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A Study on Effect of Elevated Temperature on Compressive Strength of Steel Fiber Recycled Aggregate Concrete

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Abstract— In developing country use of concrete is very high and availability of raw material is comparatively less. Total replacement of concrete is not possible due to no material plays the role of concrete in terms of strength, durability, and workability. To obtain the results, tests are conducted with respect to The Indian Standards for Mix Design IS 10262 (2009) and Scheme of Testing and Inspection - Bureau of Indian Standards to determine the compressive strength of concrete after heating at 200°C temperature for steel fibre Recycled Aggregate Concrete. The natural aggregate is replaced 20% by recycled aggregate and steel fibres are added by volume (0.5%, 1%, and 1.5%). Results of this tests supports the hypothesis that this type of Concrete Mix may be suitable for partial substitution after proper Mix Designing. Aim of this study is to suggest alternate low-cost and environment suitable building materials from industrial wastes in an economic way with good compressive strength than normal concrete. Investigation suggests successful use of steel fibres in concrete for construction activities.

Keywords—Concrete, Recycled aggregate, Steel waste, Fire resistance

I. INTRODUCTION

In the construction field, a worldwide awakening is rising that in the sooner time the natural sources of the aggregates might be replaced partially or up to greater limits by the appropriate alternatives for creating an ideal mixes of concrete. For the same purpose a gradually increase have been occurring in the use of Recycled Coarse Aggregates (RCA) which can be used for producing concrete. Using RCA mainly targets the replacement of natural aggregates in the construction and pavements. The 1994 publication by the RILEM Technical Committee of 121 titled 'Specification for Concrete with Recycled Aggregate' had been a firm step that rose the awareness for using RCA. Number of researches were then made by Europe, United States and Japan on the same. Along with the waste produced from the demolished structures that again can be used as RCA abundant waste is produced. The efforts in this research have been oriented towards understanding the basic engineering properties of the produced recycled concrete [1-3].However, including of recycled aggregate (RA) for concrete production has become more common practice, worldwide. Lower-grade applications of RCA have been reported by many researchers, but higher grade activities are not much reported, because of its effects on strength, workability, and durability[2][4].

In terms of fire resistance concrete outperforms by a wide margin the other most popular building materials i.e. wood and steel. Concrete is a non-combustible material, and, as such, it does not increase the fire load and constitutes a natural barrier preventing the spread of fire. When exposed to fire temperatures concrete does not release any toxic gases or smoke. However, in fire-simulating high temperature conditions, its internal structure undergoes several physical transformations accompanied with chemical reactions, which result in irrecoverable changes affecting the performance and in the worst case leading to a total destruction of the material. With no standardized test methods it is difficult to definitively determine the effect of high temperature conditions on concrete. The main cause of such problems is that the respective test methods and regimes use different test parameters including moisture content, age of concrete before exposure, length of time of exposure, rate of temperature rise, size and shape of concrete specimens, cooling conditions and the test start point [18].

Steel fibre reinforced concrete have the enhanced properties; more ductile, improved durability, structural strength, requirements for steel reinforcement reduces, improvement in the impact & Abrasion resistance. Fibre reinforcement addresses the shortcoming of the normal concrete e.g. Low tensile strength, Brittleness, low post cracking capacity. Fibres make the concrete bonding stronger by increasing the interlocking strength [20].

Steel fibres may be added to RAC to improve its properties, making it suitable for use in building constructions. It is well known that the use of RAC in mortar and concrete increases shrinkage because the RAC can absorb a large quantity of water. Adding fibres into concrete and mortar is an effective method to reduce shrinkage and associated cracking. The addition of steel fibres can also significantly increase the post-peak stress and the energy absorption capacity of RAC.

