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The structural performance of concrete containing crushed rock dust and fly ash with the addition of coir fibre

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ABSTRACT

The present research work has been carried out by using crushed rock dust and fly ash as cement replacement in combined proportion of 20% CRD and 0% fly ash mix together with the gradual increase of 2.5% fly ash and simultaneously gradual decrease of 2.5 % of CRD with the addition of 0.5% coir fibre by weight of cement. Last proportion taken was 10% CRD and 10% fly ash. Use of this material in concrete not only improves the strength of concrete but also leads to the proper disposal of these materials, reducing the impact of these materials on environment. In this research the compressive and flexural strength of concrete with replacement of ordinary Portland cement by crushed rock dust (CRD) and fly ash with the addition of 0.5% coirfiber are studied. Eleven concrete mixes are prepared and compared with the nominal mix (with 0% CRD, fly ash and fiber). Test results for compressive and flexural strength show higher gain in strength for mixes using CRD, fly ash and fiber as compare to nominal mix. It was observed that cement replace with 12.5% CRD and 7.5% fly ash with 0.5% coir fiber gave the highest strength value. Property workability also studied for different concrete mixes. The addition of coir fiber gives slight more variation in the workability as compare to concrete made by using CRD and fly ash. The fiber into fresh concrete can increase the ductility of the concrete and also acts as a crack arrester.

Key words : *Coir fiber, Compressive strength, Flexural strength, Crush rock dust, Fly ash.*

Introduction

Concrete is a very strong and versatile mouldable construction material. It consists of cement, sand and aggregate (e.g., gravel or crushed rock) mixed with water. The cement and water form a paste or gel which coats the sand and aggregate. Concrete can continue to harden and gain strength over many years. Workability, strength, and durability are three basics properties of concrete. Amount of useful internal work necessary to overcome the internal friction to produce full compaction is termed as Workability. Size, shape, surface texture and grading of aggregates, water-cement ratio, use of admixtures and mix proportion are important factors affecting workability. Strength is to bear the desired stresses within the permissible factor of safety in expected exposure condition. The factor influencing the strength are: quality of cement, water-cement ratio, grading of aggregates, degree of compaction, efficiency of curing, curing temperature, age at the time of testing, impact and fatigue. Durability is sustenance of shape, size and strength; resistance to exposure conditions, disintegration and wearing under adverse conditions.

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Materials and Methods

The work presented in this paper reports an investigation on the behaviour of concrete produced from partial replacement of cement with crushed rock dust (CRD), Fly ash (FA) with the addition of coir fibre. The properties of CRD, FA, Coirfibre and OPC were first investigated. Mixture proportioning was performed to produce high workability concrete with target strength of 32.1 Mpa (M25) for the control mix. The effects of CRD,FA and Coir fibre on concrete properties were studied by meansof the mechanical properties of concrete, i.e. compressive strength and flexural strength.

Properties of Material used in the study

The test specimens were casted using Cement, Fine aggregate, Coarse aggregate, crush rock dust, fly ash, fibre and water. The materials, in general, confirmed to the specifications laid down in the relevant Indian Standard Codes. The materials used for making concrete have the following properties.

Cement

Ordinary Portland Cement of 43 grade was used throughout the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 1489-1991 are listed in Table 1.

Table 1. Properties of Cement

Sr. No.	Properties	Observations
1	Fineness (90 micron IS Sieve)	4 percent
2	Initial setting time	55 minutes
3	Final setting time	385 minutes
4	Standard consistency	33 percent
5	Specific Gravity	3.15
6	28-days compressive strength	44.3N/mm^2

Coarse Aggregates

The coarse aggregates used, were obtained from local quarry. The nominal maximum size of coarse aggregate was 12.5mm. Sieve analysis and other physical properties of aggregates are listed in Table 2.

Fine Aggregate

Natural river sand owing to their rounded shape was used in this work to ensure a better packing characteristic than that of the crushed sand. The grading of sand satisfied the IS: 383-1970.the properties of aggregates are listed in Table 3.

