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Original Research Paper

Recycled Concrete Aggregate – A Substitute to Natural Coarse Aggregate

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ABSTRACT

The study deals with the investigation undertaken to examine the possibility of using recycled concrete aggregate (RCA) as a substitute to natural coarse aggregate (NCA). The concrete specimens were cast by partially replacing cement by fly ash, and NCA was replaced by 30% of RCA. Twenty % replacement of cement by fly ash gave optimum results for compressive strength, split tensile strength and flexural strength.

INTRODUCTION

With the increasing rate of demolition of buildings day by day, the demolition waste is also increasing. Recycling of concrete demolition waste as coarse aggregate for new concrete would facilitate its large scale usage (Padmini et al. 2009). The advantages of using recycled concrete from old concrete are lower environmental pollution, reduction in valuable landfill space and preservation of the natural aggregate (Sami & Abdelfatah 2009). Portland cement manufacturing industry is the significant contributor of green houses gas. In developing countries like India, the cement production is estimated to be 3 billion tons by 2020 and the amount of CO_2 released is about 3.2 billion tons (Magudeswaran et al. 2007). In order to reduce the usage of cement, supplementary cementitious materials such as fly ash can be used as a partial replacement of cement in concrete. Fly ash, which is a byproduct of thermal power generation posses good pozzolanic activity and if not used is disposed off into the landfills at a considerable cost. Use of fly ash in concrete can improve the ultimate strength and durability of concrete.

In the first part laboratory investigations were carried out to study the effect of replacement of natural coarse aggregate (NCA) by 10, 20, 30, 40 and 50% by recycled concrete aggregate (RCA). In the second stage of investigation mechanical properties of concrete made with fly ash as a partial replacement of cement in proportions of 10, 20 and 30% at a water binder ratio of 0.38 was studied with optimum percentage of replacement of RCA.

MATERIALS AND METHODS

Materials Used

Cement: Ordinary Portland cement 43 grade
Fly ash: Class F fly ash
Fine aggregate: Locally available river sand

Coarse aggregate: Natural coarse aggregate passed through 20mm and retained on 10mm sieve, and crushed concrete passed through 20mm and retained on 10mm sieve were used as recycled coarse aggregate. Physical properties of natural coarse and recycled concrete aggregate are given in Table 1

Super plasticizer: CON PLAST SP 430 was used as a super plasticizer

Mix Proportions

Two mix proportions were used in the study. Trial mix was first cast to find out the optimum level of replacement of natural coarse aggregate by recycled concrete aggregate. In each mix natural coarse aggregate was replaced by recycled concrete aggregate in increments of 10% to 50%. The mixes are designated as TM_1, TM_2, TM_3, TM_4, TM_5, TM_6. Trial mix proportions are given in Table 2. In the second stage of investigation fly ash is used as the partial replacement of cement in increments of 10% to 30% for optimum replacement of NCA by RCA and mix proportions are given in Table 3. The mixes are designated as CC, M_1, M_2, M_3. Super plasticizer was kept as 1.25% of binder.

Speciemen Casting and Curing

150 × 150 × 150 mm cubes, 100 × 100 × 500 mm prisms and 100 mm dia × 200 mm cylinders were cast in steel moulds and compacted using vibration table. After 24 hours cubes, prisms and cylinders were demoulded and kept in curing tank.

RESULTS AND DISCUSSION

As per IS specifications the aggregate crushing value, aggregate impact value and los angles abrasion value should not exceed 30% and the results are given in the Table 1.

Compressive strength of trial mixes are given in Table 4. With the increase in the percentage of recycled aggregate the compressive strength reduces when compared with control mix. The mix

Table 1: Mechanical properties of natural coarse and recycled concrete aggregate.

Proportions	100% NCA	90% NCA+ 10% RCA	80% NCA+ 20% RCA	70% NCA+ 30% RCA	60% NCA+ 40% RCA	50% NCA+ 50% RCA	Maximum permissible values as per IS 2386 Part IV (%)
Aggregate impact value (%)	16	22	23.6	24.7	25.8	26.2	30
Los angles abrasion value (%)	24	25.1	28.2	29.8	33	36	30
Aggregate crushing value (%)	24.2	25.3	26.4	27	28.2	30	30

Table 2: Trial mix proportions.

Mix	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Natural coarse aggregate (kg/m^3)	Recycled concrete aggregate (kg/m^3)	Water (litres)
TM_1	487	815	960	0	185
TM_2	487	815	864	96	185
TM_3	487	815	768	192	185
TM_4	487	815	672	288	185
TM_5	487	815	576	384	185
TM_6	487	815	480	480	185

Table 3: Mix proportions of optimized mix using 30% RCA.

