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Study on preparation of high early strength recycled aggregate concrete

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ABSTRACT

The use of recycled aggregates from demolished constructions as a coarse aggregate for concrete becomes a need to reduce the negative effects on the environment. This study aims to study the effect of using recycled materials (such as crushed concrete, crushed ceramic and crushed red brick) as coarse aggregate for high-strength concrete on the main properties of high-strength concrete. The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. the properties of recycled aggregate concrete are also determined. Basic concrete properties like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. Many researchers state that recycled concrete aggregates (RCA) are only suitable for non-structural concrete application. This research, however, shows that the recycled aggregates that are obtained from concrete specimen make good quality concrete.

Introduction

Concrete is globally the most widely used material in the construction industry. Recycled aggregates are those aggregates produced from the demolished constructions. The utilization of recycled aggregate in concrete production increases due to environmental and economic considerations to produce recycled aggregate concrete (RAC) [1, 2]. RAC is the concrete, which made with recycled aggregate as partially or fully replacement of natural coarse aggregate. RECYCLED CONCRETE AGGREGATES

1.1 RECYCLED CONCRETE AGGREGATES

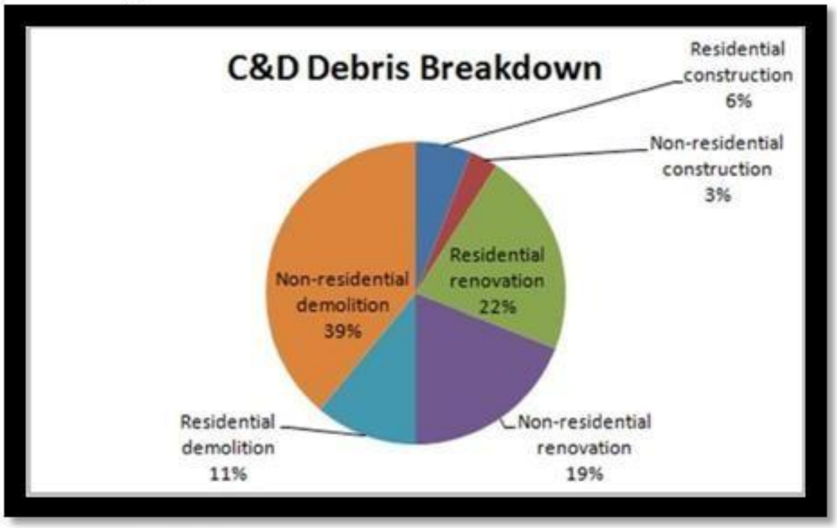


Fig. 1.2: Worldwide Estimates of Construction and Demolition Waste

Recycled aggregates are aggregates derived from the processing of materials previously used in construction. Examples include recycled concrete from construction and demolition waste material (C&D), reclaimed aggregate from asphalt pavement and scrap tyres. Coarse Recycled Concrete Aggregate (RCA) is produced by crushing sound, clean demolition waste of at least 95% by weight of concrete, and having a total contaminant level typically lower than 1% of the bulk mass. Other materials that may be present in RCA are gravel, crushed stone, hydraulic-cement concrete or a combination deemed suitable for pre-mix concrete production.

1.2 Advantages of recycling of construction materials:-

- Used for construction of precast & cast in situ gutters &kerb‟s.
- Cost saving: - There are no detrimental effects on concrete & it is expected that the increase in the cost of cement could be offset by the lower cost of Recycled Concrete Aggregate (RCA).
- 20% cement replaced by fly ash is found to control alkali silica reaction (ASR).
- Save environment: - There is no excavation of natural resources & less transportation. Also less land isrequired.
- Save time: - There is no waiting for material availability.
- Less emission of carbon due to less crushing.
- Up to 20% replacement of natural aggregate with RCA or recycled mixed aggregates (RMA) without a need for additional testing for all concrete up to a characteristic strength of 65 MPa., as per Dutch standard VBT 1995, is permitted.

1.3 Limitations or disadvantages of recycling of construction material:-

- Less quality (e.g. compressive strength reduces by 10-30%).
- Duration of procurement of materials may affect life cycle of project.
- Land, special equipments machineries are required (more cost).
- Very high water absorption (up to 6%).
- It has higher drying shrinkage & creep.

