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Research Paper

Use of Recycled Coarse Aggregate in Concrete

Engineering

KEYWORDS : Recycled coarse aggregate, Recycled coarse aggregate concrete, strength

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ABSTRACT

Although there is a critical shortage of virgin aggregate, the availability of demolished concrete for use as recycled concrete aggregate (RCA) is increasing. Using the waste concrete as RCA conserves virgin aggregate, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in many Western countries & Asian countries for construction projects. Research Paper reports the basic properties of recycled coarse aggregate. It also compares these properties with natural aggregates. Basic changes in all aggregate properties were determined. Basic concrete properties like compressive strength, flexural strength, workability etc are explained here for different combinations of recycled course aggregate with natural aggregate. In general, present status & utilization of recycled coarse aggregate in India with their future need is discussed.

I INTRODUCTION

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The aim for this project is to determine the strength characteristic of recycled aggregates, for application in structural concrete, which will give a better understanding on the properties of concrete with recycled coarse aggregate, as an alternative material to coarse aggregate in structural concrete. The scope of this project is to determine and compare the strength of concrete by using different percentage of recycled aggregates.

The investigation was carried out using workability test, Non Destructive test (NDT) (Rebound hammer & Ultrasonic pulse velocity test), Compressive strength, Split strength, Flexural strength. There were total of eighteen batches of concrete mixes, consist of every 20% increment of recycled coarse aggregate replacement from 0% to 100% for M20, M25, M30 Grade of Concrete.

Concrete is the most widely used construction material across the world. It is used in all types of civil engineering works like infrastructure, low and high-rise buildings, defense structure, and environment protection structure. Concrete is a man-made product, essentially consisting of cement, coarse & fine aggregates, water and/or admixture(s).

Recycling of concrete is needed from the viewpoint of environmental preservation and effective utilization of resources. At present, utilization of recycled aggregate is limited mainly to sub bases of roads and backfill works. A large portion of concrete waste ends up at disposal sites. It is anticipated that there will be an increase in the amount of concrete waste, a shortage of disposal sites, and depletion in natural resources especially. These lead to the use of recycled aggregate in new concrete production, which is deemed to be a more effective utilization of concrete waste. However, information on concrete using recycled aggregate is still insufficient, and it will be advisable to get more detailed information about the characteristics of concrete using recycled aggregate.

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

COMPARISON OF RECYCLED AND NATURAL AGGREGATE:

• Texture

Recycled aggregate has the rough – textured, angular and elongated particles where natural aggregate is smooth and rounded compact aggregate. The properties of the freshly mixed concrete will be affected by the particle shape and surface texture of the aggregate. The rough – texture, angular and elongated particles require much water than the smooth and rounded compact aggregate when producing the workable concrete. The void content will increase with the angular aggregate where the larger sizes of well and improved grading aggregate will decrease the void content.

Natural Aggregate   Recycled Aggregate

Figure 1.Comparison between Natural Aggregate and Recycled Aggregate

• Quality

The quality is different between recycled aggregate and natural aggregate. The quality of natural aggregate is based on the physical and chemical properties of sources sites, where recycled aggregate is depended on contamination of debris sources. It also stated that natural resources are suitable for multiple product and higher product have larger marketing area, but recycled aggregate have limited product mixes and the lower product mixes may restrain the market.

• Density

The density of the recycled concrete aggregate is lower than natural aggregate. Density of recycled aggregate is lower than the fresh aggregate because of the porous and less dense residual mortar lumps that is adhering to the surfaces. When the particle size is increased, the volume percentage of residual mortar will increase too.

• Strength

The strength of recycled aggregate is lower than natural aggregate because of the weight of recycled aggregate is lighter than natural aggregate. This is the general effect that will reduce the strength of reinforcement concrete.

II EXPERIMENTAL WORK

This experimental study includes Ph.D. research work for the workability test and hardened concrete specimens test. The whole test program is as follows

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The experimental study was divided into four major segments viz.

