IMPACT OF REPLACEMENT OF NATURAL AGGREGATE WITH WASTE MATERIAL ON THE STRENGTH CHARACTERSTICS ON CONCRETE

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Abstract

This paper presents the application potential of replacing the natural aggregate of concrete with waste materials. The waste materials from industries are simply dumped into the disposal sites and do not degrade easily thus leading to the burden on the landfills. These waste materials also have the potential to be used in concrete if taken care of some of the aspects. This paper is an effort to study similar waste materials in concrete. The waste materials taken into consideration in case are waste glass and ceramic waste tiles. A control mix of concrete having ratio of 1:1.5:3 was used in the concrete making process. While the replacement of waste materials was done up to 0-25% by weight of concrete elements. Only replacement of the natural fine aggregate was done. The workability and compressive strength of both the conventional as well as waste reinforced concrete were examined and compared. The waste materials used gave good results and showed a satisfactory scope of these materials in construction industry. However, further research should be conducted to establish these materials suitability in concrete.

Keywords- Concrete, Ceramic Waste Tiles, CA- Coarse Aggregate, FA- Fine Aggregate, Compressive strength etc.

1.1 Introduction

In order to improve the life quality of people, it is very important to improve the construction strategies by using different construction methods. In the present world, researcher is in search of economic construction. As concrete is the most widely used construction material and aggregates are important filler material and they occupy 70-80% of the volume of the concrete. The aggregates have important and considerable influence on the properties of the concrete. The demand of aggregates as a filler material is increasing at high rate. To accomplish this demand, natural resource like rocks are demolished, the aggregates near river bed are taken away for the construction activities which ultimately are affecting the ecosystem of earth. To control the negative impact on ecosystem, it is very essential to find the substitute material for aggregate but at the same time this substitute material should be economical and should fulfilled all the desirable properties of aggregate. For the sustainable development, researcher is focussing on the waste material. As in our country it has been estimated that about 35% of the waste glass and waste ceramic is generated. These waste materials are durable, tough, and resistant against weather and chemical attack. The result of workability and compressive strength of the conventional concrete and the concrete reinforced with waste tile and glass were examined and discussed in this paper

Literature review

Various studies have shown that waste glass and tile aggregates can be used in the concrete to improve its properties and reduce its cost. However, the literature (Senthamarai and Manoharan 2005) presented that fresh ceramic waste coarse aggregates in concrete improve the workability but strength of concrete is reduced at the same time. The literature (Torkittikul et al.,2010) concluded lower density and higher compressive strength of the concrete with ceramic waste as fine aggregate in concrete. Researchers (Tanquerido and Certeza 2011) designed the concrete mixtures with 25%, 50%, 75% and 100% substitution of ceramic tiles' wastes to coarse aggregates and on comparing them to the conventional concrete concluded that the samples with 25% and 50% substitution along with the control specimen, exceeded the target strength of 15 MPa. In the literature (Dhaniyal and Aahmad 2015; Wadie et al., 2017) behaviour of concrete was studied by using the waste ceramic tiles in concrete as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40%, and 50% substitution. Decrease in workability was detected as the percentage of the ceramic aggregate was increased and an appreciable increase in compressive strength of concrete was reported. Dr. Haider et al., 2009 studied the possibilities of waste glass of size up to 5mm as a fine aggregate in concrete. They concluded that waste glass aggregate can be satisfactorily substituted for natural fine aggregate at replacement levels up to 20%. Malik et al., 2013 studied the use of waste glass as partial replacement of fine aggregates in concrete of M20 mix as 10%, 20%, 30% and 40% by weight fine aggregates can be replaced by waste glass up to 30% by weight showing 9.8% increase in compressive strength at 28 days. Researchers (Vasudevan and Pillay 2016) investigated the effect of partial replacement of cement with bentonite and also replaced fine aggregates with waste glass powder on concrete and concluded that the maximum compressive strength obtained was 20.33 N/mm^2 at 7 days and 42.44 N/mm^2 at 28 days at the replacement percentage of 10% for bentonite and same for the glass powder. Jain and Singh 2018 in their study, concluded the maximum compressive strength to be attained at 20% replacement of fine aggregates with glass powder. In the previously made studies, main emphasis was laid on the use of waste tile as coarse aggregates and less researches were made on the use of tile waste as fine aggregates. As tiles have plate like shape these were subjected to flakiness problems in many cases thus leading to less satisfactory results. Control on the grading of the aggregates was also not maintained in the researches done before.

