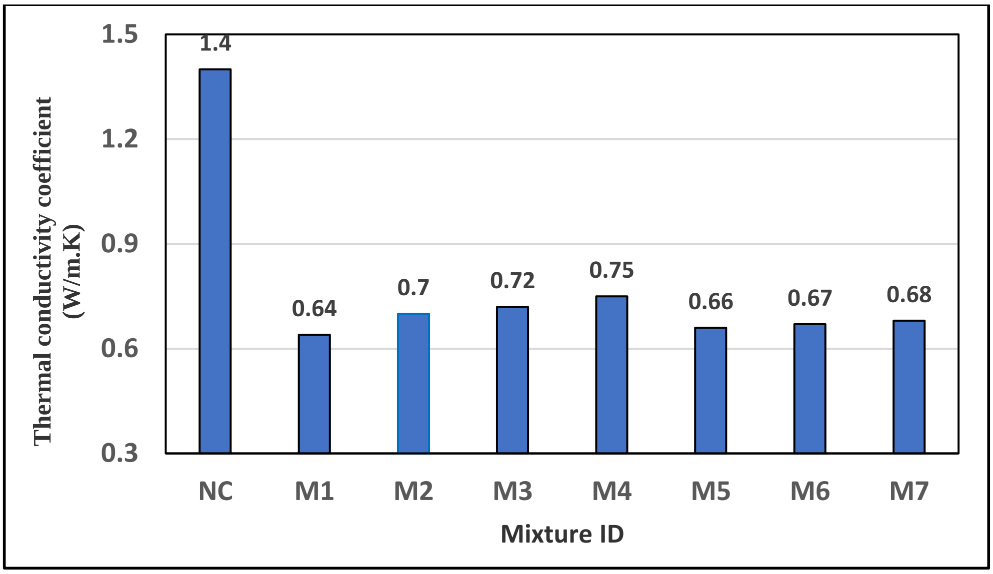


Fig. 7: Thermal conductivity coefficient variations of different mixtures at 28 days of curing

4.2.6. Ultrasonic pulse velocity

An ultrasonic pulse velocity test was performed to assess the compressive strength of concrete mixtures at 28 days of curing. Fig. 8 shows a reduction of ultrasonic pulse velocity for mixtures containing CCB with respect to the reference mix because of the high porosity of crushed clay bricks compared to normal aggregate. The higher the ratio of brick powder, the lower the ultrasonic pulse velocity but it was slightly reduction. The ultrasonic pulse velocity of M3 is higher than that of M6 because silica fume is characterized by high fineness with respect to crushed clay powder, this leads to an increase in ultrasonic pulse velocity [10, 11].

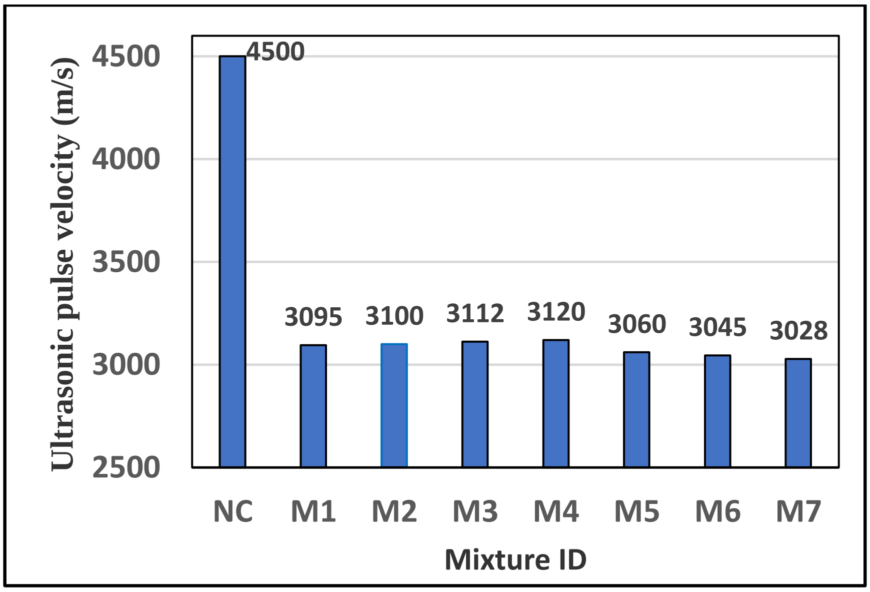


Fig. 8: Ultrasonic pulse velocity of different mixtures at 28 days of curing

4.3. Properties of microstructure

Scanning Electron Microscope (SEM) was used to examine the microstructure of concrete at 56 days of curing. Micrographs of SEM are presented in Fig. 9. It was noticed the presence of voids in the control mixture (NC), while there are crystals of calcium silicate hydrate (CSH) in M1 which were produced from the interaction of active silica in fine crushed clay bricks with calcium hydroxide (CH) resulting from the hydration of cement [11]. The images of SEM indicated that the sand in the control mixture is an inactive substance. For M4, it was observed that there are dense crystals of CSH produced from the interaction of active silica in FCB and silica fume with CH. Also, it was found lack of voids in M4. This result matches compressive strength results, as M4 had the highest compressive strength compared to other samples that had CCB. Images of M6 showed the presence of dense concrete with few voids and condensed crystals of CSH because of the pozzolanic interaction between the brick powder and the fine crushed clay bricks with CH, and this is proof that the brick powder and fine crushed clay bricks have pozzolanic behavior.