Fire represents the massive risks to building structures. Fire can cause explosive spalling and mechanical deterioration in concrete's structure extensively at higher rate. A number of measures have been explored to prevent the adverse effects of high temperatures. It has been well established that the inclusion of polypropylene fibre or steel fibres can improve the mechanical properties (e.g. residual fracture energy, spalling resistance, hardness and toughness) of normal concrete after exposure to fire or high temperatures. In the case of RAC, few studies have shown that after exposure to high temperatures, its strength is get reduced, and the higher the exposure temperatures, the longer the exposure time at high temperature the larger the strength decreases [14].

It is generally found that strength degradation mechanism of concrete subjected to high temperature is mainly due to two main factors: 1) the increase of vapour pressure arising from the evaporation of moisture; and 2) the initiation and development of cracks caused by thermal stresses due to temperature difference between concrete's different parts (e.g. surface and core). As the moisture contents and the constituent materials of aggregates (and thus the interface between aggregates and mortar) are quite different between NC and RAC, the effects of these two factors should be different for RAC and NC.

As a result, the performance of Recycled aggregate concrete during and after exposure to high temperature has been found as a significant area requiring extensive further research. So many number of measures such as addition of fibres and pozzolana, and post-fire-recurring of fire damaged concrete have been shown to effectively prevent the adverse effects of fire/high temperature for Normal concrete [14][18-20].

1. In this paper, we propose an alternative low-cost and environment suitable building materials from industrial wastes in an economic way.
2. Rest of the paper is organized as follows, Section II contain the related work about the proposed topic, Section III contain the some measures of material and methodology., Section IV contain the architecture and essential steps of experimental work., section V explain the discussion and future scope of work, Section VI describes conclusions of proposed research work.

II. Related Work

Z.Tahar, et al [27] conducted a study on 'Effect of cement and admixture on the utilization of recycled aggregates in concrete'. They have used Two type of cement CEM I 52.5 CE CP2 (C1) and CEM I 52.5 CE (C2) from Lafarge in France. It has been observed in their study that the fineness modulus of Natural sand is comparatively smaller than the recycled sand. The authors have used Two NG fraction of limestone's crushed rock (4/10 mm and 10/20 mm) from LAFARGE (Givet in France) and two RG fractions (4/10 mm and 10/20 mm) from Docks of Limeil - Brévannes (DLB) (Gonesse in France) from a recycling plant were used. Authors have replaced coarse aggregates at 15, 30, 70 and 100% with recycled aggregates. The author have tested workability and compressive strength of fresh and hard concrete. Author has found that slump value is not that much affected at 30% replacement of natural aggregate but after that it decreases up to 55-65% and higher rate of RA leads to lower compressive strength.

Prabhat kumar, et al [2] written a review paper on experimental study for recycle concrete. Authors have studied different research papers. Authors have found that water absorption is higher than the natural aggregate and Natural Aggregate decreases by replacing the Recycled Concrete Aggregate, the corresponding strength goes on decreasing.

Chakrabarti S.C., et al [13] conducted an extensive test program for assessing the residual strength of concrete after fire. The authors proclaimed that the concrete actually gained some strength between 100 to 300°C in the presence of siliceous & carbonaceous aggregates. Some other researchers too have reported this phenomenon which has more detractors than supporters. As per the authors, concrete didn't lose much of its strength up to 500°C & in fact regained 90% of lost strength up to this temperature after about a year. The theory of fire affected concrete regaining some of its strength with time is not an established one. Concrete cubes heated beyond 800°C for 4 hours started crumbling after 2-3 days.

Bararimah et al [26] investigated the potential effect of steel fibre added into reinforced Concrete slabs. They have done research on Four-point bending test is conducted on six slabs to investigate the structural behaviour of the slabs by considering two different parameters; (i) thickness of slab (ii) volume fraction of steel fibre. The researcher has done experimental work consists of six slabs, in which three slabs are designed in accordance to Euro code 2 to fulfil shear capacity characteristic, whereas, the other three slabs are designed with 17% less thickness, intended to fail in shear. Both series of slabs are added with steel fibre with a volume fraction of Vf = 0%, Vf = 1% and Vf = 2% in order to study the effect and potential of fiber to compensate the loss in

