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Characteristic Study of Concrete by Replacing Conventional Natural Agreegrates with Recycled Coarse Aggregate and Manufactured sand (M-Sand)

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Abstract: In this scientific world, nowadays various researches achieved the strength of the concrete, by replacing various alternates in the place of conventional natural aggregate (i.e., natural coarse aggregate and natural fine aggregate) so as to preserve the environment, leading to sustainable development. The exposure on recycling aggregates and M-sand (Manufactured sand) plays a vital role in the field of construction. As the price of sand and natural coarse aggregate is increasing day by day the usage of these alternates founds to be cheaper and it provides additional strength as compared to the conventional concrete. In this study, the wastes from various constructions are used in an optimum manner. A special chemical admixture Conflax which is a high range water reducer is used, that can create a desired slump for a low water-cement ratio. In this experimental study, the physical and mechanical tests are carried out in accordance with respect to the Indian standards. Concrete samples of M-20 grade prepared as IS-10262, 2009 mix design procedure with and without replacement of recycled aggregates and M-sand. The mix is performed by addition of 0%-0%, 50%-50% and 100%-100% of RCA and M-sand as same for the conventional mix. The compressive strength of concrete is determined by casting around 150x150 x150 mm cubes then they are cured under constant room temperature and finally they are tested for 3,7 and 28 days. This experiment results that strength about 50-50% replacements of RCA and M-sand reaches the maximum strength about 23.96 % than compared to the conventional concrete. Also, the cost for conventional natural aggregate and alternate aggregate i.e., RCA and M-sand are discussed in this study. Hence the usage of RCA and M-sand are recommended as an alternate material to achieve the Optimum strength with optimum percentages of quantity mix.

Keywords: Manufactured sand (M-sand), Recycled coarse aggregate (RCA), Conflax (high range water reducer), Physical properties, Mechanical properties, Compressive strength.

Highlights:

1. The Physical properties (which includes water absorbance, Sieve analysis, Specific gravity etc.,) and Mechanical property (i.e., Compressive strength of concrete) for 0%-0%, 50%-50% and100%-100 % of RCA and M-sand were observed.
2. The Compressive strength of 50%-50% replacement of recycled coarse aggregate and M-sand founds to be increases about 23.96%than compared to that control mix.
3. The cost is being analysed on the usage of M-sand and recycled coarse aggregate in the place of Natural River sand and natural coarse aggregate and founds that cost is reduced by 49.2% and46 %

Introduction:

Concrete, the most effective material used in the construction industry that plays a major role on resisting the compressive stresses. Generally, concrete is collection of cement, Stone chips (Coarse aggregate) and sand (fine aggregate) with optimum quantity of water, forming a heterogeneity component[1]. Years ago, the concrete mix is performed with the addition of conventional grade of natural materials, to achieve the adequate Compressive strength with respect to its concrete grade[1,2]. The selection of materials plays a vital role in the strength determination. With the development of recent technologies, the ultimate strength of concrete can be obtained by replacing various alternates. In this experimental study, the performance of Recycled coarse aggregate and M-sand are discussed in the place of conventional natural aggregate with different percentage about 0-0%, 50-50%, 100-100%.The Recycled coarse aggregate is generally differs from the natural coarse aggregate that contains an organic and inorganic components[3]. M-sand manufactured sand obtained from specific hard rock (Granite) which had a high crushing strength also it has a numerous advantages over the natured river sand[3]. The cement mortar overlaid in the recycled coarse aggregate inhibits the rate of water content and cement content in the concrete mix. Various reviews of paper literally describe the results taken from the addition of M-sand and Recycled coarse aggregate at different levels of mix in separate consequences[4-5]. In this experimental study, the combined effect of M-sand and Recycled coarse aggregate with different percentage are studied and the results are evaluated. The main objective of this study is to determine the compressive strength of concrete of grade M-20 by replacing the fine aggregate by M-sand and coarse aggregate by recycled aggregates with different percentages and to compare with the control concrete sample without replacement[6-8]. Also, it has been emphasized the special physical and mechanical properties of recycled coarse aggregate and M-sand with different mix proportions[9-10]. The step by step experimental investigations and results are discussed as follows below.