1.4 Objectives of the study:-

- To find out the % use feasible for construction.
- To reduce the impact of waste materials on environment.
- To carry out different tests on recycled aggregates & natural aggregates & compare their results.
- To find out the ways of cost saving such as transportation, excavation etc.

2. LITERATURE REVIEW

2.1 Sowmya.et.al. (2000), some tests were conducted using the recycled aggregates to studyand compare the results with the naturally available aggregates. The tests were conducted

on the aggregates which weren't subjected to any prior treatment. The impact value for recycled aggregate was obtained as 35% and that for natural aggregate as 29.9%. The abrasion value for recycled aggregate was obtained as 47.4% and that for natural aggregate as 29.6%. Water absorption of recycled aggregate (4.2%) was found to be higher when compared to the natural aggregate (0.4%). It was found that compressive strength of concrete made from the recycled aggregate is about 76% of the strength of concrete made from natural aggregate for normal strength concrete (M20). Flexural strength of the recycled aggregate concrete is almost 85% and 80% of natural aggregate concrete.

2.2 Amnon.et.al (2002), concrete having a 28-day compressive strength of 28 MPa was crushed at ages 1, 3 and 28 days to serve as a source of aggregate for new concrete, simulating the situation prevailing in precast concrete plants. The properties of the recycled aggregate and of the new concrete made from it, with nearly 100% of aggregate replacement, were tested. The properties of the concrete made with recycled aggregates were inferior to those of concrete made with virgin aggregates. Effects of crushing age were moderate: concrete made with aggregates crushed at age 3 days exhibited better properties than those made with aggregates of the other crushing ages.

2.3 Shailendrakumar.et.al. (2004),

in this paper, the author found the relationship between split tensile strength and compressive strength for RCA concrete as well as controlled concrete. The recycled concrete aggregate used was that passing through IS sieve 40mm and retained on IS sieve 4.75mm.

2.4 Chaurpagar.et.al. (2004),

the author investigated physical and mechanical properties of RCA with and without steel fibres and polymer against controlled concrete.

2.5 Natesan.et.al. (2005), an experimental investigation was conducted to study the mechanical properties of concrete where natural coarse aggregate is partially replaced with recycled coarse aggregate. It was concluded that RCA increases the mechanical properties of conventional concrete and it was observed that a mix of 75% RCA and 25% Natural Aggregates has good mechanical properties. RCA with rough surface allows better bonding with cement mix.

2.6 **Naik.et.al. (2006),** this paper throws some light on the production of recycled aggregates, their properties and their suitability in the production of concrete. Also, the properties and the application of recycled aggregate concrete are discussed in detail along with bringing out the limitations of recycled aggregate concrete. This study showed that recycled aggregates had higher water absorption value than natural aggregates but less density and strength.

2.7 Osei.et.al. (2013), in this study, the compressive strength properties of concrete were investigated by completely replacing Natural Aggregate (NA) with recycled concrete aggregate (RCA). Densities of both RCA concrete and NA concrete were within the range of normal weight concrete. Both RCA concrete and NA concrete showed the similar trends in the variation of strength and density with time. Reduction in the 28-day compressive strength of concrete due to complete replacement of natural aggregates with recycled concrete aggregate ranges from 11% to 33%. RCA can replace NA in the production of both non-structural and structural concrete.

3. Methodology

3.1 Production of Concrete Aggregate from Demolition Material:-

Recycled aggregates to be produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings, is crushed and processed into various size fractions. Reinforcing steel and other embedded items, if any, are removed and care is taken to prevent contamination by dirt or other waste building materials such as plaster or gypsum. It is prudent to store old concrete separately to other demolition materials to help avoid contamination. Records of the history of the demolition concrete – strength, mix designs etc. –would seldom be available, but if available these are useful in determining the potential of the recycled aggregate concrete.

