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# AN EXPERIMENTAL INVESTIGATION ON STRENGTH OF CONCRETE MADE WITH RECYCLED AGGREGATES

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***ABSTRACT***

***In the construction sector, one of the most significant problems is the depletion of natural resources used in the preparation of concrete. On the other hand, construction and demolition (C&D) debris often gets discarded without being disposed of properly. It's possible that recycling and reusing these construction and demolition debris, such as recycled coarse aggregate and recycled fine aggregate, might cut down on the use of natural resources and help solve the problem of environmental sustainability. The use of recycled resources in the building sector, namely in the production of concrete, presents a number of difficult challenges. The amount of cement mortar that is connected to the surface of recycled aggregate has a significant impact on the aggregate's quality. Because of this linked mortar, the resulting concrete formed from recycled aggregate has a lower strength and worse mechanical performance. This is because the concrete has a larger porosity, which results in increased water absorption rates. A concrete mixture was created using all three types of treated coarse aggregates. Recycled aggregate concrete (RAC) was manufactured using varying percentages of coarse and fine recycled aggregate.***

***KEYWORDS**: Concrete, Aggregates, Mortar, Debris, Natural Resources.*

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## 1. INTRODUCTION

The concrete industry is responsible for a significant percentage of the depletion of natural resources, which are becoming insufficient to fulfil the ever-increasing needs of demand. On the other hand, older structures made of concrete and masonry are reaching the end of their useful life, which means that these buildings will need to be demolished so that space may be made for new development. The rate at which buildings are being demolished is increasing at a rapid pace each day, but the costs associated with dumping sites continue to rise since adjacent locations are becoming less accessible. The effective and secure management of construction and demolition (C&D) waste is a significant environmental concern for contemporary civilization. The rapid growth of urbanization is transforming the concept of waste management from a low-need, isolated concern into an inevitable social and ecological issue that poses risks to human health and the environment. The improper management of garbage disposal has the potential to have negative effects on both the environment and public health. In order to process and dispose of wastes in an efficient way, the administration of wastes has to combine the concepts of waste reduction and reuse, as well as work toward the processing and disposal facility.

In a similar vein, Construction and Demolition (C&D) Wastes are needed to be disposed of in an efficient way at each and every step. The majority of Class C and Class D garbage in urban populations is created by the demolition of pre-existing, older, more fragile buildings. These include (1) the renovation of existing buildings, such as residential, industrial, and commercial spaces; (2) the construction of new residential, commercial, or hotel spaces; (3) the excavation or reconstruction of asphalt or concrete roadways; (4) the construction of flyover bridges; and (4) the renovation or installation of water, telephone, internet, and sewer pipe lines, among other things.

Concrete rubble, brick blocks and tiles, sand and residue, lumber, plastics, cardboard and paper, and metals are the typical components of construction and demolition wastes (C&D wastes). Concrete rubble is almost always found to be the most significant component of construction and demolition debris (C&D). It has been demonstrated that crushed solid rubble, after being separated from other construction and demolition waste and sieved, can be utilized as a substitute for regular coarse aggregate in concrete, or as a sub-base or a base layer in asphalts, both of which are examples of applications in which recycled aggregates are utilized.

When any kind of infrastructure is taken down, large volumes of garbage may be produced in a very short length of time depending on the method of destruction that is applied. The typical ratio of cement to aggregate in concrete is somewhere about 12% cement to 80% aggregate by mass. In light of this, we may deduce that the annual consumption of sand, gravel, and crushed rock used in the production of concrete is somewhere between 10 and 11 billion tons. Mining and transportation operations that are engaged in the production of a significant quantity of aggregate demand energy, which has a negative impact on the ecosystem of the surrounding wooded regions and river sites. In light of this, there is a pressing need for effective waste management. [1] Taking into consideration the future state of infrastructure in India, there is a pressing need for efficient management of waste from development projects.

It is a well-known fact that concrete, like steel and dirt, is a material that is manufactured on a large scale in the field of development. In any event, a significant amount of effort has been put in to recycling and conserving important public assets and resources, and the concept of recurrent reuse may be applicable for concrete, just as it is in the case with steel and aluminum. [2] The use of recycled aggregate in the manufacturing of recycled aggregate concrete is a strong method (RAC). On the other hand, recycled aggregates are linked to older cement mortar, which is made by compacting waste concrete that has been damaged. The production of RAC involves combining RA with a number of other natural components, including as cement, water, fine aggregate, and several other elements. When taking into consideration the advantages that it provides to the aforementioned two difficulties, the use of these materials as a substitute for natural aggregates is an intriguing choice to examine. In spite of the fact that the reuse of coarse aggregate in the production of new concrete is becoming increasingly common in the Western part of the world and the far Eastern part of the world, such as Japan and Korea, there is only a moderate amount of familiarity with the potential uses of such aggregate in India. India is the second largest consumer of cement on the globe, behind only China. This fact shows that India is also one of the key consumers of materials used in the production of concrete, such as fine and coarse aggregate. China is the world's leading consumer of cement. Given the limited availability of aggregate sources in India, it is essential that consideration be given to the possibility of reusing coarse and fine aggregate in the manufacturing of concrete there.