Table 2. Properties of coarse aggregates

Sr. No.	Properties	Observations
1.	Fineness modulus of coarse aggregate	7.34
2.	Specific gravity of coarse aggregate	2.64
3.	Bulk density of coarse aggregate	1720 kg/m^3
4.	Water absorption of coarse aggregate	0.91 %

Table 3. Properties of fine aggregates

Sr. No.	Properties	Observations
1.	Fineness modulus of fine aggregate	2.715
2.	Specific gravity of fine aggregate	2.61
3.	Bulk density of fine aggregate	1667 kg/m^3
4.	Water absorption of fine aggregate	0.8 %

Crushed rock dust

Crushed rock dust is produced during the process of large parent mass rock(Saiyad, *et al*, 2016, Venkata, *et al*, 2018).

Table 4. Properties of crushed rock dust

Sr.No.	Properties	Observations
1.	Specific gravity of fine aggregate	2.58
2.	Bulk density of fine aggregate	1750 kg/m^3

Fig. 1. Crushed rock dust

Fly ash

Fly ash is a fine gray powder consisting mostly of spherical, glassy particles that are produced as a by product in coal-fired power stations (Sathawanea *et al.,* 2013; Goud and Soni, 2016).

Coir fibre

Coir fibre used in the project work was also collected from the local market which were cut into

Table 5. Properties of fly ash (FA)

Sr.No.	Properties	Observations
1.	Specific gravity of fine aggregate	2.30
2.	Bulk density of fine aggregate	1280 kg/m^3

Fig. 2. Fly ash

small pieces (Vajje *et al.*, 2013; Khan and Ali, 2019). The properties of coir fibre are listed in Table 6.

Fig. 3. Coir fibre

Table 6. Properties of coir fibre

S No	Property	Value
1	Diameter	0.10 to 0.40 mm
2	Length	50-100 mm
3	Colour	Light brown
4	Specific gravity	1.15

Water

Fresh and clean tap water was used for casting the specimen in present study. The water was relatively free from the organic matter, silt, oil, sugar, chloride and acidic material as per Indian standard.

Super Plasticizer

The super-plasticizer used in the study was Glenium SKY777. Glenium SKY777 is based on second generation poly carboxylic ether polymers and supplied as a light brown liquid instantly dispersible in water.

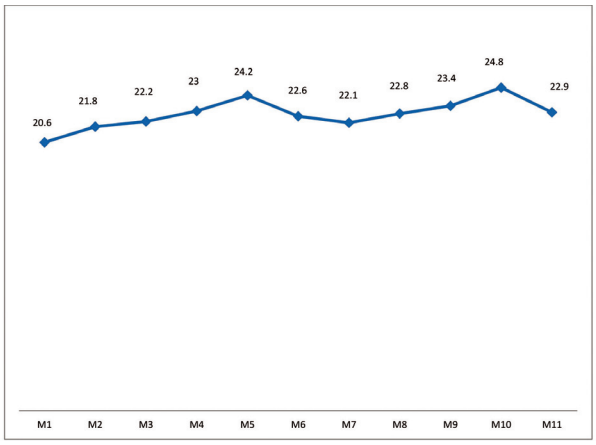

Fig. 4. 7 Days Compressive Strength for different fibres %age

Mix Design

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. Controlled concrete mix of M25 grade was designed as per BIS 10262-2009.the mix proportions are presented in the Table 7.

Table 7. Mix Design Ratio (1: 2.32: 3.11)

Mix Prop	Cement Content	Fine Agg. Content	Coarse Agg. Content	Water
Ratio	1	2.32	3.11	0.45
Kg/m^3	351	813.22	1090.38	157.73

Details of mix design

Different Proportion of Cement, CRD, Fly ash and fibre for testing

In this experimentation, cement was partially replaced by combinations of crushed rock dust(CRD) and Fly ash (FA) with the addition of coir fibre (0.5%). Test was started with control concrete of M25 grade.

