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A Study on Strength Characteristics of Concrete by Replacing Coarse Aggregate by Demolished Column Waste

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***Abstract* - A large amount of concrete structures are demolished in India and other countries. But only small quantities of demolished waste are reused. This will have serious problems creating environmental pollution and also requires large amount of space for dumping the waste. Hence, our project aims at reuse of demolished column concrete. In our research work, we have collected the demolition waste from our college work site where the column in the top floor of our college building was demolished for the purpose of renovation. The demolished column is of M20 grade concrete and the age of concrete is 10 years. Construction of any concrete structures requires huge amount of natural coarse aggregate. So by using the demolition waste, we can reduce the cost of purchasing natural coarse aggregate. Our project deals with replacing of coarse aggregate by demolished column waste in various proportions of 10, 20, 30, 40, 50 and 100. Cubes, cylinder, beams were casted for different mix proportions and kept curing for 7, 14 and 28 days. After the curing the cubes, cylinder and beams were tested to find the compressive strength, split tensile strength and flexural strength of concrete. The results were discussed and conclusions were made accordingly.**

Key Words: Demolished Column Waste, Coarse Aggregate, Compressive Strength Test, Rebound Hammer Test, Split Tensile Strength Test.

1. INTRODUCTION

Concrete is the most widely used construction material on this earth. In fact, concrete is used in virtually everything and there is still no substitute available for many of its applications. Without concrete, the community and society cannot exist. Therefore, lots of researches are going to find the new varieties of concrete which are economical for the construction. All these researches are focused on the replacements of different ingredients of the concrete which makes the concrete cheaper and even stronger too.

1.1 Demolition Waste

Demolishing the old building produces large amount of waste products. When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Concrete once routinely trucked to landfills for disposal, but recycling has a number of benefits that have made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down.

Concrete aggregate collected from demolition sites is put through a crushing machine. Crushing facilities accept only uncontaminated concrete, which must be free of trash, wood, paper and other such materials. Metals such as rebar are accepted, since they can be removed with magnets and other sorting devices and melted down for recycling elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again. After crushing has taken place, other particulates are filtered out through a variety of methods including hand-picking and water flotation.

Crushing at the actual construction site using portable crushers reduces construction costs and the pollution generated when compared with transporting material to and from a quarry. These systems normally consist of a rubble crusher, side discharge conveyor, screening plant, and a return conveyor from the screen to the crusher inlet for reprocessing oversize materials. Compact, self-contained mini-crushers are also available that can handle up to 150 tons per hour and fit into tighter areas. With the advent of crusher attachments - those connected to various construction equipment, such as excavators - the trend towards recycling on-site with smaller volumes of material is growing rapidly.

Smaller pieces of concrete are used as gravel for new construction projects. Recycling concrete can create more employment opportunities. Recycling concrete drag down the cost for buying raw materials and transporting the waste to landfill sites.

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2. OBJECTIVES

The use of demolished concrete as replacement to coarse aggregate in concrete has benefits in terms of cost and reduction of pollution from construction industry. The cost of concrete production will reduce considerably compared to conventional concrete produced by using freshly obtained coarse aggregate. Since it is readily available at very low cost, its application will reduce the construction pollution and enhances the effective use of construction waste which helps in controlling Solid Waste Management.

With these above mentioned general objectives, the following subsidiary laboratory investigations are also intended to be fulfilled.

1. Basic test on the concrete and demolished waste ingredients.
2. Rebound hammer test to confirm the grade of the demolished concrete on the existing column remains.
3. Compressive Strength, Split Tensile and Flexural Strength test for normal concrete and concrete produced with demolished aggregates.

3. LITERATURE REVIEW

G. Murali et al, (March 2012)[5] "Experimental investigation on concrete with partial replacement of coarse aggregate" The study on effects of shahabad (a variety of cudappah) stone and the chemical admixture (supaflo) on concrete were investigated. Natural aggregate had been replaced with the waste shahabad stone in four different percentages namely 10, 20, 30 & 40 %. A comparison was made between the specimens of partially replaced coarse aggregate and the same set of specimens admixed with supaflo. The effects on compressive strength, split tensile strength and modulus of rupture were reported. Test results indicated that the replacement of coarse aggregate by 30% had attained a good strength.