1) Materials and their testing
2) Concrete mix design
3) Checking the fresh properties of the mixes for M20, M25 and M30 grade.
√ Slump test
4) Tests on Hardened concrete specimens
√ Non Destructive Tests -Rebound hammer
√ Compression Test
√ Split strength test
√ Flexural strength

TABLE -1
PROPERTIES OF FINE AGGREGATE

Sr no	Particulars	sand
1	Source	Ananad, Gujarat
2	Zone	Zone II (IS: 383-1970)
3	Specific gravity	2.5
4	Fineness modulus	2.77
5	Density	1752 Kg/m^3

TABLE -2
PROPERTIES OF NATURAL & RECYCLED AGGREGATES

Sr no	Particulars	Natural agg.	Recycled agg.
1	Source	Ananad, Gujarat	Ananad, Gujarat
2	Max. aggregate size	20mm	20mm
3	Specific gravity	2.8446	2.74
4	Fineness modulus	7.086	7.476
5	Density	1805.62 Kg/m^3	1660.44 Kg/m^3

TABLE-3
IMPACT TEST VALUE

	2.36mm passing(gm)	total wt.(gm)	Impact value (%)
Natural Aggregate	26 gm	326gm	8
Recycled Aggregate	38 gm	294gm	12.92

TABLE -4
CONCRETE MIX PROPORTIONS

w/c ratio	Proportion	Cement (kg/m3)	Sand (kg/m3)	Coarse Agg. (kg/m3)	Water (kg/m3)
0.55	1:2.06:3.87	327	679.25	1265.5	180
0.5	1:2.12:3.46	360	763.51	1245.73	180
0.45	1:1.87:3.06	400	751.6	1226.3	180

TABLE -5
NO. OF SPECIMENS PER MIX

Type of Concrete Mix	No. of Mix
M20 Grade	6 mix
M25Grade	6 mix
M30 Grade	6 mix
Total No. of Mixes	18 mix

TABLE-6
DETAIL OF TESTS AND TEST SPECIMENS FOR M20, M25 and M30 GRADE CONCRETE EACH MIX

Sr. no.	Tests	Test Age	No. of Specimens	Specimens
1	Compressive Strength (150mm x 150mm x 150mm)	3, 7, 28 days	162	cube
2	Split Strength (150mm x 150mm x 150mm)	28 days	54	cube
3	Flexural Strength (100mm x 100mm x 550mm)	28 days	54	Beam

TABLE -7
DETAIL OF ALL MIX BATCHES

SR. NO.	MIX	RECYCLED COURSE AGGREGATE
M20	Mx1	0 %
	Mx2	20%
	Mx3	40 %
	Mx4	60 %
	Mx5	80 %
	Mx6	100%
M25	My1	0 %
	My2	20 %
	My3	40 %
	My4	60 %
	My5	80 %
	My6	100 %
M30	Mz1	0 %
	Mz2	20 %
	Mz3	40 %
	Mz4	60 %
	Mz5	80 %
	Mz6	100 %

V RESULTS

TABLE -8
SLUMP VALUE FOR ALL MIX BATCHES

Mix Type	Slump (mm)
Mx1	130
Mx2	127
Mx3	114
Mx4	114
Mx5	108
Mx6	102
My1	110
My2	104
My3	98
My4	95
My5	90
My6	90
Mz1	99
Mz2	93
Mz3	89
Mz4	89
Mz5	83
Mz6	80

Non-Destructive Test for compressive strength of M20, M25 and M30 Grade of Concrete:
Rebound Hammer Test:

TABLE -9
RESULT OF REBOUND HAMMER TEST FOR CUBE (150MM X 150MM X150MM) OF M20 GRADE (0%,20%,40%,60%,80%,100% RECYCLED AGGREGATE)

Type	Days of curing	Avg. Compressive str, Mpa
Mx1	3	15.4
	7	15.8
	28	20.9

Mx2	3	13.6
	7	15.9
	28	18.1
Mx3	3	12.3
	7	14.7
	28	22.9
Mx4	3	15.5
	7	16.9
	28	21.2
Mx5	3	14.3
	7	14.5
	28	20.9
Mx6	3	12.8
	7	14.16
	28	20.73

TABLE-10
RESULT OF REBOUND HAMMER TEST FOR CUBE (150MM X 150MM X150MM) OF M25 GRADE (0%,20%,40%,60%,80%,100% RECYCLED AGGREGATE)