Following table shows the percentage variations of cement, crushed rock dust (CRD) , Fly ash and coir fibre.

Table 8. Proportion of Cement, CRD, Fly ash and fibre for testing

Mix ID	Cementitious content			Coir Fibre %
	Cement OPC (%)	CRD%	Fly ash%	
M1	100.0	0	0	0
M2	80	20	0	0
M3	80	17.5	2.5	0
M4	80	15.0	5.0	0
M5	80	12.5	7.5	0
M6	80	10.0	10.0	0
M7	80	20	0	0.5
M8	80	17.5	2.5	0.5
M9	80	15.0	5.0	0.5
M10	80	12.5	7.5	0.5
M11	80	10.0	10.0	0.5

Experimental methodology

Test on fresh concrete

Fresh concrete was tested using slump cone test to find the workability of control concrete and concrete of combination of fly ash ,CRD with the addition of coir fibre.

Table 9. Workability Results of all mixes

Mix ID	Cementitious content			Coir Fibre %	Slump (mm)
	Cement OPC (%)	CRD%	Fly ash%		
M1	100.0	0	0	0	102
M2	80	20	0	0	98
M3	80	17.5	2.5	0	96
M4	80	15.0	5.0	0	95
M5	80	12.5	7.5	0	92
M6	80	10.0	10.0	0	92
M7	80	20	0	0.5	95
M8	80	17.5	2.5	0.5	93
M9	80	15.0	5.0	0.5	92
M10	80	12.5	7.5	0.5	90
M11	80	10.0	10.0	0.5	90

Tests on hardened concrete

To check the hardened properties of concrete the tests conducted are as follows:

a) Compressive Strength Test
b) Flexural strength test

Compressive Strength Test

For compressive strength test,cube specimens of dimensions 150x150x150 mm were cast for M 25 grade of concrete.The moulds were filled with different proportions of cement ,CRD ,Fly ash with the addition of coir fibre. Vibration was given to the moulds using table vibrator.thetop surface of the specimen was levelled and finished. after 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7 and 28 days . After 7 and 28 days curing, these cubes were tested on digital compression testing

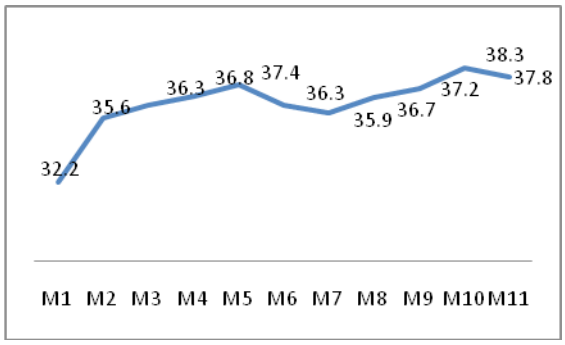

Fig. 5. 28 Days Compressive Strength for different fibres %age

Table 10. 7-Days Compressive Strength Values for various Concrete Mix

Mix ID	Cementitious content			Coir Fibre %	Failure load(KN)	7 Days Comp Strength (N/mm^2)
	Cement OPC (%)	CRD%	Fly ash%			
M1	100.0	0	0	0	463	20.6
M2	80	20	0	0	490	21.8
M3	80	17.5	2.5	0	500	22.2
M4	80	15.0	5.0	0	517	23.0
M5	80	12.5	7.5	0	545	24.2
M6	80	10.0	10.0	0	508	22.6
M7	80	20	0	0.5	497	22.1
M8	80	17.5	2.5	0.5	513	22.8
M9	80	15.0	5.0	0.5	527	23.4
M10	80	12.5	7.5	0.5	558	24.8
M11	80	10.0	10.0	0.5	515	22.9