Mohd Monish et al, (February 2013)[6] "Demolished waste as coarse aggregate in concrete" This experiment study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by demolished waste on workability and compressive strength of recycled concrete for the study at 7 and 28 d. The compressive strength thus, observed was compared with strength of conventional concrete. Test results showed that the compressive strength of recycled concrete up to 30% coarse aggregate replacement (C. A. R.) by demolished waste at the end of 28 d has been found to be comparable to the conventional concrete.

Shivakumar et al, (June 2014)[7] " Use of building demolished waste as coarse aggregate in porous concrete" In this experimental study, the utilization of building demolished waste in the manufacturing of Porous concrete as a replacement of coarse aggregate. By the investigation it is found that the porous concrete results are encouraging to use as a porous material for the drain-ability and has been found to be comparable to the conventional concrete. Porous concrete may be an alternative to the conventional concrete because of low density and high porosity.

Jitender Sharma et al, (July 2014)[8] "Study of Recycled Concrete Aggregates" This experiment describes the introduction and production of recycled concrete aggregates and its various applications in the construction industry. When the water cement ratio used in recycled aggregate mix is reduced, tensile strength and modulus of elasticity are improved.

D. V. Prasada Rao et al, (November 2014)[9] "Experimental investigations of coarse aggregate recycled concrete" The present work is directed towards the evaluation of concrete using full replacement of natural coarse aggregate (NCA) with RCA. The experimental results of mechanical and durability properties are also evaluated and compared with NCA concrete. The main problem with RCA concrete is high percentage of water absorption. RCA has high compressive strength comparable to the natural coarse aggregate concrete.

Preeti Saini et al, (April 2015)[10] "A Review on Recycled Concrete Aggregates" This experiment focuses on the coarse RCA which is the coarse aggregate from the original concrete that is created after the mortar is separated from the rock which is reused. The use of RCA in new construction applications is still a relatively new technique.

Literature survey reveals that compressive strength primarily depends upon adhered mortar, type of aggregates, age of curing and ratio of replacement from new material to aggregate and cement, water absorption, strength of parent concrete, interfacial transition zone and moisture content.

T. Subramani et al, (May 2015)[11] "Experimental Investigation Of Using Concrete Waste And Brick Waste As A Coarse Aggregate" This experiment was carried out to study on concrete which incorporate Over Burnt Brick Ballast and concrete waste partially due to their abundance. 25%, 50% (M15, M25) incorporation was used as partial replacement of natural coarse aggregate in concrete. As the percentage of crushed concrete coarse aggregates and crushed brick fine aggregates is increased, Coarse aggregate is replacement level of 25% & 50 % brick waste in concrete mixes was found to be the level to obtain higher value of the strength and durability at the age of 28 days. 25% & 50 % concrete waste in concrete mixes was found higher value of the strength compared with brick waste used in concrete. Finally conclude the compressive strength, flexural & split tensile strength was high when containing concrete waste 50 % in concrete compared with M15 and brick waste used in concrete.

Rahul Mahla, et al, (August 2015)[12] "Partial replacement of coarse aggregate by waste tires in cement concrete" In this experiment an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre rubber chips as aggregate in a systematic manner. In the present experimental investigation, the M20 grade concrete has been chosen as the reference concrete specimen. The test results shows that the addition of rubber aggregate to concrete at a lower percentages of 10 and 25 % enhanced the impact resistance of the concrete greatly and hence the application of rubberized concrete can be of great help in structures which are exposed to vibrations and impact loads.

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N. Sai Trinath Kumar et al, (October 2015)[13] "Use of construction renovation and demolition waste in partial replacement of coarse aggregate in m20 concrete" The experiment was carried out in the laboratory to scrutinize a concrete made of partial replacement of coarse aggregate with construction and demolition waste materials like ceramic tiles waste, plastic debris, crushed bricks.
The workability of concrete produced with construction waste when compared with plain cement concrete is not reliable but it produced a considerable increase in the compressive strength.