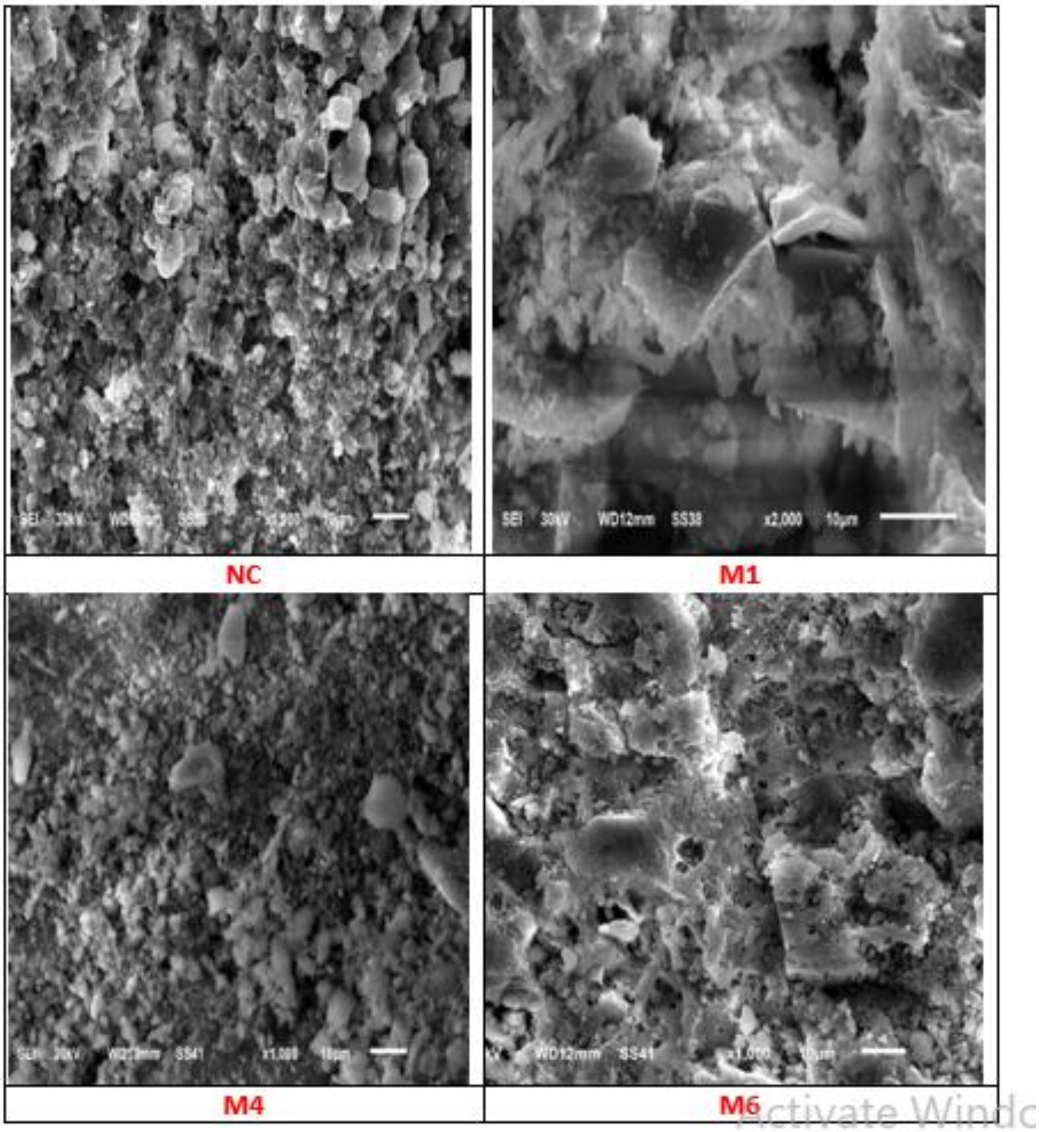


Fig. 9: Images of SEM for NC, M1, M4, and M6 at 56 days of curing

5. Recommendation

Considering the experimental investigations conducted in this study, the following recommendations and proposals might be made for any potential future research:

1. It is recommended to add more mixes where CBP is used with sand and dolomite aggregate to evaluate the CBP replacement to cement on the properties of concrete. In addition, achieving the optimum outcomes for mechanical and physical properties of lightweight concrete.
2. Air content test for fresh concrete is required to be performed since it will be extensively used to explain the results of practical program.

