Influence of Steel Crystal Powder on Performance of Recycled Aggregate Concrete

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Abstract. This research paper presents the scientific attempt of a comparative study of recycled aggregate concrete (RAC) and conventional concrete with the incorporation of waste steel crystal powder. In this study, recycled aggregate concrete has been prepared using recycled coarse aggregate as a partial substitute (0-30%) of natural coarse aggregate which provides an efficient solution to the dilemma of valuable fertile landfilling and also saves natural aggregate resources. The objective of this study is to investigate the strength and abrasion resistance of concrete made with recycled coarse aggregate. The addition of waste steel crystal powder varying from 0% to 5% by weight (with 2.5% increment) of total mix and assess its suitability for use in a series of designated applications. The compressive and flexural strength results on the recycled coarse aggregate demonstrated higher percentage loss than natural aggregate but remained within the acceptable limits. An adverse effect observed when waste steel crystal powder added into the RAC as well as conventional concrete. The results arrived from abrasion tests reveals that wear depth with the replacement of coarse concrete aggregates is enhancing with the increase in the replacement ratio but decreases with increase in waste steel crystal powder in the mix. In general, addition of waste steel crystal powder can produce stronger recycle coarse aggregate concrete as compare to conventional coarse aggregate concrete.

1. Introduction

Concrete is one of the most versatile materials employed in the construction industry. Progressively, the exigency for concrete is increasing which in turn boost the demand for their raw materials [1, 2] The consumption of concrete is second next to the water on our planet [3, 4]. The cement industry faces several challenges such that depleting fossil fuel reserves, scarcity of raw materials, perpetually increasing demand for cement and concretes, growing environmental concerns linked to climate change and an ailing world economy [5-7]. Presently, escalating industrialization results into immoderate work of construction and demolition (C&DW) activities. During last decade, the C&DW activities have increased tremendously around the world [8]. This waste is generated by the demolition of concrete elements and structures. In India, around 10-12 million tons of wastes, i.e. bricks, tiles, wood, metals, concrete etc. are annually generated by construction industry only. Concrete and bricks waste generation occupy 50% of total wastes which is not efficiently recycled [9]. Recycling of this wastes has various advantages such as reduce waste disposal problems and decreasing the consumption of natural resources. Many countries inaugurate regulations on reuse of waste materials in construction activity and have to generate recycled aggregate from the construction waste and

employed the same in concrete [10-12]. Steel crystal powder is an industrial waste material which is obtained from steel manufacturing industries, lathe machine etc. The proper utilization of such waste has not been given due attention, nor it has been appropriately reused in India. Also, this powder waste creates an environmental nuisance as they form refuse heaps in the premises of steel/rolling mills and workshops. On the other hand, the aggregate is an essential part of concrete, which occupies 60-75% of total concrete volume [13]. Therefore, the demand for aggregates overreaches 26.8 billion tons per year [14]. In India, scarcity of aggregates for the housing sector and road sector are around 55,000 and 750 million m^3 respectively [9]. Moreover, it is highly desideratum to use recycled aggregate in the construction sector to reduce scarcity and transportation cost of aggregate as well as mitigation of environmental pollution.
Several types of research had made known that recycled aggregate concrete possesses decrease in mechanical and durability properties as collate with conventional natural aggregate concrete. However, this decrease may reduce by appropriate mix design as well as the incorporation of mineral admixtures.
The purpose of present study is to investigate the influence of recycled aggregate and waste steel crystal powder on properties of recycled aggregate concrete. The compressive strength, flexural strength and abrasion resistance of concrete specimens were evaluated.
The discovery of this research provides a significant contribution to the world enlarging the use of recycled aggregate concrete with waste steel crystal powder for several structural applications.