R. Siva Kumar et al, (March 2016)[14] "An Experimental study on partial replacement for coarse aggregate by Granite Waste" This project is experimented to reduce the cost of concrete. The only way to reduce and tackle these problems is reuse and recycles. In this project work, experiments have been conducted with the collection of materials required and data required for mix design are obtained. The granite wastes were properly cut down to the size of coarse aggregate and then they were mixed with the concrete in 10%, 20%, 30%, 40%, 50%. Cubes were casted with these concrete mixes and subjected to curing of 7 days, 28 days and their strength is determined. The compressive strength of concrete is same with the conventional concrete only at 10%, 20%, 30% replacement of granite waste. The strength is gradually decreasing at 40% and 50%.

Nikita Patel et al, (April 2016)[15] "Use of Demolished Concrete Materials in Concrete and Comparative Study of its Mechanical Properties: NDT Comparison" In this experiment study, Recycled concrete aggregates are used in concrete in replacement of nominal concrete aggregates 20mm and grit aggregates, replacement of 50%.
The different result of compressive strength of 3 day, 28 day and 56 day show that replacement of recycled aggregate of 50% to achieve the M20 and get higher strength than nominal concrete.

Prakash Somani et al, (May 2016)[16] "Use of demolished concrete waste in partial replacement of coarse aggregate in concrete" In this study we have taken the demolished concrete aggregate 10%, 20%, 30% by weight of the conventional coarse aggregate and the concrete cubes were casted by that demolished concrete aggregate then further tests conducted such as workability , compressive strength for that DAC and the result obtained are found to be comparable with the conventional concrete. For 30% replacement of coarse aggregate the 28 days compressive strength is 82.65% of the compressive strength of conventional concrete.

N V V S S L Shilpa Devi Gadde et al, (March 2017)[17] "A Study on Demolished Concrete by Partial Replacement of Coarse Aggregate" The experimental investigations are carried out to evaluate the effect of partial replacement of coarse aggregate by demolished waste on compressive strength and workability of demolished concrete. The test values of compressive strength 25% and 50% of demolished concrete aggregates are near to the value of standard concrete or conventional concrete. As we observed that the difference in compressive strength of standard and demolished concrete aggregate for 28 days is about 12%. The compressive strength of demolished aggregate concrete is relatively lower up to 20% than standard concrete.

B. Govinda Rajulu et al, (March 2017)[18] "Strength of concrete by replacement of coarse aggregates with waste rubber and demolished waste materials" In this experiment, our present aims to investigate the optimal use of recycled aggregates and waste tire rubber as coarse aggregate in concrete composite and the change in mechanical properties of concrete. It is found that the use of recycled waste tire rubber aggregates results in the formation of light weight, elasticity and energy absorption and heat insulation properties.

S. Sakthivel et al, (2017)[19] "Experimental investigation on concrete with replacement of coarse aggregate by demolished building waste with steel fiber (lathe waste)" The main objective of this study is reusing of Demolished Concrete Aggregate (DCA) & introduction of Steel Fiber (SF) from the lath wastages are replacing as coarse aggregate in concrete of different percentages 40, 50, 60 DCA & 1% of steel fiber (lathe waste) to minimize the generation of demolished building wastes. Comparison of three different percentages of replacements, the strength will not reduce when compare to conventional concrete. So, the replacement of 60%DCA&1%SF in concrete gives more Economical and provides better performance.

3.1 Summary of Literature

Going through the literature it is found that many investigations were done extensively on demolition waste, Prakash Somani et al [16] & Nikita Patel et al [15] have done the study on partial replacement of coarse aggregate by demolished concrete waste. Mohd Monish et al [6] & R. Siva Kumar et al [14] in their test results showed that the compressive strength of recycled concrete up to 30% coarse aggregate replacement by demolished waste at the end of 28 days has been found to be comparable to the conventional concrete. Prakash Somani et al [16] in this study workability of the demolished aggregate concrete is lower than the conventional concrete because the rate of absorption of demolished aggregate is higher than nominal aggregate. From the literature study it is clear that the experiment on demolition waste for a particular grade of concrete (M20) is not done. So this project work is going to be very unique project.

