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Study of Mechanical Properties of Concrete using Recycled Aggregates

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Abstract: The last few decades have seen a rapid increase in urbanisation, which has increased demand for building materials, particularly aggregates. The aggregate mining has put a burden on the environment and raised concerns about swift ecological harm. Lack of building aggregates is a severe issue that requires the use of alternative recycled aggregates in its stead. Old, abandoned building debris is used to create recycled aggregates (RA), which are then hauled to a landfill and disposed of there. In addition to pushing waste sites farther away, the decades-long urbanisation of the region has also increased the expense of moving these aggregates. Utilising them in place of natural aggregates in concrete mixtures is the solution. Here in this study some proportion of natural coarse aggregate is being replaced by the recycled aggregate and analysis of its effect on various mechanical properties of concrete is being done. The mechanical properties of concrete constitute Compressive Strength, Flexural Strength, Shrinkage, Creep and Modulus of Elasticity.
Keywords: Demolition, waste aggregates, recycled, construction, compressive strength, flexural strength

I. INTRODUCTION

India has an extremely high rate of urbanisation growth as a result of industrialization. Quick infrastructure development necessitates a lot of building supplies, as well as the necessary land. Concrete is recommended for major construction projects due to its superior performance, longer lifespan, and lower maintenance costs. New buildings are built and smaller structures are dismantled in order to achieve the new infrastructure for economic growth. One fundamental element that is closely related to the survival of the human race is environmental protection. Modern construction criteria heavily effect factors like sustainable development, preservation of natural resources, and environmental consciousness. Modernization has resulted in the disposal of dismantled materials on land for no apparent use. This study deals with the experimental analysis of possibility of reusing of these aggregates in construction.

A. Scope of Problem

Aggregates comprise 70–75% of the materials needed to produce concrete. Of this, 33–40% is fine aggregate and 60–67% is coarse aggregate. If the current rate of use continues, all of the coarse aggregates are predicted to run out by 2050.Therefore, we need to consider various alternatives.

The idea behind this project is to use recycled aggregates in place of some natural coarse materials. Aggregates made from processing previously used building supplies, including masonry or concrete, are known as recycled aggregates. Hard graded pieces of inert mineral materials, such as sand, gravel, crushed stone, slag, rock dust, or powder, make up recycled aggregates. They are beneficial for environmental concerns and the materials of the future.

B. Scope for Solution

These recycled wastes come from concrete buildings that are either reinforced or unreinforced. Before using the old, destroyed concrete, it is crucial to remove any contaminants including plastics, metals, organic materials, and other contaminants. Following demolition, the concrete is run through a grading machine that divides the material into different sizes. Using demolished concrete reduces the cost of transportation since it is less expensive to transport to landfills than new concrete. The purpose of this research is to evaluate the feasibility of replacing coarse aggregates in structural concrete with recycled concrete aggregates in different ratios. Thereafter the mechanical properties of the concrete produced from these aggregates are tested for its suitability in construction. The mechanical properties of concrete constitute Compressive Strength, Flexural Strength, Shrinkage, Creep and Modulus of Elasticity.

1) *Compressive Strength*: The concrete's compressive strength is expressed in terms of the characteristic compressive strength of 150mm cubes that were tested after 28 days. Compressive strength is the most important property of concrete and gives a clear indication of the response of the hardened concrete when a compressive load is applied.
2) *Flexural Strength Test*: Flexural strength of concrete is measure of tensile strength of concrete and is done by loading 150*150*700 mm concrete beam. Flexural strength, which is the amount of stress in the material just prior to its yielding in a flexure test. Other names for it include transverse rupture strength, bend strength, and modulus of rupture. The most popular test is the transverse bending test, which bends a specimen with a circular or rectangular cross-section until it fractures or gives using a three-point flexural test procedure. Flexural strength is a measure of the maximum stress a material can withstand before yielding.
3) *Shrinkage*: Shrinkage is shortening of concrete due to drying and it does not depend on applied loads. It is determined by measuring the strain over time in an unloaded, unrestrained specimen at room temperature. Drying shrinkage is the reduction in volume of hardened concrete due to loss of moisture by evaporation. The factors that effect creep also effects shrinkage.
4) *Creep*: Creep is time dependent deformation of concrete under constant loads (self-weight) and permanent displacement. Concrete instantly deforms when it experiences compressive force. We refer to this instantaneous deformation as instantaneous strain. Currently, the concrete experiences more deformations without an increase in load when the load is sustained for an extended period of time. We call this strain that varies with time "creep."
5) *Modulus of Elasticity*: Modulus of Elasticity is the ratio of normal stress and normal strain. It is given by-