Photo1:Aggregate crushing plant

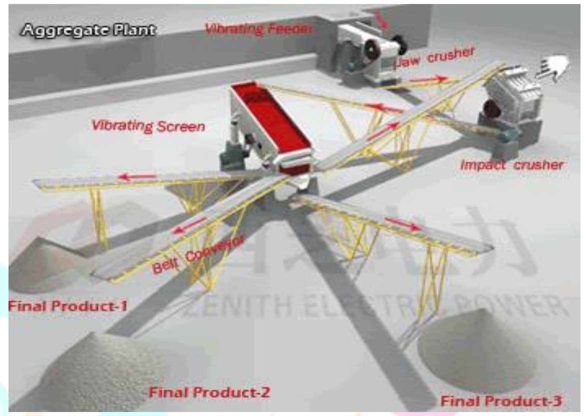


Photo2:Working Sequence of Aggregate crushing plant

3.2 Processing

Most recyclers use a jaw crusher for primary crushing because it can handle large pieces of concrete and residual reinforcement. Impact crushers are preferred for secondary crushing as they produce a higher percentage of aggregate without adhered mortar.

Most recycling plants have both primary and secondary crushers. The primary crusher usually reduces material down to 60-80 mm which is fed into a secondary crusher. The material from the secondary crushing then passes through two screens that separate the aggregate into sizes greater than 19 mm, between 19 mm and 7 mm, with the material finer than 7 mm being removed (and used as road metal). The plus 19 mm material is fed back into the secondary crusher. The 7-19 mm fraction is screened to produce coarse aggregate complying with the grading requirements of NZS 3121:198615.

3.3 Recycled Wash Water and Aggregate Recovery

Trucks returning from site to be washed out discharge into a „concrete reclaimed‟ where the coarse aggregate and coarse sand are recovered from the „liquid‟ fines for reuse. Coarse aggregate recovered from fresh concrete can be recycled and considered as equivalent to virgin aggregate, provided the mortar is adequately washed out.

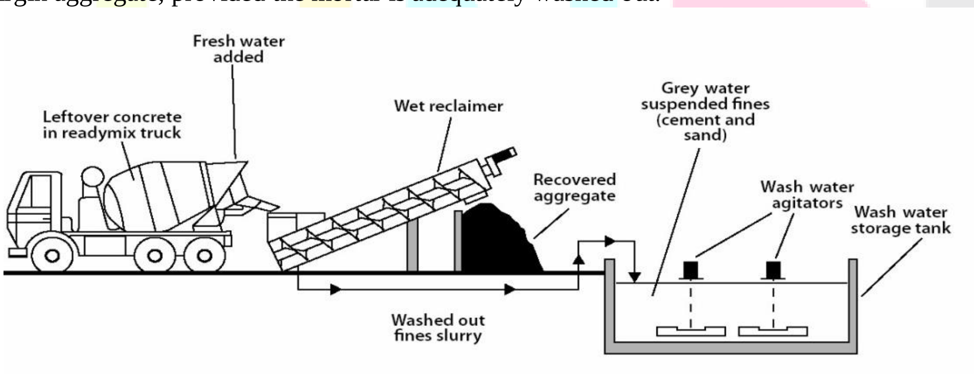


Figure2: Typical system for recycling wash water/aggregate recovery

Typical rural low volume ready mixed plants operate a recycling system that settles the solids from the fines out of suspension and then allows reuse of the clear wash water. The solids that have settled are periodically removed and allowed to dry, prior to disposal to landfill. For larger plants the amount of solid material to be disposed of is prohibitive, and a recycled wash water system (see Figure) is typically used.

3.4 QUALITY CONTROL

The flow of quality control is from investigation of the original concrete to application of the recycled coarse aggregate concrete. Quality control is carried out according to the construction specification & manufacturing guidelines for recycled coarse aggregate concrete. Quality control covers the three respective processes for the material

a) Original concrete
b) Recycled coarse aggregate
c) Recycled coarse aggregate concrete.

As a result of examination, any material that does not adapt the quality requirements of the construction specification and/or manufacturing guidelines at any of three processes is restricted from use.

4. Materials Used

Concrete is a composite material composed of water, coarse granular material (fine and coarse aggregate) embedded in a hard matrix (cement or binder) that fills the space among the aggregate particles and glues them together.