Experimental Investigations:

The experimental study was carried with the study of each materials that inhibiting the strength determination. The Properties (that includes both Physical and Mechanical Properties) of Ordinary Portland Cement of 53 grade, Recycled Coarse aggregate (RCA), Natural coarse aggregates (Jelly), Fine aggregates (Sand), Manufactured Sand (M-sand) are discussed.

Materials Used:

Cement:

The Cement used in this study is Ordinary Portland Cement of 53 grades which founds to be finer material and is considered to be Paste that binds well for the given non-homogeneity materials. The Properties of cement are studied as per the Indian Standards. In this study, Specific gravity of cement is determined by density bottle method (IS-2720, part- iii, 1988).They are tabulated as follows:

Table-1: Specific gravity of cement

Description	Trial I	Trial II
Weight of empty bottle (w_1)gm	17.48	17.62
Weight of bottle with one-third of sand (w_2)gm	30.82	31.58
Weight of bottle with one-third of sand and water (w_3)gm	66.215	66.32
Weight of bottle with full of water (W_4)gm	56.98	56.99
Specific gravity	3.2	3.15

Specific gravity of Cement = 3.10

Fine aggregate:

In this experimental study, natural river sand is being used up with different percentages about 0% and 50% and 100% for the concrete mix. The Selection of Fine aggregate is based on the sand made to pass through the 2.36mm sieve size and allowed to retain on 600µ that plays a major role in filling the Voids in the concrete mix.

Coarse aggregate:

Natural Coarse aggregate i.e. Jelly is an important constituents in the concrete. This gives the confined shape and reduces the Shrinkage for a structure. Here, the aggregates are selected in such way that allows passing through the 20mm sieve size and retaining on 10mm sieve size.

Water:

The quality of water used in this experimental study is based on PH value lies under the neutral stage (lies between 6 to 7) i.e. neither acidic nor alkaline and are founds to be odourless. Hence, the quality and quantity of water is looked carefully at different percentages of concrete mix.

Manufactured Sand (M-sand):

M-sand is an alternative composition of the natural river sand. Dredging of natural river sand leads to environmental disasters and results scarcity of natural resources. To develop a sustainable environment the alternate M-sand is used up with different percentages about 0%, 50% and 100% replacements in this study.

The following criteria results the selection of M-sand in this experimental study:

- The surfaces of the particles of M-sand are smooth and the edges are well grounded manner.
- They should not contain any organic impurities during the time of mixing.

Recycled Coarse aggregate (RCA):

Recycled coarse aggregates are aggregates collected from various building demolishes that are being considered to be wastes. The particle size are selected as similar to the natural coarse aggregate. A special care should be given at the time addition of cement content and water content. In addition to the crushed particles, the other impurities are removed during the time of mixing.

Chemical admixture:

Because of the composition of non-homogeneity materials in this concrete mix, the chemical admixtures are used other than cement, water and aggregates during or before mixing to reduce the water content or to retard the chemical reactions. In this study, a high range water reducer-Conflax is being used up that can create a desired slump for a low water-cement ratio.

Experimental Methodology:

The works carried out for the strength determination of concrete by replacing the coarse aggregate by recycled aggregate and fine aggregate by M-sand (manufactured sand) with different percentages of mix are as follows:

i. **Strength Determination of Cement:**

a. Determination of the Specific gravity of cement

ii. **Strength Determination of Coarse Aggregate**

a. Determination of the Specific gravity of coarse aggregate
b. Determination of the water absorption of coarse aggregate
c. Determination of the Toughness of the material
d. Determination of the crushing strength of the aggregate
e. Determination of various proportioning of aggregates

iii. **Strength Determination of Fine Aggregate**

a. Determination of the specific gravity of fine aggregate
b. Determination of the water absorption of fine aggregate
c. Determination of various proportioning of fine aggregates

iv. **Strength Determination of M-Sand**

a. Determination of the specific gravity of M-sand

b. Determination of the water absorption of M-sand

v. **Strength Determination of Recycled Aggregates**

a. Determination of the Specific gravity of recycled aggregates
b. Determination of the water absorption of recycled aggregates.