2. Materials and Methodology

2.1. Characteristics of materials
Ordinary Portland cement of abiding by Indian Standards IS: 8112-1989 [15] was employed (Specific gravity 3.15, Normal consistency 32%, Initial setting time 96 min, Final setting time 186 min). River sand complies with zone II as per IS: 383-1970 [16] (Specific gravity 2.6, moisture 1%, water absorption 1.6%, fineness modulus 2.74) was employed as fine aggregates. Physical properties of cement and aggregates were represented in Table 1. Waste steel crystal powder is added 0, 2.5 and 5% by weight of total mix. Particle distribution analysis of fine aggregate and mild steel powder is represented in Figure 1. 20 mm and 10 mm sizes of Coarse aggregates (specific gravity 2.65, fineness modulus-7.3, water absorption 0.25%) were employed at an equal volume fraction of 50%. The recycled aggregate was used with 0-30% replacement of Natural coarse aggregates. Recycled aggregates were obtained from concretes prepared with same natural aggregates as control mix in the laboratory, which was crushed at the age of 28 days. In order to obtain similar grading curves those of natural coarse aggregate, the RCA was sieved with after crushing. To achieve the desired workability, 2% superplasticizer by weight of the cementitious material was employed in all mixtures.

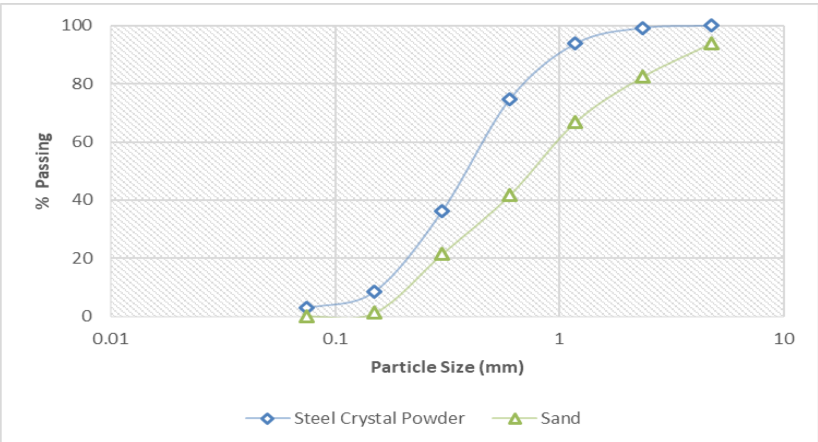

Figure 1. Particle size analysis of waste steel crystal powder and sand

Table 1. Physical properties of cement and aggregates

Sr.No.	Properties	Value	IS Code Specification
1.	Sieve analysis	Zone-II	IS:383-1970 [16]
2.	Specific gravity of fine aggregate	2.6	IS:2386-Part3, 1963 [17]
3.	Specific gravity of coarse aggregate	2.65	IS:2386-Part3, 1963 [17]
4.	Specific gravity of cement	3.15	IS:1727- 1967 [18]
5.	Consistency test of Cement	32%	IS:4031 (Part 4) – 1988 [19]
6.	Initial and Final setting time of cement	96 min 186 min	IS:4031 (Part 5) – 1988 [20]

2.2. Concrete Mixtures

The mix design for all concrete mixtures is represented in Table 2. Four series, i.e. series A, B, C and D were produced, each series incorporating a different percentage of waste steel crystal powder (SCP) (0%, 2.5% and 5%) and recycled aggregate (0%, 10%, 20% and 30%). Superplasticizer (2% by weight of cementitious material) was added to both types of concrete to achieve the desired workability of mixes. Designation details of all mixes are also represented in Table 2. The concrete is mixed by using a pan mixer in the laboratory. Firstly, the raw materials, i.e., coarse aggregates and fine aggregates are made a dry mix for one minute. Cement and waste steel crystal powder then added into the mix for further one minute. Water and superplasticizer are added into the mix for workability until all materials were mixed homogeneously. Subsequently, the prepared mixture was poured into the specimen moulds, and the mixture is compacted with the help of tamping rods as well as vibrating machine as per Indian standard. Recycled aggregates were employed in concrete after primary treatments. On account of their rough surface and angular shape, recycled aggregate concrete is less workable as compare to natural aggregate concrete. Consequently, the recycled aggregate is pre-soaked in distilled water for 24 hrs prior casting. Furthermore, to determine the effect of waste steel crystal powder on properties of concrete, 0%, 2.5% and 5% powder is employed.