$$E = 5000\sqrt{f_{ck}}$$

f_{ck} - Characteristic compressive strength of concrete after 28 days

This study primarily deals with experimental study of using recycled aggregate by performing compressive strength test and flexural strength test on concrete. Shrinkage, Creep and Modulus of Elasticity are time dependent properties and cannot be determined through experimental analysis.

II. LITERATURE REVIEW

The utilization of waste materials in the construction industry has been gaining attention in recent years. Several studies have been conducted to investigate the potential of using various waste materials as partial replacements in the production of construction materials.

Katz [6] examined the characteristics of recycled aggregate used to make new concrete using partially hydrated old concrete and the attributes that resulted from using these recycled aggregates. The findings showed that, at the same water to cement ratio, concretes composed entirely of recycled aggregates performed worse than concretes constructed of natural aggregates. Regardless of the old concrete's crushing age, there was a 25% strength drop when the new concrete was created using the same kind of OPC and w/c as the old concrete. Similar patterns were seen in other characteristics like absorption, drying shrinkage, flexural and splitting strengths, and depth of carbonation.

Topcu and Sengel [8] examined the mechanical, physical, and freeze-thaw endurance of recycled aggregate concrete made from leftover concrete aggregate. In the course of testing with both fresh and hardened concrete, combinations including 30%, 50%, 70%, and 100% of recycled concrete aggregates were prepared. The findings demonstrated that RAs had a lower specific gravity than natural aggregates. Additionally, it was shown that recycled aggregates had a substantially greater water absorption ratio. Both the control concrete and the concrete with RA saw a drop in compressive strength parallel to the w/c ratio. The key finding of the paper was that when recycled aggregate content in the mix surpasses 30%, conventional concrete's capacity to retain the same slump without the need for admixtures is greatly reduced. This reduces the strength of concrete resulting in lower concrete strength.

Paul [13] also investigated the mechanical behaviour and durability performance of concrete with varying proportions of RA. At various ages, concrete samples with recycled aggregate replacement percentages of 0%,30%, and 100% to partially replace natural aggregate (NA) were examined. To examine the mechanical characteristics of RA, concrete with cube strength classes of 30 to 40 MPa was created. Additionally, the durability, shrinkage, and creep qualities of concrete with 0% and 30% RA replacement of NA were investigated. It was discovered that, when compared to concrete that contains 100% NA, RA substitution by 30% (RA30%) of NA did not significantly alter the concrete's strength or stiffness. Although there is a slight decrease in strength and stiffness after RA100% replacement, this is not very noticeable and can be made up for in conventional methods. Tests of the durability index showed that concrete with reasonable quality (RA30%) performed similarly to concrete with NA100% in terms of durability. However, RA30% showed increased creep, which structural designers must take into account.

Bhat [15] observed that the flexural strength, splitting tensile strength, and compressive strength of the normal-, medium-, and high-strength concrete were not significantly impacted by the parent concrete's grade on providing RA. All of these mentioned characteristics fell short of those of the initial concrete that included solely NA. When RA was created using high-strength parent concrete, its mechanical characteristics outperformed those of RA built with normal and medium strength parent concrete. The investigation's findings show that recycled aggregate concrete with a lower grade strength should ideally be produced using high-strength parent concrete.

The literature shows that recycled concrete waste can be effectively used to replace conventional aggregates in various proportions. As noted, different sources of waste aggregates produce different results; The purpose of this research is to find out the optimal replacement percentage of old recycled concrete in the production of new construction concrete.