shear capacity. The slab with *Vf* = 0% steel fibre and no reduction in thickness is taken as the control slab. The experimental result of researcher suggests promising improvement of the load carrying capacity (up to 32%) and ductility (up to 87%) as well as delayed in crack propagation for the slabs with *Vf* = 2%. In addition, it is observed that addition of fibres compensates the reduction in the slab thickness as well as changes the failure mode of the slab from brittle to a more ductile manner.
Phan Long T. et al [14] performed experiments on high-strength concrete (HSC) and normal strength concrete (NSC) at elevated temperature in order to study the phenomenon of explosive spalling associated with HSC & suggest further research needs. The differences were found to be most pronounced in the temperature range of 200°C to 400°C.

III. MATERIAL AND METHODOLOGY

A. Cement

Table 1 shows the physical values of cement which were given by the manufactures of cement.

Table 1. Physical test values of cement

Particulars	IS:12269 OPC 53 Grade	IS:1489 PPC	PPC available
Fineness(m^2/kg)	225	300	353
IST minimum (minutes)	30	30	30
FST maximum (minutes)	600	600	270
3 day Comp. Strength MPa	27	16	33
7 day Comp. Strength MPa	37	22	45
28 day Comp. Strength MPa	53	33	61

B. Coarsse aggregate

1. Flakiness & Elongation Index Test
When the aggregate's least dimension is less than 3/5th of its mean dimension it is said to be flaky. Mean dimension is the average of sieve size through which the particles pass and the sieve size on which the particles are retained.
When the material's length is greater than 9/5th times the mean sieve size the material is said to be elongated. Flakiness index or elongation index is the weight of flaky or elongated particles measured as percentage of the total weight of the sample. Flakiness index in excess of 25% is considered undesirable. Table 2 values satisfy the result value to be use in construction.

Table 2. Flakiness and Elongation value

Table 2. Flakiness and Elongation value

Aggregate Type	Flakiness Value (%)	Elongation Value (%)
Natural Aggregate	16.84	17.48
Recycled Coarse Aggregate	19.56	21.50

2. Particle Size Distribution
This was conducted by sieve analysis of aggregates. Tests for NA were conducted as per IS: 2386-1963 and IS: 383-1970. The sieve analysis result of NA are shown in table 3.

Table 3. Sieve analysis of natural aggregates (20mm)

Sieve Size	Weight retained (gms)	%Weight retained (gms)	Cumulative % weight retained	Cumulative % weight passing
80mm	0.0	0	0	100
40mm	0.0	0	0	100
20mm	327	16.35	16.35	83.65
16mm	1224	61.2	77.55	22.45
12.5mm	394	19.7	97.25	2.75
10mm	55	2.75	100	0
6.3mm	0	0	100	0
4.75mm	0	0	100	0
2.36mm	0	0	100	0
1.18mm	0	0	100	0
Total	2000		691.15	
F.M =691.15/100 =6.9115				

3. Aggregate Crushing Value Test
Table 4 shows the crushing value of aggregate gives the strength of aggregates to be used in project work.

Table 4. Aggregate crushing value

Aggregate Type	Crushing Value (%)
Natural Aggregate	17.15
Recycled Aggregate	22.47

4. Aggregate Impact Value Test
Aggregates must be tough enough to resist sudden loading (impact) to prevent failure of concrete against impact loading. Natural aggregates are strong enough to be used and recycled aggregates gives satisfactory results as per Table No.5.

Table 5. Aggregate impact value

Aggregate Type	Impact Value (%)
Natural Aggregate	14.46
Recycled Aggregate	20.28

5. Abrasion Value Test

Abrasion test is to check the hardness of aggregates. Table 6 indicates the abrasion values of both aggregates which suggests it is feasible to use for construction.

Table 6. Aggregate abrasion value

Aggregate Type	Abrasion Value (%)
Natural Aggregate	8.44
Recycled Aggregate	22.56

C. Fine aggregate

1. Particle size distribution

Depending upon the particle size distribution, IS: 383-1970 has divided the fine aggregate into four Grading Zones. The grading zones becomes progressively finer from grading zone I to grading zone IV. Table 7 shows the value of particle size distribution of fine aggregates which shows that the fine aggregate is from zone-II.