AGGREGATES: Aggregates used in concrete are divided into three categories:

4.1F**ine Aggregates:** These aggregates passes through 4.75 mm I.S. sieve and retained on 150 micron. **Coarse sand, i**t contains 90% of particles of size greater than 0.6 mm and less than 2 mm .**Medium sand, i**t contains 90% of particles size greater than 0.2 mm and less than 0.6 mm, **Fine sand, i**t contains 90% of particles of size greater than 0.06 mm and less than 0.2 mm. Proper selection of sand is critical in the durability and performance of concrete mixture

4.2 Coarse Aggregates: These aggregates passes through 63 mm I.S. sieve and retained on

4.75 micron. Coarse aggregates are particles greater than 4.75 mm, but generally range between 9.5 mm to 37.5 mm in diameter. They can either be from Primary, Secondary orRecycled sources.

4.3 Mixed Aggregate: Mixed aggregate is sometimes used for unimportant work without separating into different sizes.

4.4 CEMENT: Another important material in concrete manufacture is cement. Cement is a fine ground material consisting of compound of lime, silica, alumina and iron.

5. Test Results & Discussion

Demolished material of reinforced cement concrete (RCC) & PCC is used for recycling in foundation. The life of RCC demolish material is 25 yrs. Such mated crushing, sieving & separation process are done by manual crushing method. On demolish material, aggregate tests are conducted which are mentioned in Indian Standard code for natural aggregate & check feasibility.

5.1 Properties of Recycled ConcreteAggregate:-

5.1.1Particle Size Distribution:-

Sieve analysis is carried out as per IS 2386 for crushed recycled concrete aggregate and natural aggregates. It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving, which gives the best particle size distribution. The amounts of fine particles less than 4.75mm after recycling of demolished waste were in the order of 5-20% depending upon the original grade of demolished concrete. The best quality natural aggregate can be obtained by primary, secondary & tertiary crushing, whereas the same can be obtained after primary & secondary crushing incase of recycled aggregate. The single crushing process is also effective in the case of recycled aggregate.

The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from crushed rock. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete.

Table 1:-

SR.NO.	PARTICULARS	VALUES	
		Natural Aggregate	Recycled Coarse Aggregate
1	Specific Gravity	2.4-3.0	2.35-2.58
2	Water Absorption	0.29%-0.3%	0.3%-0.32%
3	Bulk Density	1678.2 KN/m^3	1469.8KN/m^3
4	Crushing Values:	18.4%	36.3%
5	Impact Values:	17.65%	35.2%

5.1.2Specific Gravity:-

The specific gravity in saturated surface dry condition of recycled concrete aggregate was found from **2.35 to 2.58** which are less but satisfying the results. If specific gravity is less than 2.4, it may cause segregation, honeycombing & also yield of concrete may get reduced.

5.1.3Water Absorption:-

The RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from **1.5% to 7.0%,** which is relatively higher than that of the natural aggregates. Thus the water absorption results are satisfactory.

5.1.4 Bulk Density

The bulk density of recycled aggregate is lower than that of natural aggregate, thus results are not satisfactory; due to less Bulk Density the mix proportion gets affected.

5.1.5 Crushing and Impact Values

The recycled aggregate is relatively weaker than the natural aggregate against different mechanical actions. As per IS 2386 part (IV), the crushing and impact values for concrete wearing surfaces should not exceed 30% & for other than wearing surfaces 45% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications limit. From crushing & impact test it is found that use of recycled aggregate is possible for application other than wearing surfaces.

5.2 Compressive test on cubes

The average compressive strengths of cubes cast are determined as per IS 516 using RCA and natural aggregate at the age 3, 7, & 28days and reported in Table2. As expected, the compressive strength of RAC is slightly lower than the conventional concrete made from similar mix proportions. The reduction in strength of RAC as compare to NAC is in order of 8-14% and 10-16%for M-30 & M-40 concretes respectively. The amount of reduction in strength depends on parameters such as grade of demolished concrete, replacement ratio, w/c ratio, processing of recycled aggregate etc. As per test results the strength of recycled aggregate cube is more than target strength, so RCA can be used for construction purpose.