4. MATERIALS

4.1 Ordinary Portland Cement

Ordinary Portland Cement (OPC) is the most common cement used in general concrete construction when there is no exposure to sulphates in the soil or groundwater.

4.2 Fine Aggregate

The code to be referred to understand the specification for fine aggregates is: IS 383:1970. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 4.75 mm.

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4.4 Coarse Aggregate

The code to be referred to understand the specification for fine aggregates is: IS 383:1970. Locally available crushed stone aggregates are used as a coarse aggregate which have the size of 20mm. Specific gravity and Fineness modulus of the coarse aggregate are 2.75 and 6.10 respectively. IS: 383 (1970) is followed for coarse aggregates.

4.5 Demolition Column Waste

Construction materials are increasingly judged by their ecological characteristics. Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other applications. Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. The crushing characteristics of hardened concrete are similar to those of natural rock and are not significantly affected by the grade or quality of the original concrete.

4.6 Water

Potable water is used for mixing of concrete.

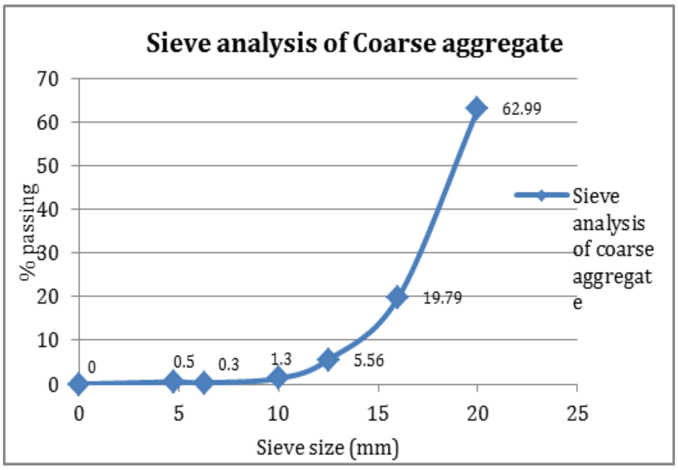
5. TEST ON MATERIALS

Table 1 - Specific gravity of materials

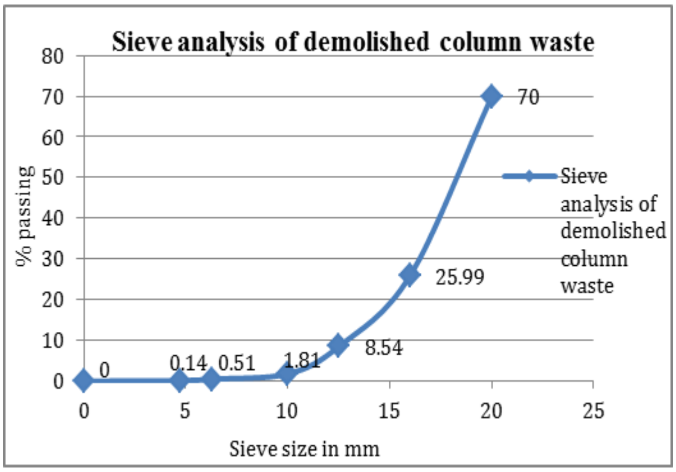
Material	Specific Gravity
Cement	3.07
River Sand	2.57
Coarse Aggregate	2.75
Demolition Waste	2.48

