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Effect of Brick Dust and Ceramic Tiles Waste on Properties of Concrete

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Abstract - *The aim of present study is to investigate the effects of brick dust (BD) and ceramic tiles waste (CW) on the properties of concrete. Fine aggregates are partially replaced with 10%, 20%, 30% and 40% of BD, by weight of natural sand (NS) and natural coarse aggregates (NCA) are partially replaced with 10%, 20%, 30% and 40% of CW by weight of NCA in the mixes. Effect of partially replaced BD and CW in the mix is studied on the basis of hardened concrete properties. In present study, combination of both waste materials in the ratio of 1:1 is taken due to their abundant availability in surroundings. The results are obtained by these partial replacements gives improved strength and durability properties of modified concrete mix than the standard mix. This research found modified concrete is more superior to that of the conventional mix. This will also contribute in making green structures by reducing the demand of natural sources.*

Key Words: Concrete properties, Brick dust (BD), Ceramic tiles waste (CW), Durability.

1. INTRODUCTION

Concrete is a chief component of any building structure and it is mainly composed of cement, sand and aggregates. Rapid advancement has been made in construction field; raised many problems like more demand of natural sources and disposal of wastes. According to a report given by solid waste management in 2018, India generates 0.53 million tons/day waste. Secondly, more demand of natural sand as fine aggregate of concrete causes excessive sand mining from river bed which disturbs aquatic life and affects ground water level. Excessive demand of coarse aggregates causes bad impact on environment by frequent usage of blasting methods. Therefore, modification of concrete by the addition of suitable waste materials in place of natural resources without compromising the properties of concrete is one of the best way came to conserve our natural environment. This would help in reducing the demand of natural resources and also more land demand for the disposal of demolished constructional waste.

In this research, an attempt has been made to replace natural aggregates with ceramic tiles waste (CW) and brick dust (BD). In most of the areas of world, both type of wastes (BD and CW) are easily available. Selection of this combination is based on the past studies that reveal better quality of concrete by using BD and CW, separately. Both materials are added in a single mix to enhance the usage of waste products with improved properties at its maximum replacement level. According to the research carried out by Bektas & Wang (2009) [1] , revealed up to 20% replacement with brick aggregates having no negative effect on strength properties. The freeze-thaw resistance property was improved by this replacement. The compressive strength result was found more than the conventional mix after 90 days curing with 25% replacement of brick aggregates. Boukour & Benmalek (2016) [2], discovered with the addition of BD in concrete mix, its dry unit weight increases due to the high water absorption effect. This study concluded the positive effect of BD due to its pozzolanic reaction. Ikponmwosa and Ehikhuenmen (2020) [3], found the use of ceramic waste resulted into decrease in the density than the normal concrete. This could help in reducing the dead load of the structure. The strength of the mix was less, but up to acceptable level than the normal mix. This happens due to the porcelain surface of ceramic waste and weaker bonding between cement paste and aggregates. But they concluded the usage of ceramic waste is an effective way to reduce the cost and also in making clean environment. Mohammad hosseini (2019) [4], discovered in his research that the performance of ceramic mortar with chloride penetration and sulphate resistance test has achieved more satisfactory results than the standard mix. Therefore, the fine ceramic aggregates revealed as a suitable alternate in concrete mix, having adequate strength and durability properties under aggressive environments by lower crack formation and expansion in comparison of normal mix. Nepomuceno & Isidoro (2018) [5], revealed in their study, recycled ceramic coarse aggregates having higher flakiness index and shape indexes than natural coarse aggregates but this caused no effect on workability of the mix. Thus, their research confirmed the acceptability of using ceramic waste in concrete mix. Seeni (2016) [6], the partial replacement of china clay waste in fine aggregates results in the enhanced compressive strength of prepared concrete mix. Wadie and Sadek (2017) [7], focused on the mechanical and physical properties of ceramic tiles as partially replaced coarse aggregates by comparing with the standard mix properties. They found decrease in the free water content of mix due to high water absorption property of ceramic wastes and this factor is responsible for the increase in compressive and flexural strength of the modified mix. Results of this literature study showed the usage of ceramic waste as fine aggregates up to 40% and as coarse aggregates up to 50% could be beneficial.