Table 2: Compressive strength

Compressive Strength	Replacement Of Natural Aggregate			
	0%	10%	20%	30%
M30-3Days	20.63 N/mm^2	16.38 N/mm^2	19.05 N/mm^2	18.46 N/mm^2
M30-7 Days	33.13 N/mm^2	23.83 N/mm^2	31.93 N/mm^2	28.05 N/mm^2
M30-28 Days	47.53 N/mm^2	42.28 N/mm^2	43.92 N/mm^2	40.27 N/mm^2
M40-3 Days	31.59 N/mm^2	28.44 N/mm^2	27.56 N/mm^2	25.78 N/mm^2
M40-7 Days	56.67 N/mm^2	53.69 N/mm^2	51.69 N/mm^2	49.78 N/mm^2
M40-28 Days	64.42 N/mm^2	60.44 N/mm^2	56.22 N/mm^2	54.22 N/mm^2

5.3 Flexural Strength

The average flexural strength of recycled aggregate are determined at the age 7, & 28 days varies from 3.30 N/mm^2- 5.637 N/mm^2 respectively. The reduction in flexural strength of recycled aggregate as compared to NAC is 3 -16% respectively, so it is satisfactory.

Table 3: Flexural Strength

Flexural Strength	Replacement Of Natural Aggregate			
	0%	10%	20%	30%
M30-7 Days	3.58 N/mm^2	3.04 N/mm^2	3.52 N/mm^2	3.30 N/mm^2
M30-28 Days	4.98 N/mm^2	4.71 N/mm^2	4.805 N/mm^2	4.601 N/mm^2
M40-7 Days	4.69 N/mm^2	4.57 N/mm^2	4.48 N/mm^2	4.396 N/mm^2
M40-28 Days	5.818 N/mm^2	5.637 N/mm^2	5.436 N/mm^2	5.334 N/mm^2

Inferences from table nos. 2 & 3:-

From table no. 2 & 3 it is observed that the M30 grade & M 40 grade of concrete satisfy the results for 10%, 20%, and 30%. As compared M 30 grade of concrete the strength reduction in M 40 grade of concrete is more asper results.

5.4 Determination of Moisture Content ofCoarse Aggregates by Oven Dry Method

Table No 4

Observations and Results:

	Conventional Aggregates	**Recycled Concrete Aggregates**
Original sample weight (M1g)	880 g	780 g
Oven dried sample weight(M2 g)	874g	754g
Moisture content, w = [(M1-M2) / M2] × 100%	**0.68%**	**3.44%**

Discussion: From the above results, it is found that RCA contains more water than that of conventional aggregates because RCA has a higher amount of cement and thus absorbs more water than normal aggregates due to larger pore sizes and hence, there is a need to encounter for water absorption. Due to this, RCA will absorb the water during mixing of concrete and this will lead to a bad mixture as there will be a lack of water and thus there will be a need to add more and more water.

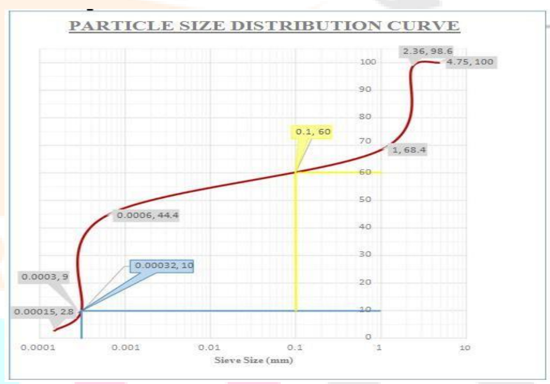
5.5 Sieve Analysis of Fine Aggregates

Fine Aggregates:

Observations and Graph:

Sieve Size (mm)	**Weight Retained (Kg)**	**Percentage Retained (%)**	**Cumulative % Retained**	**Cumulative % Passing**
4.75	**0**	**0**	**0**	**100**
2.36	0.014	1.4	1.4	98.6
1	0.302	30.2	31.6	68.4
0.0006	0.24	24	55.6	44.4
0.0003	0.354	35.4	91	9
0.00015	0.062	6.2	97.2	2.8
Pan	0.028	2.8	100	N/A
	TOTAL		**376.8**	

Table No. 5



Graph : Particle Size Distribution Curve for Fine Aggregates

Results: Effective size, in microns (D10, sieve opening corresponding to 10% finer in thegraph) = **245 Microns.** Uniformity coefficient [(D60 / D10), D to be obtained from the graph] = **310**. Fineness modulus (Sum of cumulative % weight retained / 100) = **3.77** **Discussion:** According to **IS 383 - 1970**, the fine aggregates belong to **Zone II.**