Experimental Results:

The experimental test results are evaluated for various materials and are verified with the Indian standards. The following tabulations shows the Physical and Mechanical properties in accordance with the comparisons of natural conventional aggregates and to the alternate aggregates as described in the experimental methodologies. This result highlights the various compositions and behaviour of the materials that are being used in this study.

Physical Properties of Fine Aggregates:

Specific Gravity of Fine aggregates: (IS 2386 –part III-1963)[9]

Table-2: Specific Gravity of Fine aggregates

Description	**Specific gravity of sand by pycnometer method**			**Specific gravity of M-sand by density bottle method**		
	Trial 1	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Weight of empty bottle (w_1)gm	644	645	645	17.54	17.4	17.43
Weight of bottle with one-third of sand (w_2)gm	1075	1076	1087	49.56	48.03	51.57
Weight of bottle with one-third of sand and water (w_3)gm	1742	1745	1748	86.54	86.31	88.41
Weight of bottle with full of water (W_4)gm	1476	1478	1472	66.64	67.17	67.23
Specific gravity	2.612	2.63	2..66	2.64	2.66	2.65

Specific gravity of sand = 2.63
Specific gravity of M-sand = 2.65
Water absorption of Fine aggregates (IS 2386 – Part-III, 1963)[9]

Table-3: Water absorption of Fine aggregates

Sample	**(w_1) gm**	**(w_2) gm**	**W_3 gm**	**P_{t1} %**	**(W_1^1) gm**	**(W_2^1) gm**	**W_3^1 gm**	**P_{t2} %**
1	200	206	6	3	200	208	8	4
2	200	205	5	2.5	200	206	6	3

From the above table, it indicates:

W1- Weight of oven dried sample (w_1) gm for natural river sand
W2- Weight of saturated specimen (w_2) gm for natural river sand
W_3-Weight of water absorbed W_3= (W_2-W_1) for natural river sand
P_{t1}-% of water absorption = (W_3/ W_1) x 100 for natural river sand
W_1^1- Weight of oven dried sample (w_1) gm for M-sand
W_2^1- Weight of saturated specimen (w_2) gm for M-sand
W_3^1-Weight of water absorbed W3= (W_2-W_1) for M-sand
P_{t2}-% of water absorption = (W_3/ W_1) x 100 for M-sand

This results that the:

Water absorption for natural fine aggregate = 2.75
Water absorption for M-sand aggregate = 3.5

Sieve analysis for Fine aggregates: (IS 2386 Part- I, 1963)[9]

Table-4: Sieve analysis for Fine aggregates

Sieve size	Weight of aggregate retained on sieve(gm)		% of aggregate retained on sieve		Cumulative % of aggregate retained (N)		% of finer (100 - N)	
	W_1	W_2	P_{t1}	P_{t2}	N_1	N_2	P_{tf1}	P_{tf2}
4.75mm	3	141	0.6	28.2	0.6	28.2	9.4	71.8
2.36mm	11	93	2.2	18.6	2.8	46.8	97.6	53.2
2mm	6	13	1.2	2.6	4	49.4	96	50.6
1.18mm	102	104	20.4	20.8	24.4	70.2	75.6	29.8
1mm	38	9	7.6	1.8	32	72	68	28
600µ	118	26	23.6	5.2	55.6	77.2	44.4	28.8
425µ	123	21	24.6	4.2	80.2	81.4	19.8	18.6
300µ	26	8	5.2	1.6	85.4	83	14.6	17
212µ	55	25	11	5	96.4	88	3.6	12
150µ	8	13	1.6	2.6	98	90.6	2	9.4
75µ	6	21	1.2	4.2	99.2	94.8	0.8	5.2
Pan	3	25	0.6	5	99.8	99.8	0.2	0.2

Where 1 and 2 represents the Comparisons corresponding calculated values for natural river sand and manufactured sand.Graphical representation of the particle size distribution of fine aggregates.