2. METHODOLOGY

2.1 Materials

2.1.1 *Cement*

Ordinary Portland Cement of grade 43 as per IS 456:2000 [8], conforming to 8112 is used for all mixes in this study.

2.1.2 Fine aggregates

Sand (NS) and BD is used as fine aggregates in this experimental work. NS is taken from the local distributor and BD which is formed from the fragments of fired clay bricks is obtained from brick manufacturers with a particle size passing through 4.75 mm sieve. Standard sieve sizes of 4.75, 2.36, 1.18, 0.60, 0.30 and 0.15 mm are used to analyse fineness modulus.

2.1.3 Coarse aggregates

Natural coarse aggregates (NCA) are taken from local distributor and CW is from local tile manufacturing factory of Jalandhar (India) with a particle size retained on 4.75mm sieve. Standard sieve sizes of 20, 16, 12.5, 10 and 4.75 mm are used to analyse its fineness modulus.

2.1.4 Water

Portable water (free from any reactive material) is used for making the workable mix.

2.1.5 Superplasticizer

Dynamon SX , admixture is added in the mortar mixes. It is a high performance and water - reducing admixture used to reduce the water content and helps in increasing the strength of concrete. This admixture meets the requirements of ASTM 494 Type A and Type F and AASHTO M194 Type A and Type F. In current study, it is used from 0.8% to 1.25% by the weight of cement to ensure the improved workability and strength with different proportions of BD and CW in the concrete mixes.

2.2 Physical properties

2.2.1 Preliminary tests

Specific gravity, water absorption, impact value, fineness modulus and some other physical properties of both fine and coarse aggregates (natural and waste materials) are tested to compare the suitability of waste materials. Preliminary tests according to IS standards and values are preformed and their values are discussed in Table 1.

Table 1- Physical Properties

Properties	NS	BD	NCA	CW	Standards
Color	Yellowish grey	Yellowish red	Grey	-	-
Shape	Spherical	Spherical	Angular	Angular	IS 456:2000
Size (mm)	0.06 -2.00	0.06 -2.00	20 – 10	20 – 10	IS 383-1970
Specific Gravity	2.7	2.41	2.88	2.0	IS 2386 (Part III)-1963
Water absorption (%)	1.5	2.45	2.86	9.89	IS 2386 (Part III)-1963
Fineness modulus	2.9	2.08	6.89	8.51	IS 383-1970
Impact value (%)	-	-	5.38	7.82	IS2386 (Part IV)– 1963

2.3 Mix Design

Four different concrete mixes (CWBD2, CWBD3, CWBD4 and CWBD5) are prepared with BD and CW as partial replacement with fine and coarse aggregates in absolute weight percentages. A conventional mix (CWBD1) is prepared without replacement and having target mean strength of 30 MPa, used as a reference concrete mix in this study (Table 2). All the concrete mixes are designed for a water-cement ratio of 0.40. Quantities for concrete ingredients to be used in 1m^3 are based on preliminary tests according to IS codes 456:2000 and IS 10262:2009 [9] and are discussed in Table 3.

Table 2- Mix Design Proportions

Mix	Cement (OPC 43 Grade) (%)	NS + BD (%)	NCA + CW (%)
CWBD1	100	(100 + 0)	(100 + 0)
CWBD2	100	(90 + 10)	(90 + 10)
CWBD3	100	(80+ 20)	(80+ 20)
CWBD4	100	(70+ 30)	(70+ 30)
CWBD5	100	(60+40)	(60+40)