The Clean and Beautiful India Mission, which is overseen by the Ministry of Urban Development, has set a primary goal of managing all of the garbage that is generated in urban neighbourhoods by the second of October in 2019. This goal includes C&D waste. [3]

In India, inappropriate and unlawful disposal of waste is often the norm, which results in a wide variety of issues. In addition, the potential resource value of C&D waste cannot be recovered until it is recycled. The necessity of managing construction and demolition waste is not lost on any of the stakeholders, particularly in big cities, which have already suffered the effects of the catastrophe. However, there are several obstacles that stand in the way of efficient management of C&D waste in India. However, if construction and demolition debris is processed and managed correctly, it may lead to lucrative recycling, as shown by the experiences of other nations.

The piles of construction and demolition debris that aren't adequately handled have a variety of negative effects on both the built and natural environments. These effects may be generally grouped into the following categories:

## 2. EXPERIMENTAL PROGRAM

### 2.1 Materials Used

#### 2.1.1 Cement

In this study, ordinary Portland cement that met the requirements for 53-grade ordinary Portland cement and was formulated in accordance with the IS code 12269-1987 was utilized. 3.15 were determined to be the specific gravity of cement.

**TABLE 1 Testing of OPC**

| Type of test | Test results | IS limits |
|---|---|---|
| Types of cement | OPC-53grade | - |
| Fineness test | 7% | <10% |
| Normal consistency | 32% | - |
| Soundness test | 7mm | <10 MM |
| Initial setting time | 85min. | >30 Min. |
| Final setting time | 240 min | <600 Min |

**TABLE 2 Chemical composition of OPC**

| Component | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $SO_3$ | $MgO_3$ | $Na_2O$ | $K_2O$ | CI | LOI | IR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Content (%) | 21.66 | 4.75 | 3.8 | 63.7 | 2.15 | 0.85 | 0.20 | 0.45 | 0.04 | 2 | 0.4 |

#### 2.1.2 Water

For the purpose of the test, consumable tap water that did not include any salts or other concoctions was employed. The water supply might be accessed at the laboratory that tests materials.

#### 2.1.3 Admixture

The use of super plasticizer makes it possible to reduce the amount of water that is included in a solid mixture while maintaining the blend's consistency. During this particular test, an admixture from a well-known brand was employed in the role of a plasticizer. The Master Rheobuild 823PQ product is made up of designed polymers, which are seldom used for the purpose of imparting rheoplastic properties into concrete. Rheoplastic concrete is liquid cement that has a slump of at least 200 millimeters, is capable of efficiently streaming, while at the same time being free from isolation and having a water-to-cement ratio that is comparable to that of a slump that has admixture (25 millimeters). The M40 and M50 grades of concrete are the only ones allowed to make use of this particular additive. The use of super plasticizer improves the cement's strength, quality, and uniformity while also reducing the cost of the practical mix outline and accelerating the building process. Super plasticizers may also save money.

### 2.1.4 Micro Silica

Micro Silica is a kind of super pozzolana that is a substance that has been finely powdered and is used in concrete mix to provide strength and durability. Micro fine is a crucial component in the production of high-strength concrete, which is often required for significant construction endeavours such as the construction of record-breaking tall buildings, highways, and bridges. These technical applications that call for high strength concrete make use of micro silica as a technique of increasing compressive strength that is both cost effective and efficient. Micro silica's particle packing and pozzolanic reaction both contribute to the material's increased strength. Micro silica concrete has a thinner transition zone (interface) between the cementitious paste and the aggregate. Additionally, the CH crystals in micro silica concrete are smaller and more randomly oriented, which leads to a reduction in porosity and an increase in interface bonding strength. Micro silica concrete has a number of other advantages as well.