Table 7. Sieve analysis of fine aggregates

Sieve Size	Weight retained (gms)	%Weight retained (gms)	Cumulative % weight retained	Cumulative % weight passing
80mm	0	0	0	100
40mm	0	0	0	100
20mm	0	0	0	100
16mm	0	0	0	100
12.5mm	0	0	0	100
10mm	0	0	0	100
6.3mm	0	0	0	100
4.75mm	0	0	0	100
2.36mm	192.0	19.2	19.2	80.8
1.18mm	215.0	21.5	40.7	59.3
600	77.0	7.7	48.4	51.6
300	362.0	36.2	84.6	15.4
150	117.0	11.7	96.3	3.7
Lower than 150	37.0	3.7	-	0.0
Total	1000	100	245	
F.M. =245/100=2.45 and zone-II				

D. Steel fibres

CNC and VMC machines produces huge amount of steel waste all over the country. This waste can be used in concrete to overcome crack failure of concrete due to high temperature and use of recycle aggregate. Steel fibres are generally use in slab floor as replacement of steel bar. For the purpose to make concrete more economically eco-friendly with a finest quality, application of Computer Numeric Controlled Lathe machine waste can have immense importance. Just because using this large amount of (according to ICI 1200 million tons annually) this waste can help to produce large quantity of eco-friendly concrete and reduces large amount of land pollution [ ]. From all of the waste, the fibres had a length of range 24 mm – 40 mm and 0.6mm of diameter. The fibres had a length of 22 mm, an aspect ratio of 40 and a tensile strength of 650MPa [8] with spiral in nature are selected for this project. Table 8 shows the cost comparison between steel waste reuse versus recycle which shows that better to go for reuse than recycle.

Table 8. Cost comparison between steel wastes recycle versus reuse

Activity	Recycle (in rs.)	Reuse (in rs.)
Collection and Transport	5-6/km up to steel plant	5-6/km to site or mix plant.
Process to use	Reproducing steel takes time and money. At the end, price is around 35-41/kg.	No such activity required. It is being sold at 7-9/kg in market.
Total	48-52 rs./kg	15-20 rs/kg

E. Mix design

Table 9. Mix Design for M25 (RAC1, SFRAC 1, SFRAC2, SFRAC3)

Parameters	M25
Cement (Kg/m^3)	435.4
Fine aggregate (Kg/m^3)	653.384
Coarse aggregate (Normal) (Kg/m^3)	939.024
Coarse aggregate (Recycled) (Kg/m^3)	234.756
Water (Kg/m^3)	203.430
W/C ratio	0.50

Table 10. Mix Design for M25 (NC 1)

Parameters	M25
Cement (Kg/m^3)	435.4
Fine aggregate (Kg/m^3)	653.384

Coarse aggregate (Normal) (Kg/m^3)	1173.78
Water (Kg/m^3)	203.430
W/C ratio	0.50

Table 11. Series of mix proportion

Series	Natural aggregate	Recycled aggregate	Volume of VMC waste
NC 1	100%	0%	0%
RAC 1	80%	20%	0%
SFRAC 1	80%	20%	0.5%
SFRAC 2	80%	20%	1%
SFRAC 3	80%	20%	1.5%

IV. EXPERIMENTAL WORK

A. Casting of cubes

1.Schedule for casting for 28 days

Table 12 shows the date the cubes were casted for compressive strength test after 28 days of curing.

Table 12. Schedule for casting for 28 days

Date	Series
9/1/2018	NC 1, RAC 1
10/1/2018	SFRAC 1
11/1/2018	SFRAC 2, SFRAC 3

2. Schedule for casting for 14 days

Table 13 shows the date the cubes were casted for compressive strength test after 14 days of curing.