Table 3 – Quantities for Concrete ingredients to be used in 1m^3

Materials	CWBD1	CWBD2	CWBD3	CWBD4	CWBD5
Cement (kg/m^3)	492.5	492.5	467.8	453.1	430.75
Water (Ltrs)	197	197	187.5	181.24	172.3
NS (kg/m^3)	628.5	580.86	516.32	459.27	403
BD(kg/m^3)	-	57.4	114.73	175	240
NCA(kg/m^3)	1191.9	1101.5	979.12	870.9	764
CW(kg/m^3)	-	84.99	170	259.2	353.7
W/C (Ratio)	0.40	0.40	0.40	0.40	0.40
Superplasticizer (ltr)	-	-	2.34	3.62	5.38

3. TESTING ON HAREDENED CONCRETE

3.1 Compressive Strength

The test is used to measure the load resisting capacity of hardened concrete by dividing the failure load with the cross-sectional area of the sample. It is carried out on three samples of each mix having 150 mm X 150 mm X 150 mm size and tested under compressive testing machine of capacity 2000 KN at 7, 14 and 28 days of curing as per IS 516-1959 [10].

3.2 Split Tensile Strength

The test is used to determine tensile strength of concrete using a set of three cylindrical specimens having 100 mm diameter and 200 mm height at 28 day of curing as per IS 5816-1999 [11].

3.3 Durability test

The test is based on acid resistance performance of the samples. Cubes made from modified concrete, having maximum strength results (partially replaced fine aggregates with BD and coarse aggregates with CW) and conventional concrete (a mix of M30 grade, without any replacement) cubes immersed into water containing 2% of Sulphuric acid solution for 7, 14, 21 and 28 days at room temperature. After the specified duration, the specimens were taken out and dried in air. Weight of these samples has been noted. Compressive strength test is done on these specimens for examining their durability.

4. RESULTS AND DISCUSSION

4.1 Compressive Strength Test

The result (Fig. 1) indicated that the strength of mix by partial replacement of 30% of BD and 30% of CW with fine and coarse aggregates respectively has highest compressive strength value (Table 4). The compressive strength value showed increase from 38.4 MPa to 43.1 MPa as compared to nominal mix. Concrete mix prepared by 10% replacement with BD and 10% with CW, showed a small increase in compressive strength without addition of any admixture due to the pozzolanic effect of BD [2]. The waste products used in this study, (BD and CW) having less density than natural aggregates that makes the mix more compact and in lighter weight than the conventional mix [3]. Thus, the dead load of structures made by this partial replacement can be reduced. Irregular shape and rough surfaces of CW aggregates helps in increasing the bonding between cement and aggregates in the mix [7]. But the concrete mixes prepared by further increasing the amount of BD and CW required the addition of admixture as 0.5% by weight of cement in CWBD3. Similarly, 0.8% by weight of cement of admixture is added in CWBD4 mix for better results in compressive strength. This also reduces the quantity required for cement and water in the mix. In CWBD5 mix, even by the addition of 1.25% of admixture by weight of the cement, strength slightly decreases which is comparable with the strength of conventional mix.