Type	Days of curing	Avg. Compressive str, Mpa
My1	3	14.3
	7	15.2
	28	18.1
My2	3	14.1
	7	14.1
	28	19.8
My3	3	15.50
	7	16.76
	28	20.10
My4	3	14.7
	7	15.63
	28	18.26
My5	3	12.13
	7	15.6
	28	16.2
My6	3	14.76
	7	16.33
	28	16.76

TABLE-11
RESULT OF REBOUND HAMMER TEST FOR CUBE (150MMX150MM X150MM) OF M30 GRADE (0%,20%,40%,60%,80%,100% RECYCLED AGGREGATE)

Type	Days of curing	Avg. Compressive str, Mpa
Mz1	3	14.96
	7	15.46
	28	19.33
Mz2	3	14.6
	7	16.3
	28	17.8
Mz3	3	14.26
	7	17.76
	28	20.03
Mz4	3	14.1
	7	14.46
	28	16.73
Mz5	3	13.16
	7	18.96
	28	19.96
Mz6	3	13
	7	18.03
	28	19.13

TABLE -12
RESULT OF REBOUND HAMMER TEST FOR BEAM (100MMX100MMX550MM) OF M20 GRADE

Type	Days of curing	Rebound Number R	Avg. Compressive str, Mpa
Mx1	28	31.36	27.36
Mx2	28	35.30	27.40
Mx3	28	30.53	31.03
Mx4	28	30.00	25.1
Mx5	28	27.53	21.2
Mx6	28	30.2	25.4

TABLE -13
RESULT OF REBOUND HAMMER TEST FOR BEAM (100MMX100MMX550MM) OF M25 GRADE

Type	Days of curing	Rebound Number R	Avg. Compressive str, Mpa
Mx1	28	25.93	18.66
Mx2	28	28.23	22.26
Mx3	28	30.03	25.16
Mx4	28	28.76	23.26
Mx5	28	27.13	20.50
Mx6	28	28.63	22.73

TABLE-14
RESULT OF REBOUND HAMMER TEST FOR BEAM (100MMX100MMX550MM) OF M30 GRADE

Type	Days of curing	Rebound Number R	Avg. Compressive str, Mpa
Mx1	28	28.23	22.26
Mx2	28	27.50	21.2
Mx3	28	30.43	25.8
Mx4	28	29.60	24.46
Mx5	28	30.46	25.53
Mx6	28	27.86	21.63

TABLE -15
COMPRESSIVE STRENGTH OF CUBES VARIOUS CONCRETE MIXES FOR M20 GRADE CONCRETE

Sr. No.	Mix	Average Compressive strength in N/mm2		
		3 day	7 day	28 day
1	Mx1	23.11	29.78	40.29
2	Mx2	26.14	31.11	40.5
3	Mx3	25.26	31.41	43.4
4	Mx4	28.29	33.92	40.28
5	Mx5	25.07	27.63	31.5
6	Mx6	21.14	31.4	34.47

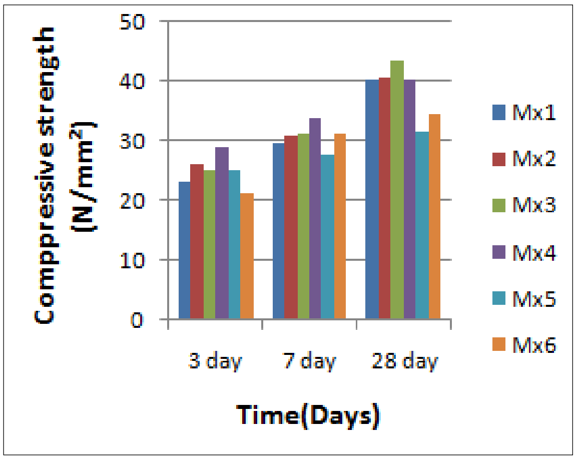

Figure 2.Compressive Strength of cubes various concrete mixes for M20 Grade Concrete

TABLE -16
COMPRESSIVE STRENGTH OF CUBES VARIOUS CONCRETE MIXES FOR M25 GRADE CONCRETE

Sr. No.	Mix	Average Compressive strength in N/mm2		
		3 day	7 day	28 day
1	My1	21.18	29.03	35.1
2	My2	26.66	24.59	39.52
3	My3	27.11	31.11	39.84
4	My4	25.18	27.11	37.92
5	My5	20.15	24.59	36.14
6	My6	27.03	29.86	38.51