Table 13. Schedule for casting for 14 days

Date	Series
17/4/2018	NC 1, RAC 1
18/4/2018	SFRAC 1
19/4/2018	SFRAC 2, SFRAC 3

B. Compression test

1. Compression test values of concrete for 28 days

For each series, 2 cubes were casted. Table 14 shows the average value of compressive strength of cubes which are heated at 200°C for 2 hours and compressive strength of cubes before heating which are unheated. From all, SFRAC 3 is showing highest value of compressive strength. Meanwhile, RAC 1 possesses lowest values when compared to all the other series of mixtures.

Table 14. Comparison of average compressive strength before heating and after heating (28 days)

Series	Average compressive strength before heating	Average compressive strength after heating
NC 1	30.885	25.535
RAC 1	29.88	24.92
SFRAC 1	30.5	26.32
SFRAC 2	31	26.9
SFRAC 3	31.5	27.9

2. Compression test values of concrete for 14 days

For each series, 2 cubes were casted. Table 14 shows the average value of compressive strength of cubes which are heated at 200°C for 2 hours and compressive strength of cubes before heating which are unheated. Among all, SFRAC 3 is showing highest value of compressive strength.

Table 15. Comparison of average compressive strength before heating and after heating (14 days)

Series	Average compressive strength before heating	Average compressive strength after heating
NC 1	26.9	20.7
RAC 1	26.1	19.1
SFRAC 1	27.4	21.2
SFRAC 2	27.7	21.8
SFRAC 3	28.8	23.9

V. DISCUSSION AND FUTURE SCOPE

C. Discussions

The testing values of recycled aggregates are low in comparison of Natural aggregates. Normal concrete and RAC, colour change was observed on the surface of both of the concrete cubes after heated up to 200℃, due to chemical and physical changes in concrete's structure. Cracks can be easily seen on the normal concrete's surface and recycled aggregate concrete after exposure to elevated temperature. While, there were no sign of cracks in steel fibers recycled aggregate concrete for both 14 days and 28 days. An increase of steel fibers is effective in restraining cracks and their width.

Higher temperature have their effects on compressive strength of concrete. For 28 days, Normal concrete which is unheated having high compressive strength than the other. 20% replacement of Natural aggregate by recycled aggregate leads to loss of 4-6% of compressive strength compared to normal concrete. It is seen that after heating for 2 hours at rate of 2.5℃/min to reach 200℃, the compressive strength of concrete is negotiable for higher fiber content concrete. Increase in addition of steel fibers leads to higher compressive strength than one and other. For 14 days, NC 1 losses its strength up to 19% and RAC 1 losses its strength up to 21% after heating in comparison with before heating. After adding the fibers, it can be seen that fibers helps to keep bonding between constitutes even after heating. SFRAC 1, SFRAC 2 and SFRAC 3 losses its strength in the range of 13-15%.

Steel fibers actually transforms brittle material into ductile because fibers continue support load carrying capacity of concrete. Steel fibers exhibits high post cracking strength, improved fatigue strength, high resistance to spalling at high temperatures. The distribution of steel fibers into concrete ensures crack free structure of concrete throughout. Thus micro cracks are intercepted before they develop and impair the performance of concrete.

D. Future scope of work

Investigation of other mechanical properties like tensile strength, flexural strength.Investigation of other mechanical properties like tensile strength, flexural strength.Investigation of concrete at high temperature like 400℃ and up.

IV. CONCLUSIONS

It is been observed that recycled aggregates are having lower physical values than the natural aggregates but recycled aggregates gives satisfactory results which allows it use in construction sector. The rate of increase in compressive strength of SFRAC 3 is higher than the other mixtures for 14 days. Similarly, the rate of increase in compressive strength of SFRAC 3 is higher than the other mixtures for 28 days. The higher content of steel fiber is the main reason for increase in the rate of compressive strength. Among all different series of mix proportion, SFRAC 3 is giving higher values of compressive strength in both cases (before heating and after heating). From the results, it could be suggested that the SFRAC 3 is feasible for use in construction.

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