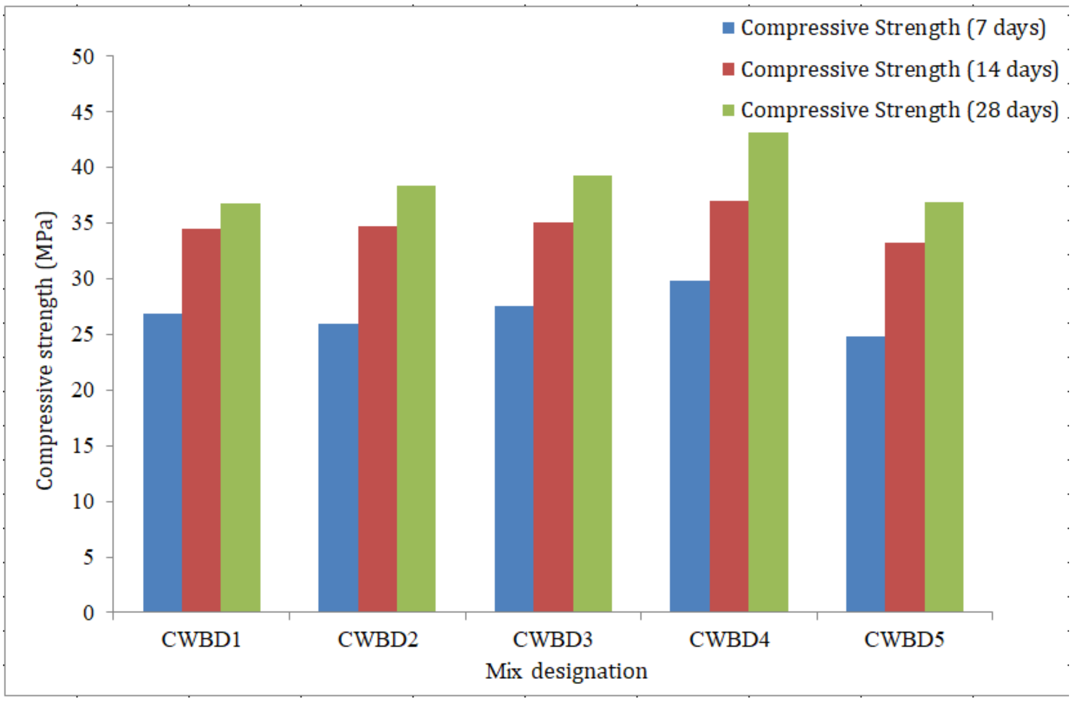

Fig. 1: Variation in Compressive strength with different proportions of concrete mixes

Table 4 – Compressive strength values of different mixes

Mix Designation	Compressive Strength (MPA)		
	7 days	14 days	28 days
CWBD1	26.88	34.5	36.8
CWBD2	26.0	34.7	38.4
CWBD3	27.5	35.03	39.28
CWBD4	29.8	37	43.1
CWBD5	24.83	33.28	36.9

4.2 Split Tensile Test

The Split tensile strength of various concrete mixes is carried out on a triplicate set of different mixes and the average tensile strength values are illustrated in Fig. 2. The split tensile strength is may be increased through glazed surface of CW. Most of the glazed surface gets removed by crushing of ceramic tiles into aggregates sized particles. This glazed particles turns into microfibers and contributes for increasing the tensile strength of the mix [7]. The other reasons for increasing the split tensile strength are similar as discussed for increasing the compressive strength. The split tensile strength showed increase from 4.15 MPa to 5.20 MPa in CWBD2, CWBD3 and CWBD4 mixes as compared to the nominal mix (Table 5). By further increasing partial replacement percentage of BD and CW in CWBD5 mix shows slight decrease which is comparable with the standard mix. This happens due to the decrease in the workability and increase in the water absorption of the mix at more percentages by partially replacing fine and coarse aggregates with BD and CW in the mix.

Table 5- Split tensile strength values of different mixes

Mix designation	Split tensile strength (MPa) 28 days
CWBD1	3.91
CWBD2	4.15
CWBD3	4.87
CWBD4	5.20
CWBD5	3.94