**TABLE 3 Technical specification of Micro silica**

| Chemical & Physical Characteristics | Unit | G-Chem(BL-Z) |
|---|---|---|
| $SiO_2$ | % | 92+ |
| CaO | % | 0.91 |
| $Al_2O_3$ | % | 0.59 |
| $Fe_2O_3$ | % | 0.33 |
| Loss on ignition | % | 2.00 |
| Moisture | % | <1 |
| Bulk density | $Kg/m^3$ | Densified & Undensified (Reported) |
| Pozzolanic Activity Index (7 Days) | % | 105+ |

### 2.1.5 Natural Aggregates

According to the requirements of the Indian standard code, the aggregate is divided into fine and coarse categories.

### 2.1.6 Natural Coarse Aggregates

During these trials, Indian Standard 383-1970-compliant crushed coarse aggregate that was readily accessible in the surrounding area was employed. Particle size distribution was found to be in accordance with the standards of IS

(2386 part I). The sieve employed has a nominal size that must pass through size 20 mm while retaining on size 10 mm. The density of coarse aggregate has a specific gravity of 2.86. The many additional physical and mechanical features of natural aggregates are outlined in Table 3.5. In line with the International Standard 2386-1963, the mechanical characteristics of both natural aggregate and recycled aggregate were evaluated (Part IV). Table 3.6 presents the results of a sieve study performed on natural coarse particles.

**2.1.7. Natural Fine Aggregate**

The phrase "fine aggregate" refers to the fractions that range from 4.75 millimetres to 150 microns in size. According to Indian Standard 383-1970, river sand, which is readily accessible in the area, was utilized. According to Indian Standard 2386 (Part III)-1963, different physical parameters of river sand were found (IS 1963). Sand was indicating that Zone-I was correct. Sand had a specific gravity of 2.65 and a fineness modulus of 3.35.

**2.1.8 Recycled Coarse Aggregates**

Waste from construction and demolition, abbreviated as C&D, was gathered from two different sources: (a) a demolished concrete beam, which was destroyed for the purpose of adding on to and modifying the existing frame structure; its age was about less than five years. (a) Laboratory-ground concrete cubes that have been crushed (approx. aged up to 2-year-old). A pilot recycling test set up has been built to process recycled aggregates so that they may be utilized for laboratory studies. The laboratory analysed and crushed concrete specimen trash, making it accessible in large quantities to an institution in the area. The cubes being examined in this laboratory were a part of the building work being done on a nearby bridge. This was one of the sources that was utilized to calculate RA.

**2.1.9 Recycled Fine Aggregates Material**

The Recycled Fine Aggregates (RFA) that were employed in this experimental investigation were the remnants that were left over after the coarse aggregate had been subjected to an abrasion treatment, as well as the remnants that had been left over after using a jaw crusher to generate the coarse aggregate. The size of the recycled fine aggregate (RFA) that was employed in the studies was 4.75 millimeters and maintained 150 microns. The sample of fine recycled aggregate that was utilized in the investigation may be seen in Fig.3.3. The water absorption percentage was 10.71%, and the specific gravity was 2.2.

**2.2 Types of Tests**

The fresh qualities of concrete as well as its properties after it has been hardened were investigated in this research.

**2.2.1 Evaluation of the Slump in Fresh Concrete**

Utilizing the Methods of Sampling and Analysis of Concrete (IS: 1199, 1959), IS 456 for concrete mixtures, we were able to assess the workability of the concrete by using a slump cone. Workability of concrete is controlled by numerous aspects including water content, mix proportion, size and shape of aggregate, grading of aggregate, surface roughness of aggregate, and usage of additive. The goal of this study is to examine the fresh qualities of recycled aggregate concrete (RAC). The slump test and the compaction factor test are being used in this investigation to establish workability. The preparation of concrete mixtures included the replacement of 10%, 20%, and 30% of the coarse RA with and without treatment. Concrete that has RA that has been treated by abrasion is designated as RAC (AT), while concrete that has RA that has been treated by cement slurry is designated as RAC (CST). In addition, there was substitution of fine aggregate in the aforesaid concrete mix with fine recycled aggregate in the proportions of 10%, 30%, 50%, and 100% respectively. A mixture of coarse recycled aggregate that had been treated and fine recycled aggregate was used to make the concrete mix, with the amount of coarse RA that could be replaced being limited to 30 per cent.

In addition, the compacting factor test is used in order to establish the fresh concrete's level of workability. Due to the apparatus's extreme heaviness, it is never used for on-site testing. The compacting factor test provides a more accurate assessment of the new concrete's workability than the traditional slump test. It was said that the compacting factor test, also known as the "drop test," is a measurement that compares the weight of completely compacted concrete to the weight of partly compacted concrete. This test is also known as the "drop test."