Table 2. Quantities of raw materials (per m^3)

Mixes	Cement (kg)	Fine aggregate (kg)	Course aggregates			Steel crystal powder (kg)	Water (kg)	Superplasticiser (kg)	Remarks
			20 mm (Kg)		10 mm (kg)				
			NA	RA					
R0-SP0.0	450	623	542	0	542	0	180	9	0% RA, 0% SCP
R0-SP2.50	450	623	542	0	542	58.65	180	9	0% RA, 2.5% SCP
R0-SP5.0	450	623	542	0	542	117.3	180	9	0% RA, 5% SCP
R10-SP0.0	450	623	488	54	542	0	180	9	10% RA, 0% SCP
R10-SP2.50	450	623	488	54	542	58.65	180	9	10% RA, 2.5% SCP
R10-SP5.0	450	623	488	54	542	117.3	180	9	10% RA, 5% SCP
R20-SP0.0	450	623	434	108	542	0	180	9	20% RA, 0% SCP
R20-SP2.50	450	623	434	108	542	58.65	180	9	20% RA, 2.5% SCP
R20-SP5.0	450	623	434	108	542	117.3	180	9	20% RA, 5% SCP
R30-SP0.0	450	623	380	162	542	0	180	9	30% RA, 0% SCP
R30-SP2.50	450	623	380	162	542	58.65	180	9	30% RA, 2.5% SCP
R30-SP5.0	450	623	380	162	542	117.3	180	9	30% RA, 5% SCP

2.3. Specimen preparation and curing

150 x 150 x 150mm size cube specimens were cast for compressive strength test, and abrasion resistance tests, as well as 100 x 100 x 500 mm size beams specimens, were employed for the flexural

strength test. The details of specimen preparation are represented in Table 3. Specimens were cast in steel moulds and demould after 24 hrs and after that specimen are allowed to water curing. Curing was performed for 28 days; following samples were kept at laboratory room temperature until the testing age. The compressive strength and flexural strength tests were conducted on 7th, and 28th days whereas, abrasion test was performed on the 28th day.

Table 3. Specimens and testing details

Test	Indian standard	No. of specimens cast for each mix
Compressive strength	IS:516-1959 [21]	06
Flexural strength	IS:516-1959 [21]	06
Abrasion Resistance	IS:1237-1980 [22]	03

3. Testing methods

Compressive strength and flexural strength tests were performed in accordance with Indian standard IS516-1959 [21] with the universal testing machine. The standard rate of loading applied per minute 140 kg/cm^2. Abrasion resistance test was conducted as per Indian standard IS1237-1980 [22] using abrasion testing machine.

3.1. Results and Discussion

3.1.1. Compressive strength: The compressive strength of both types of concrete at the age of 7th day and 28th day is represented in Figure 2. Each value of compressive strength is an average of three specimens. Figure 2 demonstrates that compressive strength decreased when RA content increased from 0-30%. This observation is analogous to past researcher [8]. It is well known that the strength of concrete depends upon the strength of aggregate, cement matrix, as well as an interfacial transition zone between the matrix and the aggregate [8]. Results reveal that bonding recycled aggregate concrete and recycled aggregates were less as compared to bonding natural aggregates and conventional concrete.

Figure 2 also demonstrates the converse effect when waste steel crystal powder added into both types of concrete, i.e., the compressive strength increases. This improvement occurs as steel crystal powder, and cement matrix prepared homogenous concrete mix which results in bonding of its particles along with the mixed aggregates in concrete. However, concrete with 5% steel crystal powder represented highest compressive strength at the age of 28th day.