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	Fine aggregate (kg/m^3)	Natural coarse aggregate (kg/m^3)	Recycled concrete aggregate (kg/m^3)	Water (litres)
CC	487	0	815	672	288	185
M_1	438.3	48.7	815	672	288	185
M_2	389.6	97.4	815	672	288	185
M_3	340.9	146.1	815	672	288	185

Table 4: Compressive strength for trial mixes.

Proportions	TM_1	TM_2	TM_3	TM_4	TM_5	TM_6
Compressive strength (MPa)	49	47.9	45.9	45.4	42.1	39.4

Table 5: Mechanical properties of optimized mix using 30% RCA.

Properties	CC	M_1	M_2	M_3
Compressive strength (MPa)				
7 day	28.9	29.3	29.4	28.8
14 day	34.9	35.8	35.9	35.1
28 day	45.9	46.4	46.5	44.7
56 day	46.6	48.6	48.8	46.7
90 day	49.1	52.8	53.4	51.1
Split tensile strength (MPa)	3.54	3.74	3.89	3.6
Flexural strength (MPa)	4. 65	4.88	5.05	4.72

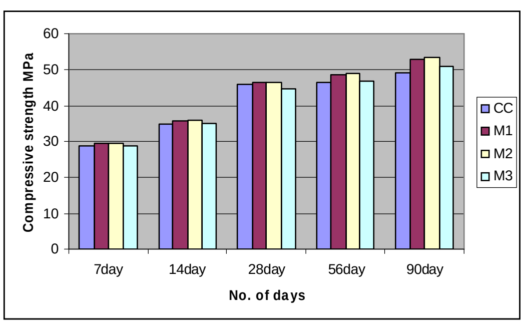

Fig. 1: Compressive strength of optimized mix.

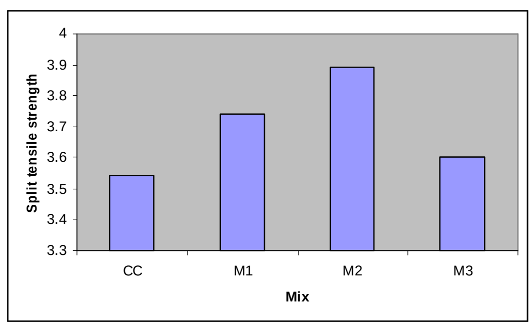

Fig. 2: Split tensile strength for optimized mix.

TM_1, TM_2, TM_3 and TM_4 achieve the required target strength M40 and satisfies above criteria. Hence up to 30% replacement of NCA by RCA can be used for wearing surfaces

The results of compressive strength, split tensile strength and flexural strength of concrete made up of fly ash as partial replacement of cement are given in Table 5 and Figs. 1, 2 and 3. When fly ash is added as a partial replacement to cement there was an improvement in the strength of concrete due to its pozzolanic action. Maximum compressive strength is achieved with 20% replacement of fly ash. With the increase in age the compressive strength also increases.

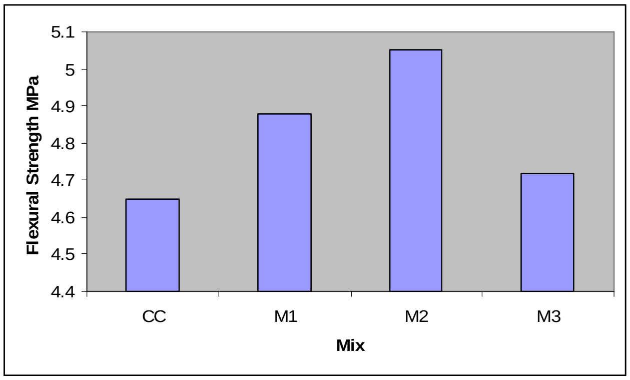

Fig. 3: Flexural strength of optimized mix.

Maximum split tensile strength was achieved with 20% of fly ash and thereafter the strength reduced. It was observed that split tensile strength was about 7.8 to 8.4 % of compressive strength.

The flexural strength of various mixes varied from 4.65 MPa to 5.05 MPa. Maximum flexural strength was achieved when cement was replaced by 20% of fly ash. The flexural strength of concrete was about 9 to 10 % of compressive strength.

CONCLUSIONS

1. Replacement of natural coarse aggregate by recycled concrete aggregate reduces the strength of the concrete when compared to concrete made of natural aggregate. Up to 30% replacement of natural coarse aggregate by recycled concrete aggregate can be done as it satisfies IS requirements.
2. Optimum level of replacement of cement by fly ash is found to be 20% to obtain better compressive strength, split tensile strength and flexural strength.
3. Partial replacement of natural coarse aggregate with recycled concrete aggregate and cement by fly ash leads to considerable savings in cost. Moreover, the replacement can solve the environmental issues related to disposal of old concrete and fly ash. Hence, it can be concluded that replacement of cement with 20% of fly ash and natural coarse aggregate by 30% of recycled concrete can be done.

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