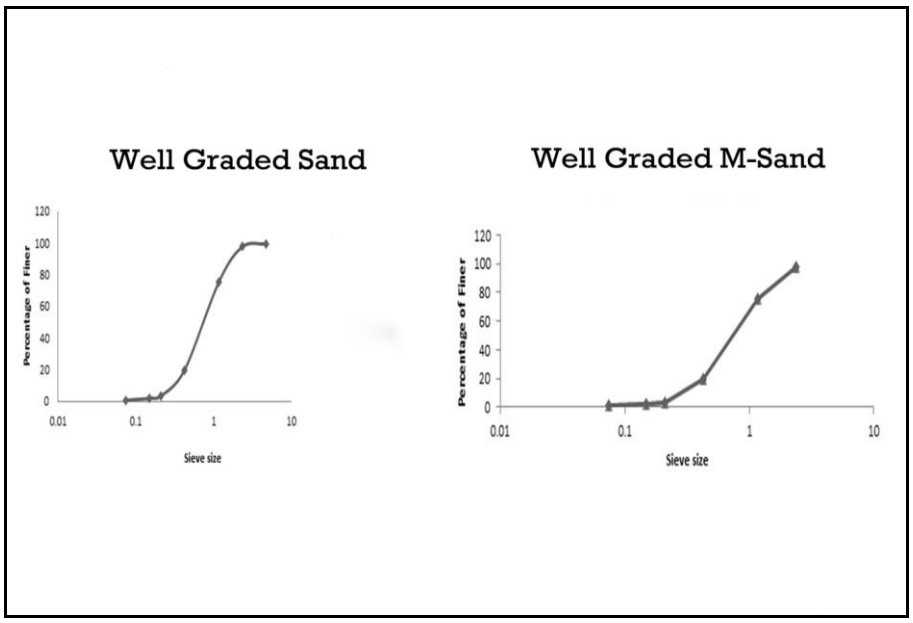

Fig: 1- Sieve analysis for Fine aggregates

Physical Properties of Coarse Aggregates:

Specific gravity for coarse aggregate: (IS 2386 -Part 3, 1963)[9]

Table 5: Specific gravity for coarse aggregate

Description	Specific gravity of natural coarse aggregate	Specific gravity of Recycled coarse aggregate
Weight of saturated aggregate suspended in water with the basket (W_1)	3.58 kg	3.98 kg
Weight of basket suspended in water W2	0.78 kg	0.78 kg
Weight of saturated surface dryaggregate (W3)	4.41	4.82 kg
Weight aggregate after oven dry (W4)	4.2 kg	4.52 kg
Specific gravity for coarse aggregate	2.605	2.79

Specific gravity for Recycled coarse aggregate = 2.79
Specific gravity for coarse aggregate = 2.605
Water absorption for coarse and recycled coarse aggregate (IS 2386 - Part 3, 1963)[9]

Table-6: Water absorption for coarse and recycle coarse aggregate

Sample	(w_1) gm	(w_2) gm	W_3 Gm	P_{t1} %	(W_1^1) gm	(W_2^1) gm	W_3^1 gm	P_{t2} %
1	200	204	4	1	100	94.5	5.5	5.5
2	200	203	3	1.5	100	94	6	6

From the above table, it indicates:

W1- Weight of oven dried sample (w_1) gm for natural coarse aggregate
W2- Weight of saturated specimen (w_2) gm for natural coarse aggregate
W_3-Weight of water absorbed W_3= (W_2-W_1) for natural coarse aggregate
P_{t1}-% of water absorption = (W_3/ W_1) x 100 for natural coarse aggregate
W_1^1- Weight of oven dried sample (w_1) gm for recycled coarse aggregate
W_2^1- Weight of saturated specimen (w_2) gm for recycled coarse aggregate
W_3^1-Weight of water absorbed W3= (W_2-W_1) for recycled coarse aggregate
P_{t2}-% of water absorption = (W_3/ W_1) x 100 for recycled coarse aggregate

Water absorption for coarse aggregate = 1.25 %
Water absorption for coarse recycled aggregate = 5.8 %