6. Conclusions

From the previous results, it can be deduced that:

1. The workability of the different mixtures containing CCB decreased compared to that of the reference mixture however utilizing crushed clay bricks in a saturated, surface dry (SSD). The mixtures included brick powder had lower workability than mixtures containing silica fume.
2. The compressive strength values of mixtures containing CCB had a clear decrease compared to the reference mix at all ages. The compressive strength of the M1, M4, and M5 reduced by 30.5%, 22%, and 26.8%, respectively at the age of 56 days with respect to the control mixture.
3. The modulus of rupture had the same path as compressive strength and the modulus of rupture values for CCB mixtures reduced with respect to that of the control mix at all ages. The modulus of rupture of M1, M4, and M5 decreased by 38.3%, 23.3%, and 18%, respectively, at the age of 56 days compared to the reference mixture.
4. The water absorption rate increased for all the mixtures containing CCB with respect to that of the control mixture. With increasing CBP, the water absorption rate increases slightly in the case of using CBP as a partial substitution for cement. The water absorption rate of mixtures M2, M3, and M4, which contain silica fume, is less than that of mixtures M5, M6, and M7, which contain brick powder.
5. The density of the mixtures containing CCB is lower than that of the reference mixture. The density of the mixtures containing brick powder is less than that of the mixtures containing silica fume. Increasing brick powder as a partial replacement of cement did not have a clear effect on the density, where the mixtures containing brick powder have close densities.
6. The thermal conductivity coefficient (K) for mixtures including CCB decreased compared to the reference mix. K-values of M1, M3, and M6 reduced by 54.3%, 48.6%, and 52.1%, respectively with respect to the control mix. The k value of M3 increased by 4.5 % more than that of M6.
7. Ultrasonic pulse velocity for mixtures containing CCB reduced with respect to reference mix. The higher the ratio of brick powder, the lower the ultrasonic pulse velocity but it was slightly reduction. The ultrasonic pulse velocity of M3 is higher than that of M6.

8. The images of SEM indicated that fine crushed clay bricks and brick powder have pozzolanic behavior.

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دراسة خصائص الخرسانة خفيفة الوزن الصديقة للبيئة المصنعة من كسر الطوب الطينى

الملخص العربى

تعد إعادة تدوير كسر الطوب الطيني بالخرسانة عملية مستدامة وفعالة من حيث التكلفة. تسبب الكميات الهائلة من مخلفات كسر الطوب الطيني العديد من المشكلات البيئية الخطيرة حول العالم ولمعالجة هذه المشكلة تم إعادة تدوير كسر الطوب في صناعة الخرسانة كبديل للموارد الطبيعية، كما تم إعادة استخدام بودرة الطوب كبديل جزئي للأسمنت. الهدف من هذا البحث هو دراسة تأثير كسرالطوب الطيني على خصائص الخرسانة. تم تحضير ٧ خلطات خرسانية تحتوي على كسر الطوب الخشن وكسر الطوب الناعم كبديل كلي للرمل والدولوميت على التوالي. تم استخدام بودرة الطوب الطيني وغبار السيلكافيوم كبديل جزئي للأسمنت بنسبة ٥٪، ١٠٪، و١٥٪ من وزنه. وكانت نسبة الماء إلى الأسمنت ٠,٣٥ . تم إعداد خلطة مرجعية للمقارنة بين الخلطات.وقد تم إجراء اختبارات مختلفة لتقييم أداء الخرسانة. وأظهرت النتائج أن قابلية تشغيل الخلطات المختلفة المحتوية على كسر الطوب الخشن انخفضت مقارنة بقابلية تشغيل الخلطة المرجعية. كما أن مقاومة الضغط للخلطات التي تحتوي على كسر الطوب الخشن انخفضت انخفاض واضح مقارنة بالخلطة المرجعية عند ٧ و ٢٨ و ٥٦ يومًا من المعالجة. واخذت نتائج مقاومة الانحناء للخلطات نفس مسار نتائج مقاومة الضغط. وانخفض معامل التوصيل الحراري للخلطات المحتوية على كسر الطوب الخشن مقارنة بالخلطة المرجعية. كما أشارت صور المجهر الإلكتروني الماسح إلى وجود بلورات من سيلكات الكالسيوم المماهة بسبب التفاعل البوزولاني بين بودرة الطوب وكسر الطوب الناعم مع هيدروكسيد الكالسيوم.