2.1 Material used and their properties

The various materials used for the analysis are basic ingredients of concrete like cement, natural coarse and fine aggregates, water and waste material RTA (Waste Tile Aggregate). Some of the important properties of the above-mentioned materials are explained below:

2.1.1 Cement

Cement is important constituent to make concrete. For this research work Ordinary Portland

Cement of 43-Grade (ACC) confirming to IS 8112: 2013 is used. The table given below represents the found properties.

Table 1: Different properties of the cement used

Sr. No.	Properties	Laboratory result	IS standard result
1.	Fineness	3.2 %	<10 %
2.	Specific gravity	3.14	3.14 to 3.15
3.	Normal consistency	27 %	26 to 33 %
4.	Initial setting time	87 min	>30 min
5.	Final setting time	184 min	>600 min
6.	Soundness	3.20 mm	<10 mm
7.	Compressive strength 3 days 7day 28 days	 23.23 N/mm^2 33.40 N/mm^2 45.10 N/mm^2	 > 23 N/mm^2 > 33 N/mm^2 > 43 N/mm^2

Fig.1. OPC (43 grade)

2.1.2 Natural fine aggregate

Locally available crushed aggregates were used as a fine aggregate. For this research work fine aggregate conforming to grading zone-II as per **IS: 383-1970** is used. To get this required grade for zone-II sieve analysis was done. Fineness modulus was controlled for better result and was calculated as shown below:

Table 2: Calculation of fineness modulus by sieve analysis

Sr. No.	IS Sieve Size (mm)	Retained weight (kg)	Percentage weight retained (kg)	Cumulative percentage retained	Percentage finer
1.	4.75	0.025	0.025	2.5	97.5
2.	2.36	0.135	0.16	16	84
3.	1.18	0.190	0.35	35	65
4.	0.60	0.205	0.55	55	45
5.	0.30	0.255	0.81	81	19
6.	0.15	0.185	0.995	99.5	0.50
7.	0.075	0.005	1	100	0

Table 3: Physical properties of fine aggregate

Sr. No.	Properties	Recommended value	Observed value
1.	Fineness modulus	2-4	2.89
2.	Specific gravity	2.5-2.7	2.51
3.	Water absorption	2 %	1.10 %

2.1.3 Natural coarse aggregate

Coarse aggregates of sizes 20-10 mm were graded separately and mixed in the proportion 60:40 in order to avoid gap grading and hence increasing the strength. The fineness modulus details for the same are given below:

Table 4: Fineness modulus of 20 mm coarse aggregates using sieve analysis

Sr. No.	IS sieve size (mm)	Retained weight (kg)	Percentage weight retained (kg)	Cumulative percentage retained	Percentage finer
1.	20	0.0196	0.0196	1.96	98.04
2.	12.5	0.348	0.3676	36.76	63.24
3.	10	0.493	0.8606	86.06	13.94
4.	4.75	0.1394	1	100	0
5.	2.36	0	1	100	0
6.	1.18	0	1	100	0
7.	0.6	0	1	100	0
8.	0.3	0	1	100	0
9	0.150	0	1	100	0

Table 5: Physical properties of the 20 mm coarse aggregates

Sr. No.	Properties	Recommended value	Observed value
1.	Fineness modulus	6.5 to 8	7.24
2.	Specific gravity	2.6-2.7	2.63
3.	Water absorption	2 %	0.60 %

Table 6: Fineness modulus of 10 mm coarse aggregates using sieve analysis

Sr. No.	IS sieve size (mm)	Retained weight (kg)	Percentage weight retained (kg)	Cumulative percentage retained	Percentage finer
1.	10	0.122	0.122	12.26	87.8
2.	4.75	0.834	0.956	95.6	4.4
3.	2.36	0.044	1	100	0
4.	1.18	0	1	100	0
5.	0.6	0	1	100	0
6.	0.3	0	1	100	0
7.	0.150	0	1	100	0

Table 7: Physical properties of 10 mm aggregate

Sr. No.	Properties	Recommended Value	Observed value
1.	Fineness modulus	6.5 to 8	7.24
2.	Specific gravity	2.6-2.7	2.63
3.	Water absorption	2 %	0.60 %

2.1.4 Waste tile aggregate

Tile waste was used in concrete as the replacement of the 4.75 mm sized natural aggregates. This tile waste was collected from the local market and crushed with the help of jaw crusher. The 4.75 mm sized tile waste was separated with the help of sieve.