Impact value test (IS 2386 - IV, 1963)[9]

Table-7: Impact value test

S.NO	Detail of sample	Trial I	Trial II
1	Total weight of aggregate sample filling the cylinder measure (W_1)gm	300	300
2	Weight of aggregate fraction passing 2.36mm sieve after test (W_2)gm	50	70
3	Weight of aggregate fraction retained 2.36mm sieve after test (W_3)gm	250	230
4	$W_1 - W_2 + W_3$	500	460
5	A.I.V= (W_2 X 100 / W_1)%	16.67	23.33

Aggregate impact value = 20 %

Proportioning of Coarse aggregate (IS 2386 - Part 1, 1963)[9]

Table-8: Proportioning of Coarse aggregate

Sieve size (mm)	Weight of aggregate retained on sieve(kg)	% of aggregate retained on sieve	Cumulative % of aggregate retained (N)	% off finer (100 - N)
100	0	0	0	100
80	0	0	0	100
63	1.19	8.5	8.5	91.5
40	3.906	27.9	36.4	63.6
37.5	0.643	4.5	40.9	59.1
26.5	0.489	3.49	44.39	55.61
20	1.501	10.72	55.11	44.89
16	3.85	27.5	82.61	17.39
12.5	1.89	13.5	96.11	3.89
10	0.41	2.9	99.01	0.99
Pan	0.09	0.64	99.65	0.35

Fresh concrete test (slump cone test):

Table-9: Slump cone test

S.No	Percentage Added (%)		% of Water	Initial Value (Cm)	Final Value (Cm)	Slump Value (Cm)
	M-Sand	Recycled Aggregate				
1	-	-	0.35	30	29.4	**0.6**
			0.4	30	29	**1**
			0.45	30	25	**5**
2	50	50	0.35	30	29.5	**0.5**
			0.4	30	28	**2**
			0.345	30	22	**8**
3	100	100	0.35	30	30	**0**
			0.4	30	29.7	**0.3**
			0.45	30	29.5	**0.5**

Mix- Design (as per Indian Standards)

Concrete mixes can also be designed using software program. But in this experimental study the manual design was done using Indian Standard Codes such as IS 10262:2009, IS456:2000 and IS 383: 1962[1,2,3]. The choice of concrete mix design is performed to achieve the maximum target strength and appearance.

Design of a concrete mix for M20 grade using M-sand and recycled aggregate using the following data's:

a) Type of cement	OPC 53 grade
b) Maximum size of aggregate	20mm
c) Maximum size of M-sand	2.36mm
d) Maximum cement content	320 kg/m^3
e)Maximum W/C ratio	0.45
f)Workability	100 mm slump
g) Exposure condition	Severe (RCC)
h) Chemical admixture	Super plasticer (Conflax)

Grading of Coarse aggregate is conforming as per IS 383[6] and grading of fine aggregate is falling in Zone II.

Target mean strength f 'ck	=	26.6 N/mm²
Maximum water content per cubic	=	186 liter
0water content for 100mm slump	=	197 liter
Cement content	=	350.22 kg
Volume of concrete	=	1m³
Volume of cement	=	0.113 m³
Volume of water	=	0.1576 m³
Volume of super plasticizer	=	0.0017 m³
Volume of aggregate	=	0.7294 m³
Volume of coarse aggregate	=	1026 kg
Volume of fine aggregate	=	882.04kg

The final Mix-proportion for M-20 Grade of Concrete is found to be: 1: 1.8: 3.1

Based on the test results and Mix-Proportions of M-20 grade of concrete Cubes of 150m³ are prepared then are cured and the Mechanical test results are evaluated.