**2.2.2 Evaluation of Compressive Strength**

In accordance with the Indian Standard IS: 516-1959, the compressive strength of specimens is evaluated after 7 and 28 days of curing, respectively, in a surface-dried state. The compressive strength of the material was measured using molds measuring 150mm x 150mm x 150mm. Cube specimens were positioned in the machine's center in such a way that the load would be delivered perpendicular to the casting faces. This was accomplished by following these instructions. The load was delivered in a manner that was both very continuous and uniform, and there was no shock to the system. The highest load that each specimen was able to support while being tested has been noted here. The formula for determining a material's compressive strength involves dividing the greatest load under test by the cross-sectional area of the specimen. Because each kind of mix was represented by three specimens in the tests, the mean compressive strength of the three specimens was used as the standard for the measure of compressive strength.

**2.2.3 Tensile Splitting Strength**

According to International Standard 516-1959, the tensile splitting strength of concrete was determined. Throughout the experiment, cylinders of 150 mm in diameter and 300 mm in height were utilized to determine the tensile splitting strength of concrete. Compression testing equipment was used to conduct a split tensile strength test. Results were positive. The casting of the specimens and the testing of their tensile strength were carried out in accordance with IS: 5816- 1970.

The formulae below may be used to calculate the specimen's tensile strength at the splitting point.

$$\mathbf{T = 2P/\pi LD}$$

Where

T = Splitting tensile strength

P = Maximum applied load

L = Length,

D = Diameter

### 2.2.4 Strength in the Flexure

Flexural strength is a measurement that reflects the resistance of a material to deformation when put under bending stress. This resistance is shown by the material's ability to flex without being deformed. The cross-sectional dimensions of the beam specimens were 100 mm x 100 mm x 500 mm. An investigation of the flexural strength of recycled aggregate concrete beams was carried out using various grades of concrete. In accordance with IS: 516-1959, the flexural strength of concrete was determined. The formula for calculating the flexural strength,

$$f = \frac{pl}{bd^2}$$

**Where,**

p = max. Load (kg)

b is the breadth of the specimen in centimeters,

d is the failure point depth in centimeters, and

l is the supported length (cm)

### 2.2.5 Elastic Modulus of the Material

Concrete has many important characteristics, the most important of which are its compressive strength and static modulus of elasticity. These are the primary parameters that are used in the calculation of the deflection of structures made of reinforced concrete. In light of the empirical link that exists between the static modulus of elasticity and the compressive strength of plain concrete after it has been allowed to cure for a period of 28 days, many countries' practice codes have been established. Concrete is not an elastic material in any sense of the word, but it does exhibit nonlinear behaviour when it comes to the relationship between stress and strain. Concrete's elastic modulus is one of the most essential mechanical qualities since it reflects the material's ability to deform elastically and is thus among the most important mechanical properties. In order to properly evaluate the modulus of elasticity of concrete in accordance with IS 516-1959, the test specimen will be a cylindrical specimen with the dimensions of 150 mm in height and 300 mm in diameter, and the height-to-diameter ratio will be maintained at 2.0. Six examples were cast for each grade, with 30% of the coarse material replaced by replacement and 50% of the fine aggregate replaced by replacement. M20, M40, M50, and M70 were the several grades of concrete that were available. The mixing of the specimens and the casting of them both followed a procedure that was quite similar to the one that was explained in the previous section.

## 3 RESULTS AND DISCUSSION

The primary objective of this chapter is to show and talk about the findings of a study that compared the characteristics of recycled aggregate concrete in its fresh and hard states. These fresh qualities include things like slump and the compaction factor, whereas the hard condition values include things like compressive strength, tensile strength, flexure strength, and modulus of elasticity. The discussion is on the impact that recycled aggregate has on the slump. The effects of using treated recycled aggregate on recycled aggregate concrete's compressive strength, tensile splitting strength, and static modulus of elasticity are provided below. These results may be seen in the recycled aggregate concrete.

### 3.1 Workability Measurement by Slump Test

Even if the test is really simple, it still has to be carried out in an accurate manner since a significant setback may occur if there is any unpleasant impact throughout the procedure.

Utilizing the Methods of Sampling and Analysis of Concrete (IS: 1199, 1959) for concrete mixtures allowed for the determination of workability as measured by the slump cone. The IS: 7320 – 1974 standard was followed in order to carry out the slump test. The amount of droop was given in millimeters as the measurement. To make the concrete mixtures, coarse RA was substituted at percentages of 10%, 20%, and 30%, both with and without Treatment. Concrete that has RA that has been treated by abrasion is designated as RAC (AT), while concrete that has RA that has been treated by cement slurry is designated as RAC (CST).