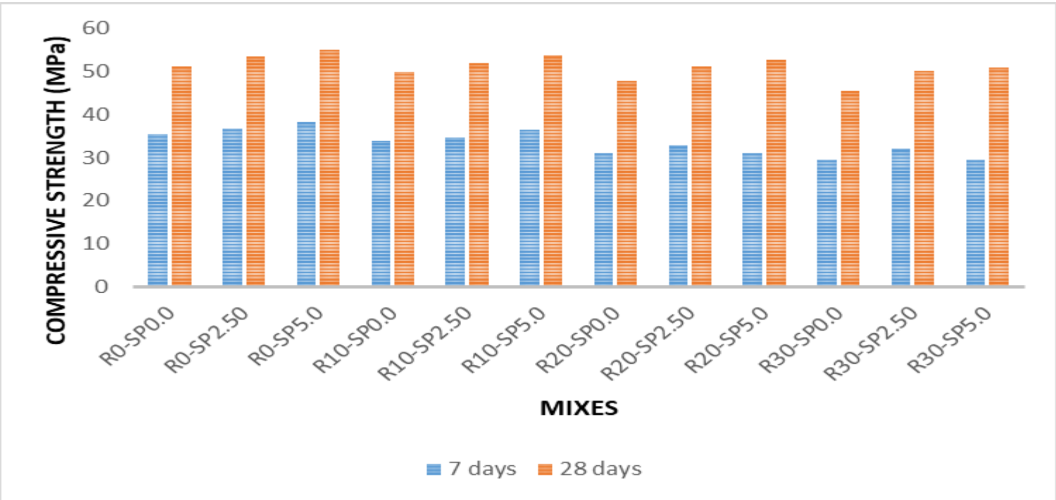

Figure 2. Compressive strength of CONVENTIONAL CONCRETE and RAC specimens

3.1.2. Flexural strength: The 7th day and 28th-day flexural strengths of the different mixes prepared in this study are represented in Figure 3. The results demonstrate that the addition of RA into RAC creates a decrease in flexural strengths of the concrete, whereas the use of steel crystal powder caused an increase in flexural strength for both types of concrete. The enhanced flexural strength of NAC may be due to the improved bond strength between cement paste and NA. Moreover, it depends upon contribution to the formation of the secondary C-S-H are other contributing factors to the enhanced strengths [23]. The results demonstrate that the replacement of NA with 5% steel crystal powder has higher tensile strength among all the mixes. On seventh day, the maximum value 5.0 MPa was observed for the mixes with 0% RA and 5% SCP and minimum value 2.5 MPa found for the mixes with 30% RA and 0% SCP. The similar trend followed at the 28th day; the maximum value 6.2 MPa was obtained in combination with 0% RA and 5% SCP and minimum value 4.5 MPa was obtained for mixes with 30% RA and 0% SCP.