Mechanical Properties:

Compressive strength of concrete[8]:

CASE-01

Cube size 150mm x 150mm x 150mm

Percentage of M-sand added 0 %
Percentage of Recycled aggregate added 0 %

Table-10: Compressive strength of concrete

Age at the Time of Testing (Days)	Weight of the Sample (Kg)	Ultimate Load (KN)	Ultimate Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
3	8.22	345	15.33	
3	8.35	340	15.11	
3	8.33	330	14.67	**15**
7	8.32	400	17.77	
7	8.35	390	17.33	
7	8.38	415	18.44	**17.85**
28	8.27	440	19.55	
28	8.5	480	21.33	
28	8.4	455	20.22	**20.37**

CASE-02

Cube size 150mm x 150mm x 150mm
Percentage of M-sand added 50 %
Percentage of Recycled aggregate added 50 %

Table-11: Compressive strength of concrete[8]

Age At The Time Of Testing (Days)	Weight Of The Sample (Kg)	Ultimate Load (KN)	Ultimate Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
3	8.54	365	16.22	
3	8.44	355	15.78	
3	8.48	370	16.45	**16.15**
7	8.46	470	20.88	
7	8.39	455	20.22	
7	8.37	460	20.45	**20.52**
28	8.1	580	25.77	
28	8.19	560	24.88	
28	8.26	565	25.11	**25.25**

CASE-03

Percentage of M-sand added 100 %
Percentage of Recycled aggregate added 100 %

Table-12: Compressive strength of concrete[8]

Age at the Time of Testing (Days)	Weight of the Sample (Kg)	Ultimate Load (KN)	Ultimate Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
3	8.33	280	12.44	
3	8.27	265	11.78	
3	8.38	285	12.67	**12.3**
7	8.42	330	14.67	
7	8.36	345	15.33	
7	8.3	335	14.89	**14.5**
28	8.28	380	16.88	
28	8.34	395	17.55	
28	8.27	410	18.22	**17.55**

Results and Comparisons:

The effect of concrete on the replacement of Manufactured sand and recycled coarse aggregate at different percentages of M-20 concrete grade of mix is resulted with the effects of 28 days curing under constant room temperature. They are tabulated as follows:

Table-13:Compressive strength of concrete at 28 days of curing[8]

% of M-sand and recycled aggregate added	Age at the Time of Testing (Days)	Wt of the Sample (Kg)	Ultimae Load (KN)	Ultimate Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
0	28	8.27	440	19.55	
0	28	8.5	480	21.33	
0	28	8.4	455	20.22	**20.37**
50	28	8.1	580	25.77	
50	28	8.19	560	24.88	
50	28	8.26	565	25.11	**25.25**
100	28	8.28	380	16.88	
100	28	8.34	395	17.55	
100	28	8.27	410	18.22	**17.55**

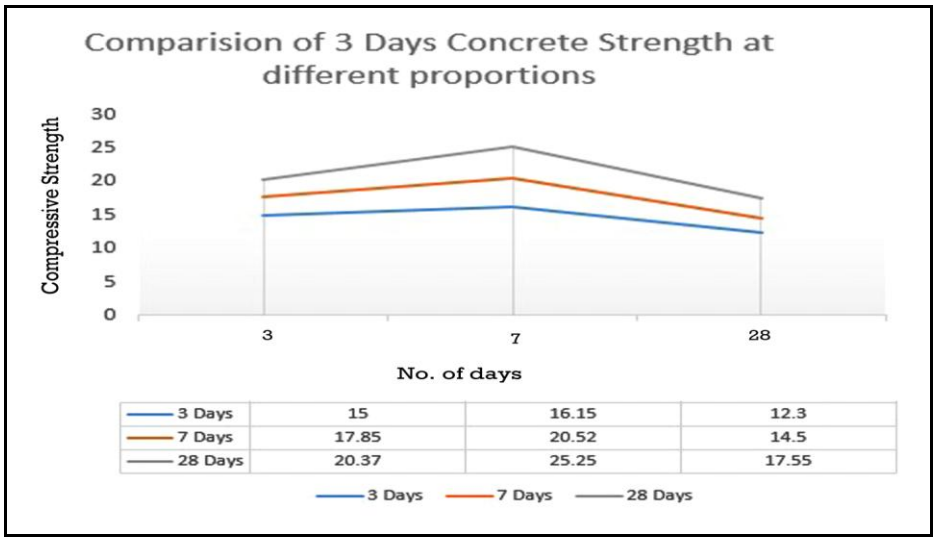

Fig-2: Comparison of 3 days concrete strength

Fig-3: Graphical representation of compressive strength at 28 days strength

From the above tabulation and graph it clears that the compressive strength of M-20 grade of concrete in 50% replacement of M-sand and recycled aggregate attains higher strength compare to the control mix and 100% of replacement about 23.96%. This shows the Optimum mix of 50-50 (%) replacement results the maximum strength compared to the control mix.