Table 2 - Impact value on aggregate

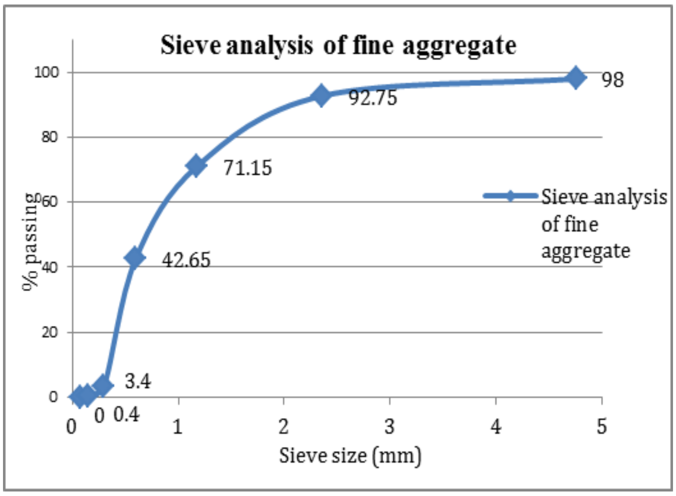
Material	Impact Value %
Coarse aggregate	15.10
Demolished Column waste	20.30



Graph 1 - Sieve Analysis of Coarse Aggregate



Graph 2 - Sieve Analysis of demolished column waste



Graph 3 - Sieve Analysis of Fine Aggregate

6. REBOUND HAMMER METHOD

The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion chart, the rebound value can be used to determine the compressive strength. When conducting the test the hammer should be held at right angles to the surface which in turn should be flat and smooth.

The age of the demolished column considered in our project is 10 years. We have conducted the test at different points on the surface of the column and we taken the average of all the rebound values and we got the grade of concrete as 20 N/mm^2.

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Fig 1 - Rebound Hammer

7. CONCRETE MIX DESIGN

Grade designation = M20
Type of cement = OPC43 grade conforming to IS8112
Maximum nominal size of aggregate = 20mm
Workability= 75 mm (slump
water-cement ratio = 0.45

Below given are the mix proportions used in this project for M20 grade concrete:

Trial mix - 1
Mix proportion for normal concrete
Cement = 427.93kg/m^3
Fine aggregate (sand) =636.15 kg/m^3
Coarse aggregate = 1159.04 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45

Trial mix - 2
Mix proportion for replacement of 10% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 1043.14 kg/m^3
Demolition column waste = 115.9 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45
Trial mix - 3
Mix proportion for replacement of 20% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 927.23 kg/m^3
Demolition column waste = 231.81 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45

Trial mix - 4
Mix proportion for replacement of 30% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 811.328 kg/m^3
Demolition column waste = 347.712 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45

Trial mix - 5
Mix proportion for replacement of 40% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 695.42 kg/m^3
Demolition column waste = 463.62 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45

Trial mix - 6
Mix proportion for replacement of 50% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 579.52 kg/m^3
Demolition column waste = 579.52 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45

Trial mix - 7
Mix proportion for replacement of 100% coarse aggregate by demolished M20 grade concrete
Cement = 427.93 kg/m^3
Fine aggregate = 636.15 kg/m^3
Coarse aggregate = 0 kg/m^3
Demolition column waste = 1159.04 kg/m^3
Water = 191.58 lit/m^3
Water cement ratio = 0.45


Fig 2 - Oiling of moulds

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Fig 3 - Mixing

Fig 4 - Washing of demolished column waste

Fig 5 - Demolished column waste added in the mix

8. TEST RESULTS AND DISCUSSION

Table 3 - Compression Strength Test values

No. of days of curing		7	14	28
Compression Test Values (N/mm^2) for different proportions	0%	22.22	30.22	34.22
	10%	21.33	29.33	32.88
	20%	20.44	28.44	31.55
	30%	20.00	27.55	30.20
	40%	19.11	25.77	28.88
	50%	18.22	24.44	27.11
	100%	14.20	20.88	23.11