III.PROPOSED METHODOLY AND EXPERIMENTATION

The methodology for this study involves preparation of M25 cubes and a beam for testing compressive strength and flexural strength of concrete. The casting is done by replacing some proportion of natural aggregate by the recycled aggregates in concrete. Here in this study, 0%, 10%, 20% and 30% of natural aggregates are being replaced by recycled aggregates and at each proportion 3 cubes and 1 beam was casted. The preparation of sample is done in following steps:

1) *Procurement of used Aggregates from a Demolished Building*: The recycled aggregates used here in this study is taken from demolished building of Raj theatre which was situated near Vijay Chowk in Gorakhpur, Uttar Pradesh. This was a 50 year old cineplex in Gorakhpur city. The below images shows the demolished site.

Fig 1 : Site location

Fig 2 : Demolished aggregates on site

2) *Cleaning of Obtained Recycled Aggregates:* For obtaining the required aggregates for the study, the embedded steel and the other materials are removed, cleaned and crushed from the concrete in a specified size. It is done so by a crushing machine as shown below:

Fig 3: Crushing Machine

3) *Testing of Physical Properties of Cement and Aggregates used for Casting*: Specific gravity of cement, fine and coarse aggregates is found out.
4) *Casting 3 Cubes and 1 beam by Replacing at each 0%, 10%, 20% and 30% of Natural Aggregates with Recycled Aggregates*: The images depicting casting of cubes and beam are:


Fig 4: Mixing of Aggregates


Fig 5: Preparation of Cubes


Fig 6: Casted cubes


Fig 7: Casted Beam

5) *Performing Compressive Strength test and Flexural Strength Test*: The test are performed on all the cubes and beams casted on various proportions for further analysis.


Fig 8: Compressive Strength Testing machine

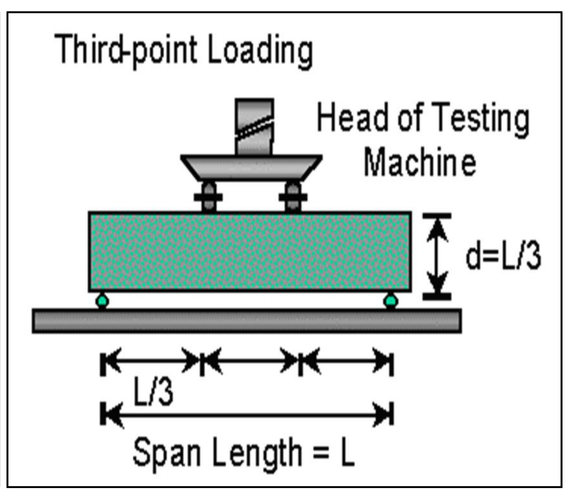

Fig 9: Flexural Strength test principle

6) *Analysis of test result and conclusion* – The test result obtained is analysed for determination of results.

IV. RESULT ANALYSIS AND DISCUSSION

The experimental investigation on the casted cubes and beams has led to the following results:

A. *Compressive Strength Test Results*

1) At 0% replacement

Table I: Result at 0% replacement of natural aggregates with recycled aggregates

% of natural aggregate	% of recycled aggregate	Compressive load(kN)	Area of cube(cm^2)	Compressive strength(N/mm^2)
100	0	720	15*15	32
100	0	700	15*15	31.11
100	0	725	15*15	32.22

2) At 10% replacement

Table II: Result at 10% replacement of natural aggregates with recycled aggregates

% of natural aggregate	% of recycled aggregate	Compressive load(kN)	Area of cube(cm^2)	Compressive strength(N/mm^2)
90	10	650	15*15	28.89
90	10	620	15*15	27.56
90	10	650	15*15	28.89

3) At 20% replacement

Table III: Result at 20% replacement of natural aggregates with recycled aggregates

% of natural aggregate	% of recycled aggregate	Compressive load(kN)	Area of cube(cm^2)	Compressive strength(N/mm^2)
80	20	585	15*15	26
80	20	580	15*15	25.78
80	20	575	15*15	25.56

4) At 30% replacement

Table IV: Result at 30% replacement of natural aggregates with recycled aggregates

% of natural aggregate	% of recycled aggregate	Compressive load (kN)	Area of cube(cm^2)	Compressive strength(N/mm^2)
70	30	463	15*15	20.58
70	30	467.53	15*15	20.80
70	30	469.47	15*15	20.87