5.6 Determination of Aggregate Impact Value for Conventional and Recycled Concrete Aggregates

Table No. 6 **Results:**	**Conventional Aggregates**	**Recycled Concrete Aggregates**	**Discussion:** 10% → Exceptionally strong. 10–20% → Strong. 20–30% → Satisfactory for road surfacing. >35% → Weak for road surfacing
Original weight of aggregates, W1 g	320 g	300 g	
Weight of fraction passing through 2.36mm IS sieve, W2 g	100 g	100 g	
Aggregate Impact Value = (W2 / W1) ×100%	**31.30%**	**33.30%**	

5.7 SPECIFIC GRAVITY OF A CEMENT

Table No .7

	Portland Cement (OPC)	**Slag Cement (PSC)**
Weight of empty dry bottle, W1 g	66.3 g	80.3 g
Weight of empty bottle + water, W2 g	176.9 g	178.8 g
Weight of empty bottle + kerosene, W3 g	153.4 g	157.6 g
Weight of cement, W4 g	57.6 g	49.3 g
Weight of bottle + cement + kerosene, W5 g	196.5 g	193.9 g
Specific gravity of kerosene, 'g'	0.79	0.79
Specific gravity of cement, G = {W4 (W3-W1)} / {(W4+W3-W5)(W2-W1)}	**3.15**	**3.00**

Table: Determination of Specific Gravity of Cement

Discussion :
The specific gravity of Ordinary Portland Cement (OPC) varies from 3.1 to 3.15 and that of Portland Blast Furnace Slag Cement varies from 3.0 to 3.05.

5.8 Compressive strength on concrete CUBES

COMPRESSIVE STRENGTH OF CONCRETE CUBES(USING PSC)								
Trial Mix Designation	RCA Proportions	Compaction Factor	7 DAYS			28 DAYS		
			Ultimate Load / KN	Ultimate Strength / MPa	Average Strength / MPa	Ultimate Load / KN	Ultimate Strength / MPa	Average Strength / MPa
MIX 6	0%	0.9	801	35.6	34.5	1050	46.7	46.1
			749	33.3		1150	51.1	
			778.9	34.6		911.9	40.5	
MIX 7	25%	0.92	691	30.7	31.0	918.4	40.8	37.9
			700	31.1		850	37.8	
			703	31.2		790	35.1	
MIX 8	50%	0.87	598	26.6	26.7	650	28.9	29.2
			603	26.8		646	28.7	
			601.4	26.7		675	30.0	
MIX 9	75%	0.94	563	25.0	25.2	674.9	30.0	27.4
			572	25.4		575	25.6	
			566	25.2		600	26.7	
MIX 10	100%	0.91	703	31.2	31.1	757.9	33.7	37.3
			697	31.0		850	37.8	
			699.4	31.1		910	40.4	

5.9 Compressive strength on concrete Cylinders

6. CONCLUSIONS

COMPRESSIVE STRENGTH OF CONCRETE CYLINDERS (USING PSC)								
Trial Mix Designation	RCA Proportions	Compaction Factor	7 DAYS			28 DAYS		
			Ultimate Load / KN	Ultimate Strength / MPa	Average Strength / MPa	Ultimate Load / KN	Ultimate Strength / MPa	Average Strength / MPa
MIX 6	0%	0.9	493.5	27.9	28.5	582.9	33.0	35.6
			515.3	29.2		639.3	36.2	
			502	28.4		665.1	37.6	
MIX 7	25%	0.92	375.6	21.3	21.7	515.1	29.1	28.3
			386	21.8		495.8	28.1	
			388.9	22.0		489.4	27.7	
MIX 8	50%	0.87	352	19.9	20.5	468.3	26.5	25.8
			368.5	20.9		465.6	26.3	
			366.4	20.7		433.8	24.5	
MIX 9	75%	0.94	403	22.8	22.2	468.6	26.5	26.7
			375.8	21.3		481.8	27.3	
			398.1	22.5		465	26.3	
MIX 10	100%	0.91	345.6	19.6	19.9	441.4	25.0	24.8
			354.5	20.1		448.3	25.4	
			355	20.1		425.2	24.1	

1. Use of recycled aggregate up to 30% does not affect the functional requirements of the structure as per the findings of the test results.
2. Various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386.
3. Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

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