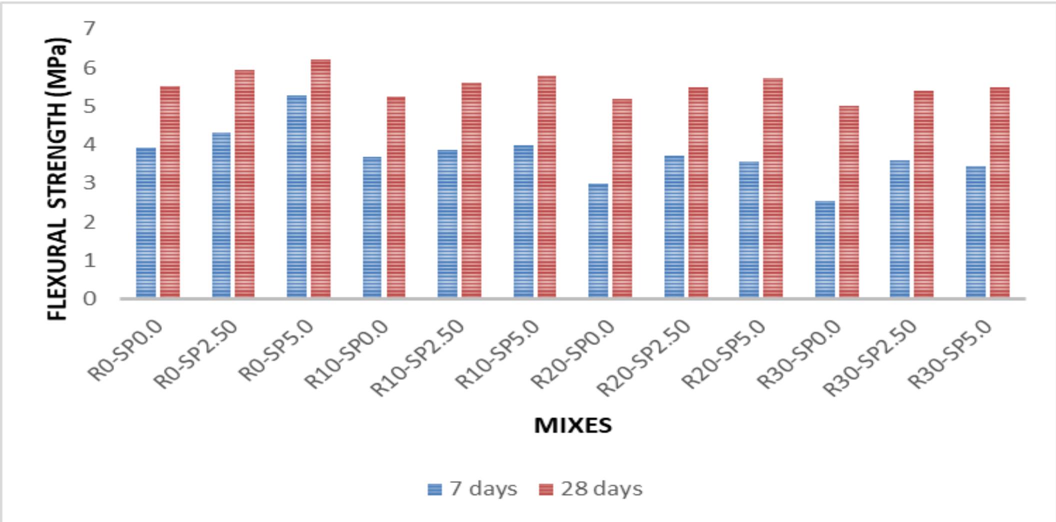

Figure 3. Flexural strength of CONVENTIONAL CONCRETE and RAC specimens

3.2 Abrasion resistance

Figure 4 demonstrates the variations in depth of wear of specimens observed concerning RA and SCP. It was represented in the Figure 4 that depth of wear is less in control mix as compared to RAC. SCP fill the pores of the recycled aggregate concrete result in an increase in homogeneity of mix followed by strength. The depth of wear observed less as employed steel crystal powder in concrete for both the case as compared to control concrete. The maximum depth of wear 1.52 mm was found for the control mix with 30% RA and 0% SCP and the minimum value 0.9 mm was seen in the concrete with 0% RA and 5% SCP. All the mixes had less than 2 mm depth of wear which demonstrates better resistance against abrasion as recommended by Indian standard. The steel crystal particles present in the concrete create a smooth surface of the concrete. This helps to minimize wearing depth.

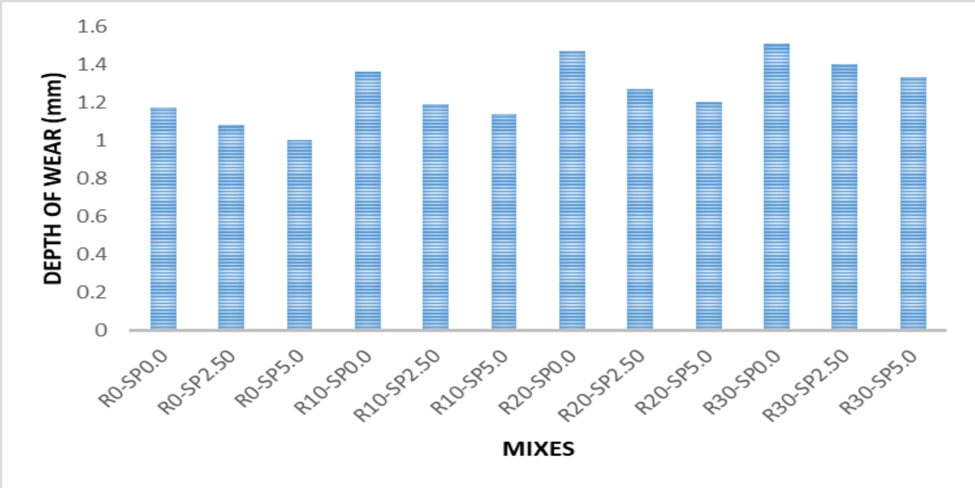

Figure 4. Depth of wear of CONVENTIONAL CONCRETE and RAC specimens

4.Conclusion

The present study includes the effect of recycled aggregate and wastes steel crystal powder on properties of concretes. The following conclusions can derive from this study.

The compressive strength and flexural strength were gradually decreasing with an increase in the amount of recycled aggregate in concrete. But, when steel crystal powder added into both types of concrete strength is found increased. Using SCP as an additional material helps to enhance better bonding between cement matrix and aggregate phase owing to SCP is working as filler material. The addition of the 5% SCP content in NAC, as well as RAC, increases the flexural and compressive strength. The concrete containing SCP exhibited better resistance against abrasion than each control mixes. This study drew attention to the researchers that it is possible to produce recycled aggregate concrete in which waste steel crystal powder may be utilized as additional material. A suitable proportion of the replacement of natural aggregate with recycled aggregate and SCP as the additional material can help this product to apply commercially in structures. Ultimately, it can be concluded that greater efforts for creating awareness and related specifications for the application of recycled aggregate in construction sector may provide great relief to reduce the disposal problem of construction and demolition wastes.

5. References

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