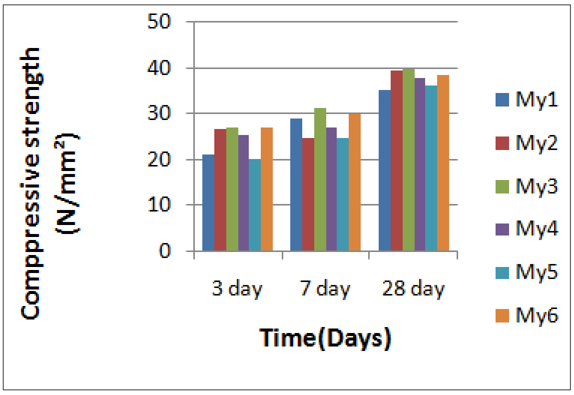

Figure 3. Compressive Strength of cubes various concrete mixes for M25 GradeConcrete

TABLE -17
COMPRESSIVE STRENGTH OF CUBES VARIOUS CONCRETE MIXES FOR M30 GRADE CONCRETE

Sr. No.	Mix	Average Compressive strength in N/mm2		
		3 day	7 day	28 day
1	Mz1	18.81	29.18	41.48
2	Mz2	19.14	21.62	35.84
3	Mz3	25.48	39.6	43.26
4	Mz4	24.83	29.11	41.33
5	Mz5	25.38	31.69	38.07
6	Mz6	23.45	32.29	39.25

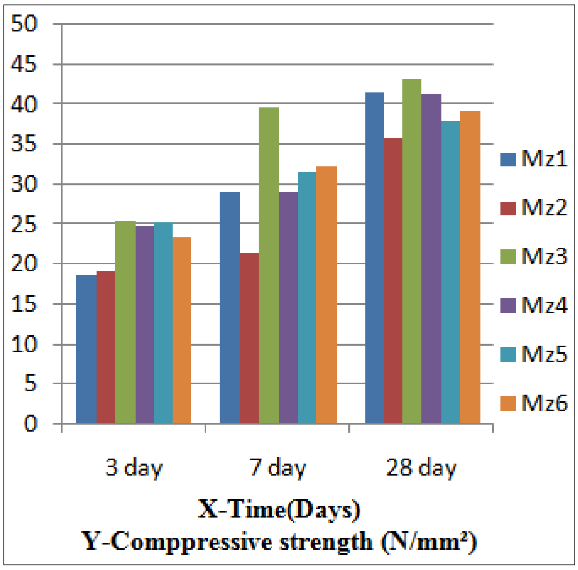

Figure 4. Compressive Strength of cubes various concrete mixes for M30 Grade Concrete

Result of Flexural Strength of Beam

TABLE -18
RESULT OF FLEXURAL STRENGTH TEST FOR BEAM (100MM X 100MM X 550MM) OF M20 GRADE AFTER 28 DAYS

Type	Avg. Flexural strength (fb), Mpa
Mx1	9.047
Mx2	8.882
Mx3	8.057
Mx4	6.242
Mx5	7.122
Mx6	6.27

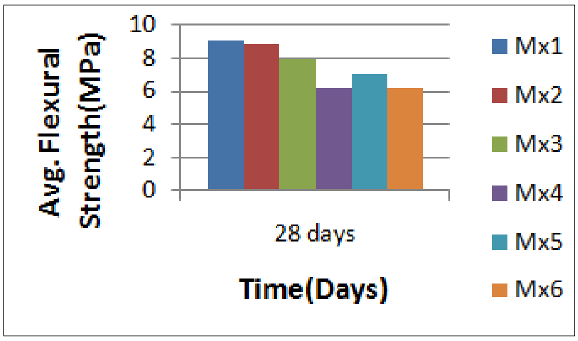

Figure 5.Flexural Strength for Beam of M20 Grade

TABLE- 19
RESULT OF FLEXURAL STRENGTH TEST FOR BEAM (100MM X 100MM X 550MM) OF M25 GRADE

Type	Avg. Flexural strength (fb), Mpa
Mx1	8.112
Mx2	9.515
Mx3	6.902
Mx4	8.36
Mx5	8.30
Mx6	6.38