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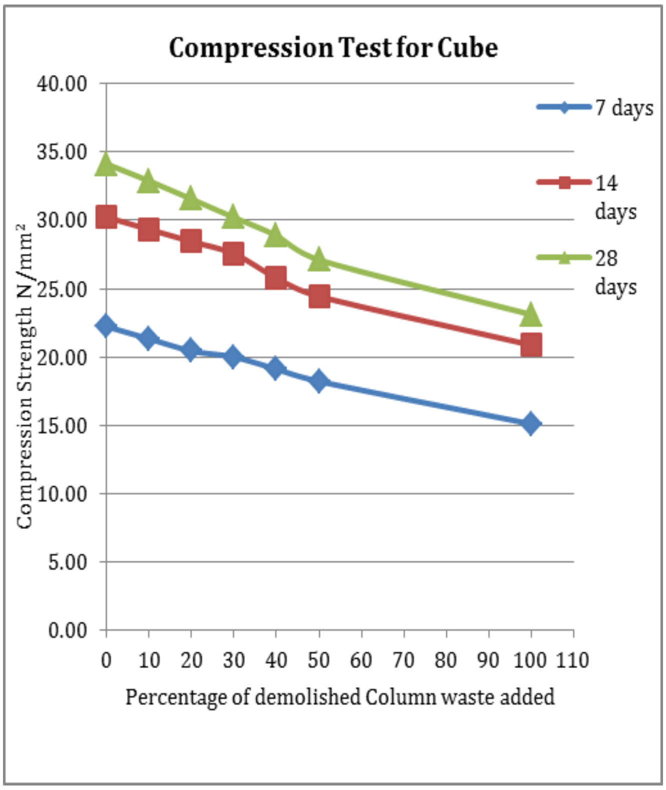
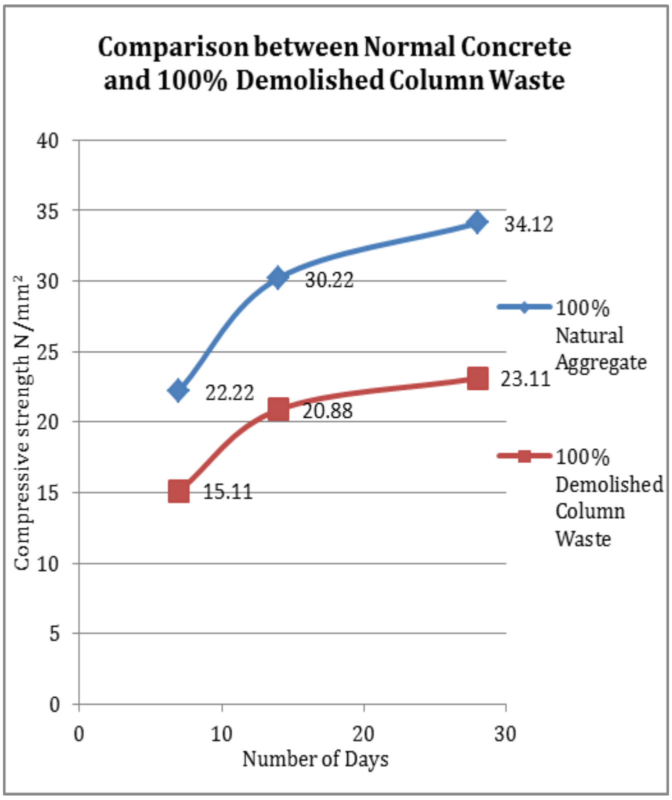
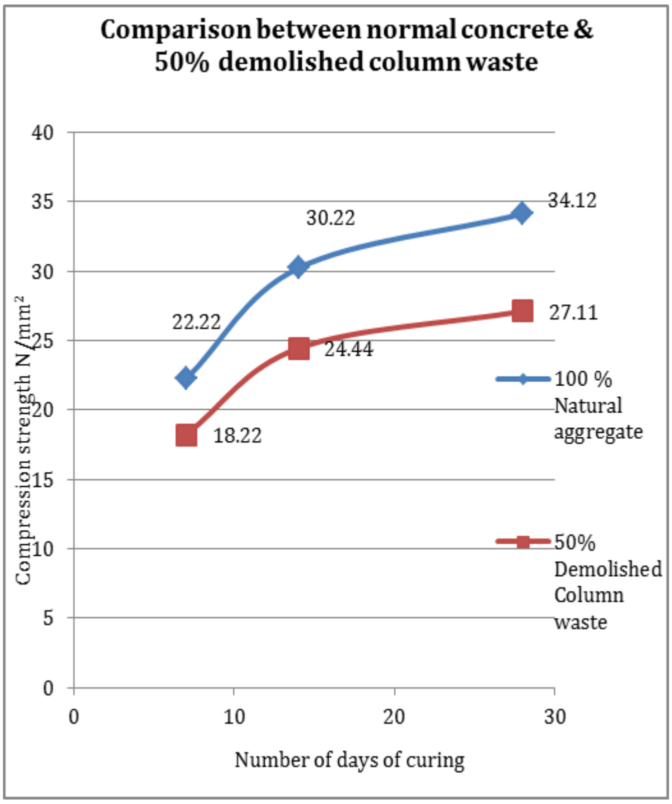