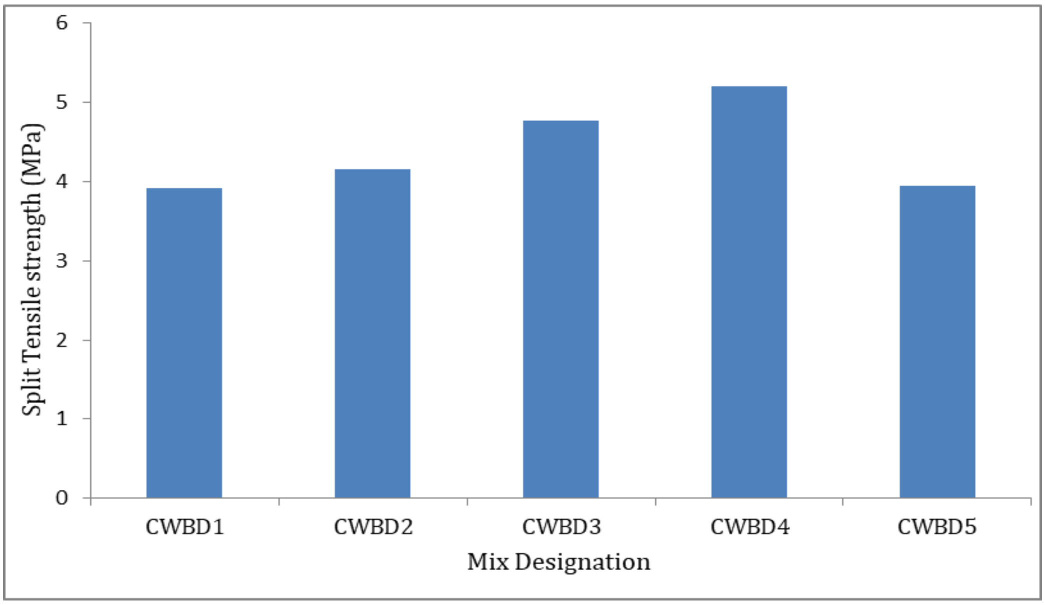

Fig. 2: Split tensile strength values of different mixes

4.3 Durability test

4.3.1 Durability in Weight:

The test results (Table 6) concluded less weight reduction up to 31.25% of modified mix (CWBD4), in comparison with the conventional mix (Fig. 3). This leads to lower crack formation in comparison of conventional mix and also increases the life span of a building made from partially replaced concrete with BD and CW.

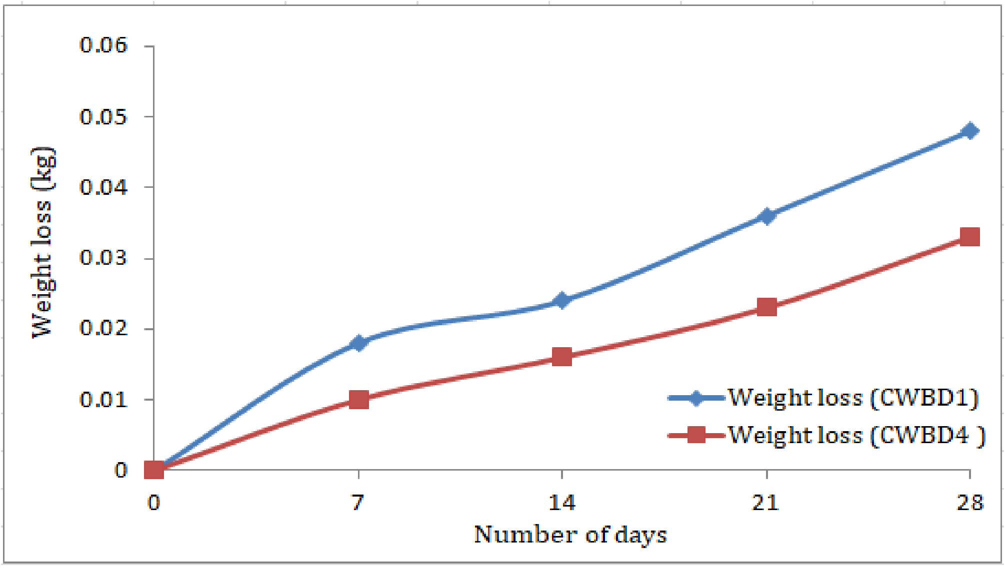

Fig. 3: Weight loss in acid reduction

Table 6 - Results of durability test (Weight loss)

No. of Days	Weight loss in Kg (CWBD1)	Weight loss in Kg (CWBD4)
0	0	0
7	0.018	0.01
14	0.024	0.016
21	0.036	0.023
28	0.048	0.033

4.3.2 Durability in strength

Compressive strength test is performed after examining the weight of samples at 7, 14, 21 and 28 days of acid immersion on samples (CWBD1 and CWBD4). Values obtained (Table 7) by testing are discussed below and the results indicate (Fig. 4) that the modified concrete has more compressive strength than the standard mix. This concludes structures made from partially replaced concrete with BD and CW having more durability in terms of strength than the normal concrete.