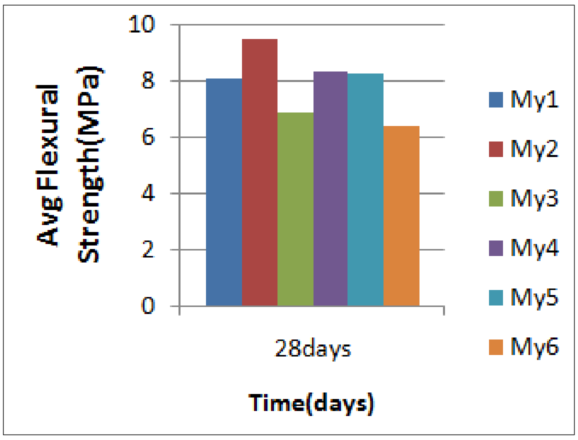

Figure 6.Flexural Strength for Beam of M25 Grade

TABLE -20

RESULT OF FLEXURAL STRENGTH TEST FOR BEAM (100MM X 100MM X 550MM) OF M30 GRADE

Type	Avg. Flexural strength (fb), Mpa
Mx1	9.295
Mx2	8.002
Mx3	9.487
Mx4	6.627
Mx5	6.737
Mx6	6.82

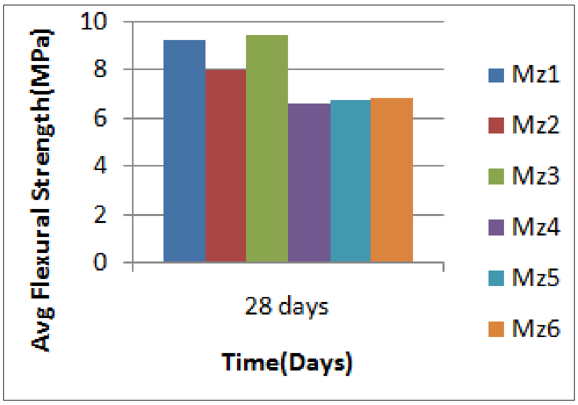

Figure 7.Flexural Strength for Beam of M30 Grade

V.CONCLUSION

Research on the usage of waste construction materials is very important due to the materials waste is gradually increasing with the increase of population and increasing of urban development. The reasons that many investigations and analysis had been made on recycled aggregate are because recycled aggregate is easy to obtain and the cost is cheaper than virgin aggregate.

After detailed study of the result and analysis the following conclusions were made.

- The experimental results show that the early compressive strength of concrete made of natural coarse aggregate and recycled coarse aggregate is approximately same.
- The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate are increased. According to the result, the highest slump obtained was 130mm and the lowest slump was 102mm for M20 grade concrete. Slump obtained was 110mm and the lowest slump was 90mm for M25 grade concrete and Slump obtained was 99mm and the lowest slump was 80mm for M30 grade concrete Therefore; target slump had been achieved, where the range is from 75mm to 150mm. The workability was good and can be satisfactorily handled for 0% recycled aggregate to 100% recycled aggregate. The slump observed is less with more percentages of recycled aggregate concrete mixes.
- It is found that the rebound number which gives the surface hardness of the concrete is higher at the replacement of 40% recycled aggregate for all type of concrete grade. The rebound number are observed more or less same for all the concrete i.e. M20, M25 and M30 grade of concrete.
- The compression test result indicates an increasing trend of compressive strength in the early age of the concrete specimens with 60% recycled aggregates. However, it shows that the strength of recycled aggregate specimens were gradually increase up to 40% replacement of recycled aggregate & then it decreases at the 100% replacement of recycled aggregate after 28 days. The target strength for M20, M25, and M30 grade is respectively 26.6Mpa, 31.6MPa and 38.25MPa that are achieved for all the specimens tested in the study. The results also show that the concrete specimens with 40% replacement of recycled aggregate get the highest strength when compared to the concrete specimens with different percentage of recycled aggregate. From the obtained result, it is possible to use 40% recycled aggregate for higher strength of concretes.
- Hence the recycled aggregate can be used in concrete with 40% replacement of natural coarse aggregate.

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