Graph 4 - Compressive strength vs. Percentage of demolished column waste added for 7, 14 and 28 days



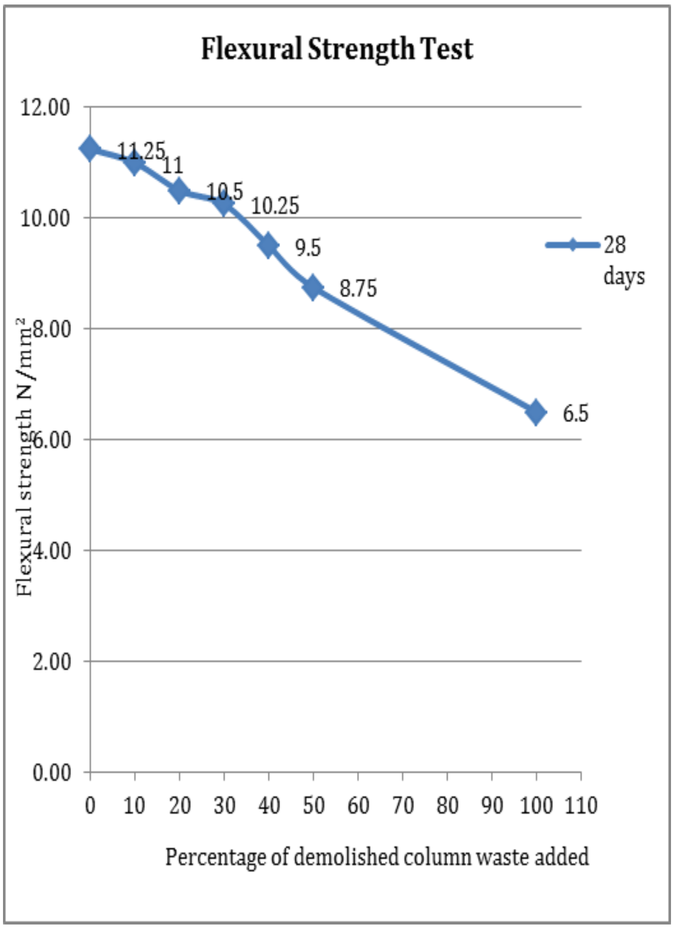
Graph 5 - Comparison of compressive strength between Normal concrete and 100% demolished column waste