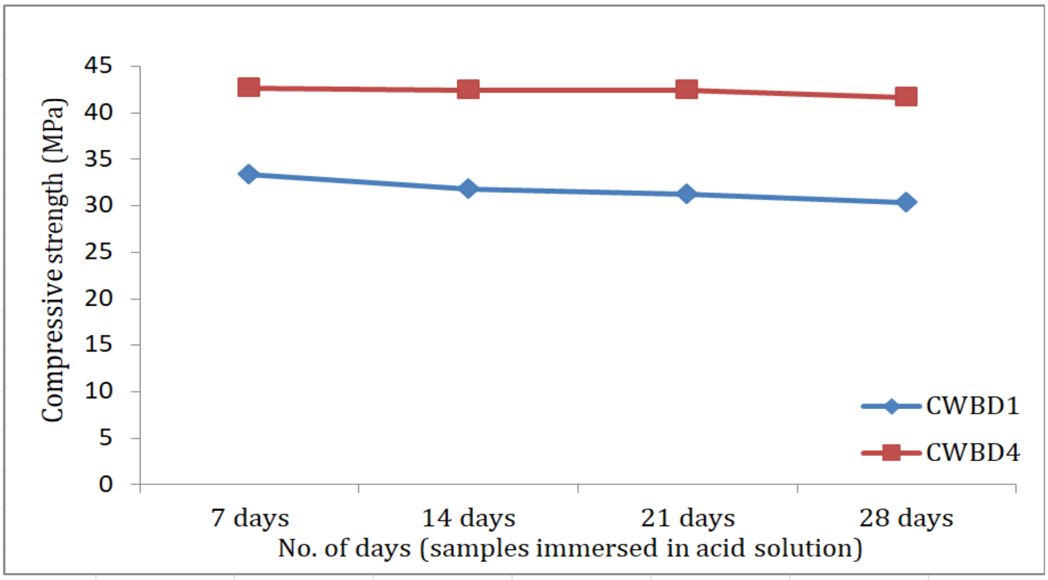

Fig. 4: Compressive strength values after acid immersion

Table 7 - Results of durability test (Compressive Strength)

Mix Designation	7 days (MPa)	14 days (MPa)	21 days (MPa)	28 days (MPa)
CWBD1	33.4	31.8	31.3	30.3
CWBD4	42.7	42.4	42.4	41.6

5. CONCLUSIONS

- The use of BD and CW as fine and coarse aggregates in concrete mix should be taken up for acceptable and environmental friendly construction.
- The use of BD and CW can decrease the disposal issues and also cost of construction up to a certain level.
- The compressive strength results of this study clearly specified that BD and CW could be used as partial replacement of fine and coarse aggregates in percentages up to 30% of BD in place of NS and 30% of CW in place of NCA (CWBD4). The effect of this replacement showed an increase of 17 percent in compressive strength from the conventional mix. In CWBD5 mix, compressive strength has decreased due to the waste products used in this study are having high water absorption capacity than natural aggregates. Therefore, partial replacement at higher percentages could not be possible.

- The increase found in split tensile strength is more as compared to that of increase in compressive strength. This experimental study permitted strength to concrete in tension also. The split tensile strength showed highest increase up to 33% from the normal mix in CWBD4 mix.
- Durability test done by pure sulphuric acid (2% dissolved in water) showed 31.25% better performance in weight loss reduction. The compressive strength loss of 9 percent is noted in standard mix which was kept in acid solution for specified time (7, 14. 21 and 28 days). The loss of 5 % in compressive strength of modified concrete signifies that partially replaced concrete with BD and CW is more durable and resistant to thermal cracking than the normal concrete.

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