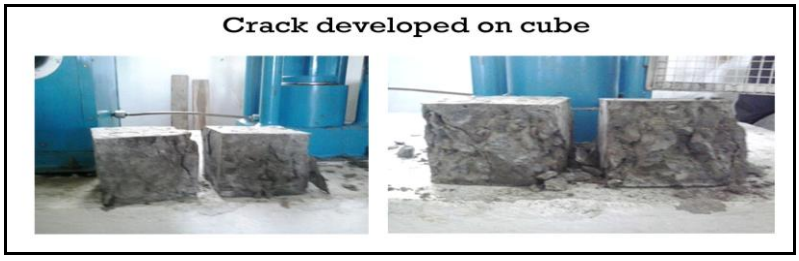

Fig-4: Different crack Patterns

Cost Analysis:

Cost Analysis for Fine Aggreagte

Table-14: Cost analysis for fine aggregate

Description	Cost Calculation For River Sand	Cost Calculation For M –Sand
One unit of Fine aggregate	Rs. 5500 /m^3	Rs. 2800 /m^3
100cft (1 unit)	100/35.33 = 2.83 m^3	100/35.33 = 2.83 m^3
Required amount of Fine aggregate in 1 m^3 of concrete	0.335 m^3	0.335 m^3
Cost evaluated	Rs. 651	Rs. 331

Cost difference for sand and M-sand = Rs.320
Percentage of profit per m^3 of concrete = 49.2%

Cost Analysis for Coarse Aggregate

Table-15: Cost analysis for coarse aggregate

Description	Cost Calculation for Natural Coarse Aggregate	Cost Calculation for Recycled Coarse Aggregate
One unit of coarse aggregate	Rs. 3000 /m^3	Rs. 1600 /m^3
100cft (1 unit)	100/35.33 = 2.83 m^3	100/35.33 = 2.83 m^3
Required amount of coarse aggregate in 1 m^3 of concrete	0.4 m^3	0.4 m^3
Cost evaluated	Rs. 424	Rs. 226

Cost difference for coarse aggregate and recycled coarse aggregate = Rs.198
Percentage of profit per m^3 of concrete = 46%

Conclusion

This study summarizes that the investigations carried out as part of this dissertation and reports some important conclusions that drawn as an outcome of this work.

- The replacement of 0 % of M-sand and 0 % of recycled aggregate without using any chemical admixtures, the strength for 3 days, 7 days and 14 days was found to be 15.33 N/mm^2,17.77 N/mm^2 and 20.37 N/mm^2
- The replacement of 50 % of M-sand and 50 % of recycled aggregate without using any chemical admixtures , the strength for 3 days, 7 days and 14 days was found to be 16.57 N/mm^2, 20.52 N/$mm^2$and 25.25 N/mm^2
- The replacement of 100 % of M-sand and 100 % of recycled aggregate without using any chemical admixtures, the strength for 3 days, 7 days and 14 days was found to be 12.44 N/mm^2, 14.667 N/mm^2 and 17.55 N/mm^2
- This Study shows that the Maximum Strength is attained about Replacement of 50% of M-sand and 50% of Recycled aggregates in the nominal mix of concrete. The strength increment about23.96 % compared to the nominal mix.
- The cost is being analyzed on the usage of M-sand in the place of natural river sand and the cost is reduced by 49.2 % when sand costs Rs.5500/unit and M-sand costs Rs. 2800/unit.
- The cost is being analyzed on the usage of Recycled coarse aggregate in the place of Coarse aggregate and the cost is reduced by 46 % when Coarse aggregate costs Rs.3000/unit and Recycled coarse aggregate costs Rs. 1600/unit.

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