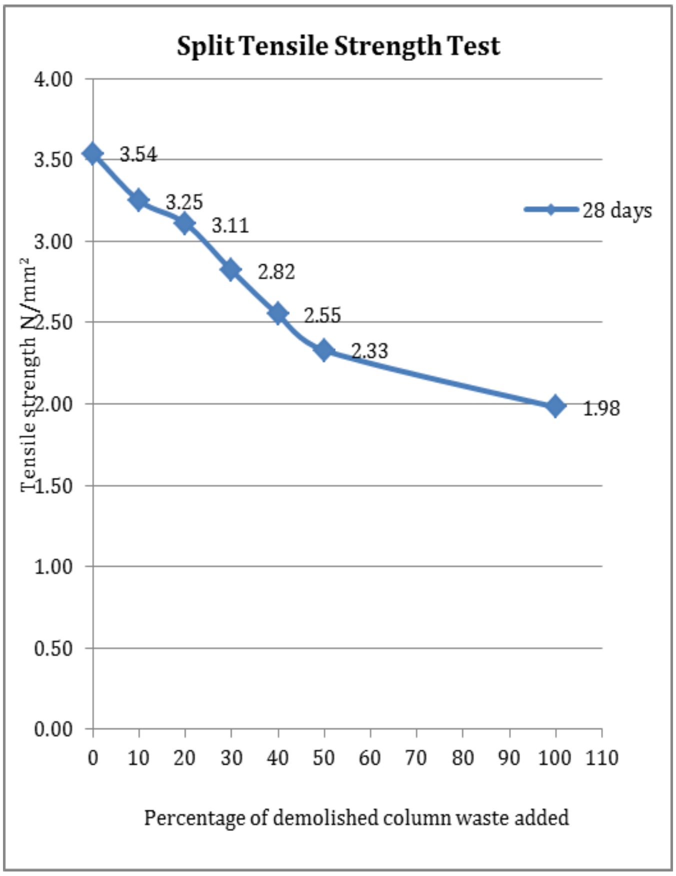
Graph 6 - Comparison of compressive strength between normal concrete and 50% demolished column waste

Table 4 - Flexural strength test values

Percentage of Demolition Waste	Flexural Strength for 28 days of curing (N/mm^2)
0	11.25
10	11
20	10.5
30	10.25
40	9.5
50	8.75
100	6.5



Graph 7 - Flexural Strength vs Percentage of demolished column waste added for 28 days



Graph 8 - Split Tensile Strength vs Percentage of demolished column waste added for 28 days

Table 5 - Split Tensile Strength Test Values

Percentage of Demolition Waste	Strength (N/mm^2) for 28 days of curing
0	3.54
10	3.25
20	3.11
30	2.82
40	2.55
50	2.33
100	1.98

Fig 6 - Compression Strength Test 1

Fig 7 - Compression Strength Test 2

Fig 8 - Flexural Strength Test

Fig 9 - Tensile Strength Test

7. CONCLUSIONS

Usually, demolished waste is dumped either in the dumping yard or low lying areas. A huge quantity of construction and demolition waste is produced every year. These waste materials need a large place to dump and hence the disposal of waste has become a serious problem. Also, the continuous use of natural resources for producing conventional concrete leads to reduction in their availability of resources and results in the increase of the cost of the coarse aggregate. On the basis of the test results in this project, following conclusions are made:

1. On comparing the test results for concrete with fresh aggregate to that of concrete with demolished aggregate, the compressive strength of demolished concrete was slightly lesser than the conventional concrete.
2. Upto 30% replacement of fresh coarse aggregate, the compressive strength was found above 30 N/mm^2.
3. When replaced by 50%, the compressive strength was observed 27.11 N/mm^2 which is higher than target strength of 26.6 N/mm^2. Hence, this concrete upto 50% replacement is more suitable for the regular construction works.
4. When fully replaced with demolished aggregates, the compressive strength of the concrete after 28 days of curing process was found to be 23.11 N/mm^2. Concrete with 100% demolished aggregate can be used for temporary works at construction site, trenches, low height retaining walls, etc where load acting on the structure is comparatively less.
5. When demolished waste is used in concrete, the cost of production will be economical. Hence, overall cost of the project will come down.

6. Use of demolished waste in concrete will save in energy and reduce noise pollution which will create during the blasting of rocks for obtaining fresh coarse aggregate, thus helps in protecting the environment which is the need of the hour for present and in future too.

8. SCOPE FOR THE FUTURE STUDY

1. This study can be carried out for concrete with different grades with different percentage of demolished waste to find the feasibility.
2. Further study on the savings in the consumption of energy for different mix proportions can be determined.

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