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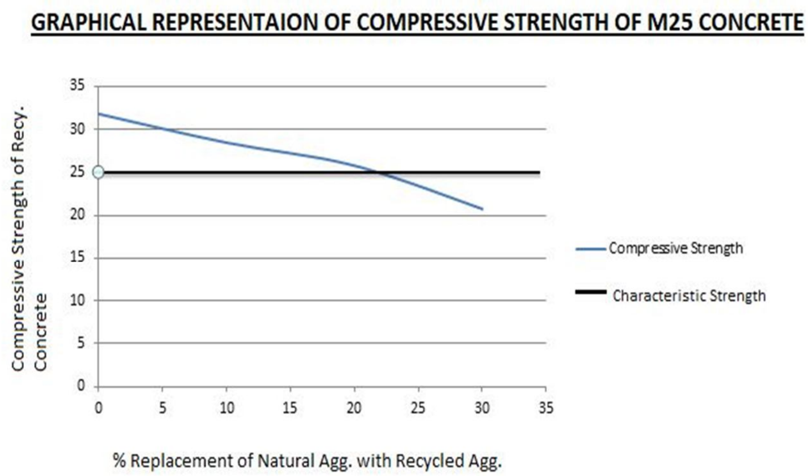
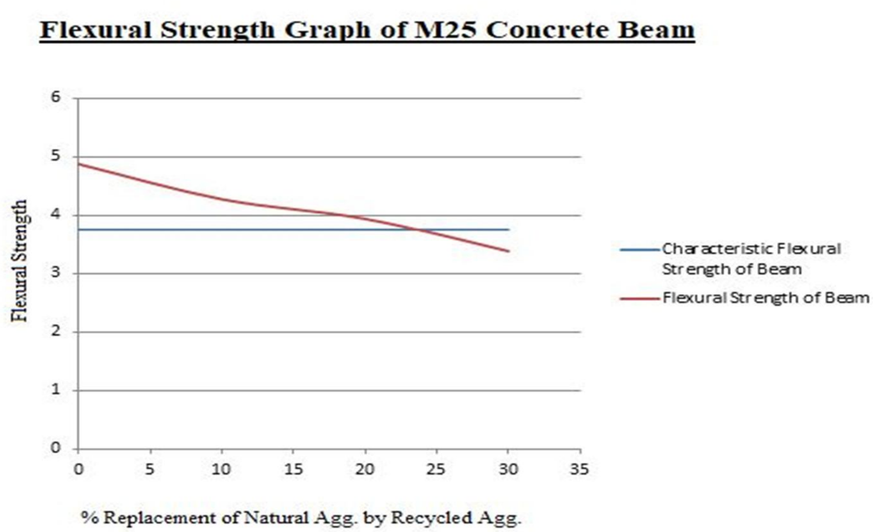


B. Flexural Strength Test Result for M25 Beam

Table V: Result of flexural strength test on beam

% natural aggregate	**% recycled aggregate**	**Compressive load(kN)**	**Area of beam(cm^2)**	**Compressive strength(N/mm^2)**
100	0	27.42	70*15	4.475
90	10	24.05	70*15	4.27
80	20	22.15	70*15	3.94
70	30	19	70*15	3.38



V. CONCLUSION AND FUTURE SCOPE

Conclusion - From the analysis of result it is found that on 22% replacement of natural coarse aggregate with recycled aggregate, the concrete cubes gives the desired compressive strength and thus the same % of coarse aggregate can be replaced with recycled aggregates. It was also found that on 24% replacement of natural coarse aggregate with recycled aggregate, the concrete beam of M25 gives the desired flexural strength and thus the same % of coarse aggregate can be replaced with recycled aggregates. Thus, it can be concluded that the average value i.e. 23% of natural coarse aggregate can be replaced with recycled aggregate for the desired strength of the construction.

Future Scope - It is definite that recycled aggregates are the 'Materials of Future' and should be adopted on large scale in construction. The future scope of this study involved testing the cubes and beams of other grades of concrete at different proportions of replacement of recycled aggregates with natural aggregates. Cost estimate of a building made with recycled aggregates can be done and compared with cost estimate of a building made with only natural aggregates. Moreover, microscopic study of chemical reactions occurring on combining recycled aggregates with cement can also be done.

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