Table 11. 28 - Days Compressive Strength Values for various Concrete Mix

Mix ID	Cementitious content			Coir Fibre %	Failure load(KN)	28Days Comp Strength (N/mm²)
	Cement OPC (%)	CRD%	Fly ash%			
M1	100.0	0	0	0	724	32.2
M2	80	20	0	0	801	35.6
M3	80	17.5	2.5	0	816	36.3
M4	80	15.0	5.0	0	828	36.8
M5	80	12.5	7.5	0	841	37.4
M6	80	10.0	10.0	0	816	36.3
M7	80	20	0	0.5	808	35.9
M8	80	17.5	2.5	0.5	825	36.7
M9	80	15.0	5.0	0.5	837	37.2
M10	80	12.5	7.5	0.5	861	38.3
M11	80	10.0	10.0	0.5	850	37.8

Table 12. 28 Days flexural Strength Values for various Concrete Mix

Mix ID	Cementitious content			Coir Fibre %	Failure load(KN)	28Days flexural Strength (N/mm²)
	Cement OPC (%)	CRD%	Fly ash%			
M1	100.0	0	0	0	157	3.14
M2	80	20	0	0	170	3.4
M3	80	17.5	2.5	0	176	3.52
M4	80	15.0	5.0	0	187	3.74
M5	80	12.5	7.5	0	195	3.9
M6	80	10.0	10.0	0	180	3.6
M7	80	20	0	0.5	177	3.54
M8	80	17.5	2.5	0.5	182	3.64
M9	80	15.0	5.0	0.5	192	3.84
M10	80	12.5	7.5	0.5	203	4.06
M11	80	10.0	10.0	0.5	186	3.72

machine as per IS 516-1959. the failure load was noted. In each category, three cubes were tested and their average value is reported (Patil, 2012).

Results of compressive strength

Flexural Strength Test

Thestandard sizes of beam specimen were 100x100x500mm. The beam moulds confirm to IS:10086-1982.compacting of concrete will be done by vibration as per IS:516-1959.the flexure test was performed on two point loading system.

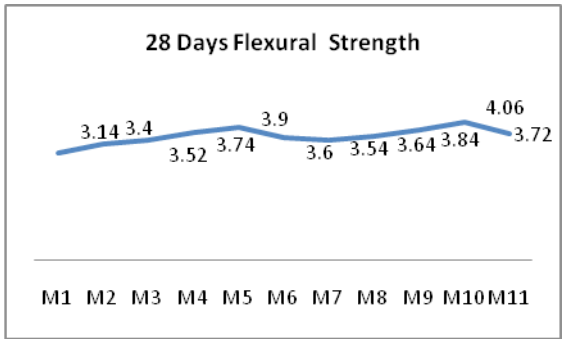

Fig. 6. 28 Days flexural strength for different fibres %age

Conclusion

Based on the 28 day compressive strength,concrete containing 17.5% CRD and 2.5% Fly ash as cement replacements with 0.5% coir fibre can be adopted as an optimal combination.

The environmental and economic benefits from the reuse of both CRD and Fly ash in concrete can also be significant and the utilisation of these materials in concrete may be recommended.

The workability of concrete had been found to be decrease with increase Fly ash and by adding coir fibres.

Compressive strength increases with the increase

in the percentage of Flyash (7.5%) up to replacement of cement in concrete for different mix proportions.

The maximum 28 days flexural strength was obtained with the combination of 12.5% CRD, 7.5% Fly ash with 0.5% coir fibre.

The concrete mix with 0.5% coconut fibre content, 12.5 % CRD and 7.5% Fly ash gives highest strength value

The partial replacement of cement with CRD (17.5%) and fly ash (2.5%) andaddition of coir fibre in concrete mix results in increase of compressive and flexural strength as compared to control mix .

Maximum value of compressive strength of concrete mix having (17.5%CRD+2.5% fly ash) replacement of cement and 0.5 % addition of coirfibre was 24.8 N/mm^2 for 7 days and 38.3N/mm^2 for 28 days.

It was observed that concrete involing CRD Fly ash and fibre does not show sudden failure.

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