Fig.2. Ceramic Waste tile aggregate

Fig.3. Water Absorption of waste tile aggregate

2.2 Sample preparation

During sieve analysis it was observed that the aggregate sample procured was containing 42 % of 4.75 mm sized aggregate by weight. This 4.75 mm natural aggregate was replaced by 4.75 mm of waste tile aggregate partially upto 25 % with an interval of 5 %. Percentage replacement of natural aggregate i.e., 4.75 mm size aggregate by waste tile agggregate is done on the basis of trial mixes. The percentage of the natural aggregate and waste tile aggregate of 4.75 mm size used for different samples is given in table below:

Table 8: Percentage of 4.75 mm sized aggregate added to different specimens

Sample	Natural aggregate (%)	Waste tile aggregate (%)
D_0	100	0
D_5	95	5
D_{10}	90	10
D_{15}	85	15
D_{20}	80	20
D_{25}	75	25

2.3 Concrete mix design

Concrete mix of Grade M20 was designed as per of the code guidelines of IS: 10262-2009. The weight ratio of the trial mix obtained was 1:1.53:2.93 and the cement ratio was kept 0.50.

2.4 Casting of specimens

The mixing of the ingredients was done manually. Workability of the mixes was determined by slump test and compaction factor test. The mould of size 150 mm x 150 mm x150 mm was used for the casting and testing of specimens.

2.5 Testing done on fresh and hardened concrete

1. Compaction factor test on fresh concrete
2. Compressive strength test on hardened concrete
3. Flexural strength test on hardened concrete

Fig.4. Compaction factor test apparatus

Fig.5. Compressive strength testing machine

3. Result and Discussion

3.1 General

In this chapter different results obtained from experimental study conducted on concrete by replacing the natural single size aggregate with waste tile aggregate are discussed. The effect of the replacement done on the properties of concrete in its fresh and hardened state are analysed.

3.2 Effect of RTA on workability of the concrete

It was observed that the workability of M20 grade concrete was increased with the addition of RTA (at 5% RTA replacement) as compared to conventional concrete. But the workability reduced gradually as replacement percentage of RTA was increased.

Table 9: Workability Results

Sr. No.	Specimen Designation	Compaction value
1.	D_0	0.88
2.	D_5	0.92
3.	D_{10}	0.91
4.	D_{15}	0.86
5.	D_{20}	0.84
6.	D_{25}	0.78

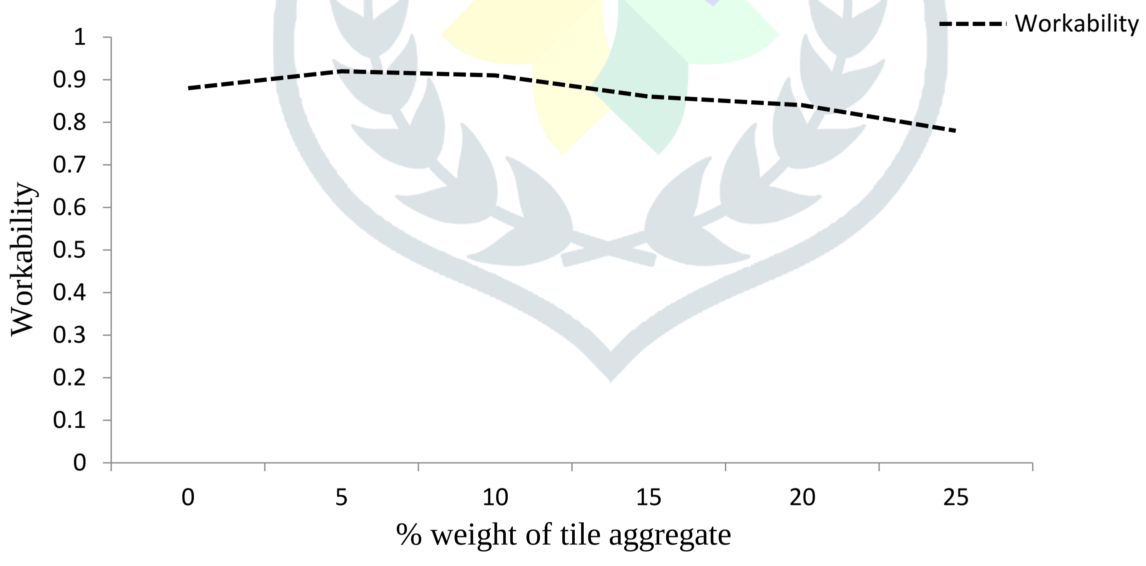

Fig.4. Effect of RTA on workability

3.3 Effect of RTA on compressive strength of concrete

From the testing result it was observed that the compressive strength of the compared samples was having large variations. With the result it was found that compressive strength was more in case of concrete with RTA at 5%, 10%, 15%, 20%, 25% replacement as compared to standard concrete mix. The compressive strength at 5%, 10%, 15%, 20%, 25% are tabulated below:

Table 8: Compressive strength of the specimens at 7 days, 14 days, 28 days

Sr. No.	Mix designation	Compressive strength at 7 days (N/mm^2)	Compressive strength at 14 days (N/mm^2)	Compressive strength at 28 days (N/mm^2)
1.	D_0	10.67	15.51	21.56
2.	D_5	22.74	26.59	29.00
3.	D_{10}	17.19	24.67	27.00
4.	D_{15}	21.78	25.26	25.00
5.	D_{20}	22.15	25.48	26.32
6.	D_{25}	24.07	28.67	30.04

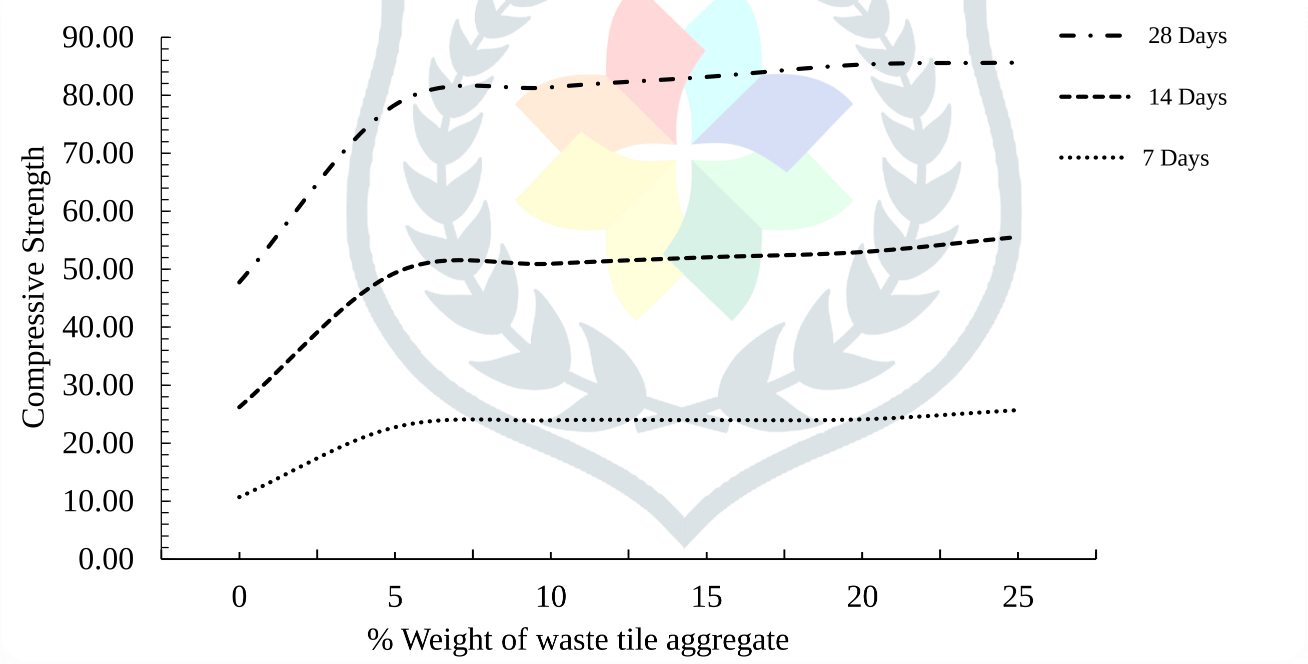

Fig.5. Effect of RTA on compressive strength

4. Conclusion

Workability

The workability of the concrete with the replacement of 5% RTA is maximum and with further addition of RTA there is a gradual reduction in the workability.

Compressive strength

This study shows that there is a good increase in compressive strength of concrete with the addition of RTA. The strength obtained is maximum at 25% replacement of RTA and a slight decrease is found in strength with further addition of RTA. Thus, it can be concluded that we can increase the percentage replacement further to obtain the strength equal to that of conventional concrete.

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