In addition, there was substitution of fine aggregate in the aforesaid concrete mix with fine recycling aggregate in the proportions of 10%, 30%, 50%, and 100% respectively. Replacement aggregates were used in the preparation of the concrete mix, which included both coarse recycled aggregate that had been processed and fine recycled aggregate.

The amount of coarse RA could only reach 30 per cent. The findings of the slump test are shown in Fig.3.1, which may be seen below. It has been noticed that coarse RA contains ten, twenty, and thirty per cent replacement and produces workable concrete that is on par with NAC, but fine RA has ten, thirty, fifty, and one hundred per cent replacement and produces hard concrete. One of the most important things that was discovered here was that the concrete mixes were more cohesive than those that had been created using natural aggregates when fine recycled material was utilized at larger percentages (such as 30%, 50%, and 100%).

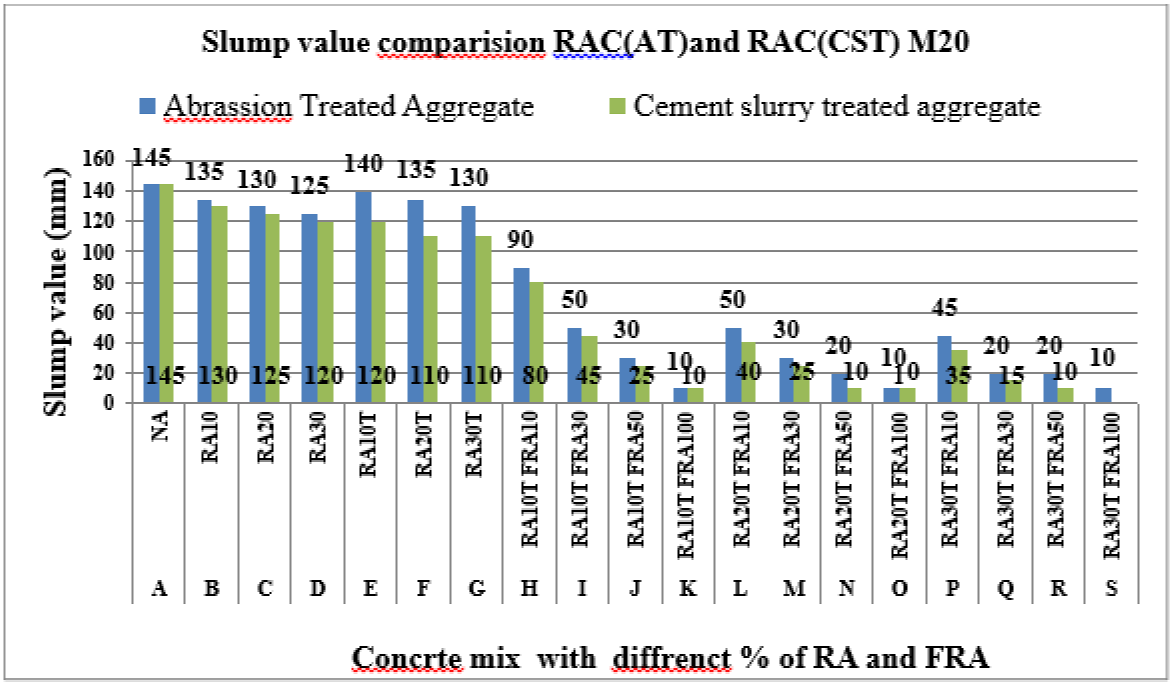



**FIGURE 3.1 Slump value for various concrete mix (M20)**

### 3.2 Determination of Compressive Strength of Recycled Aggregate Concrete

A compression machine with a loading capacity of 3,000 KN was used to measure the compressive strength of all grades of concrete in accordance with the standards established in IS 516-1959 (IS 1959). The compressive strength was measured using a cube specimen that was 150 mm on each side and 150 mm long. The specimen of a cube may be seen in Fig.5.5. Both seven and twenty-eight days were spent curing the specimens in water. In order to understand the impact of the coarse and fine recycled aggregate replacement, six identical specimens are cast for each concrete mix. These specimens are used in the casting process. When the testing age had arrived, the specimens were removed from the curing tank and placed in the open air for ten to fifteen minutes. The specimen is then tested by being put one at a time on the steel platen of the machine in such a way that the specimen is tested at an angle that is perpendicular to the casting face. The loading rate of 5 KN/s, as prescribed by IS: 516 – 1959, is used for the duration of the test.

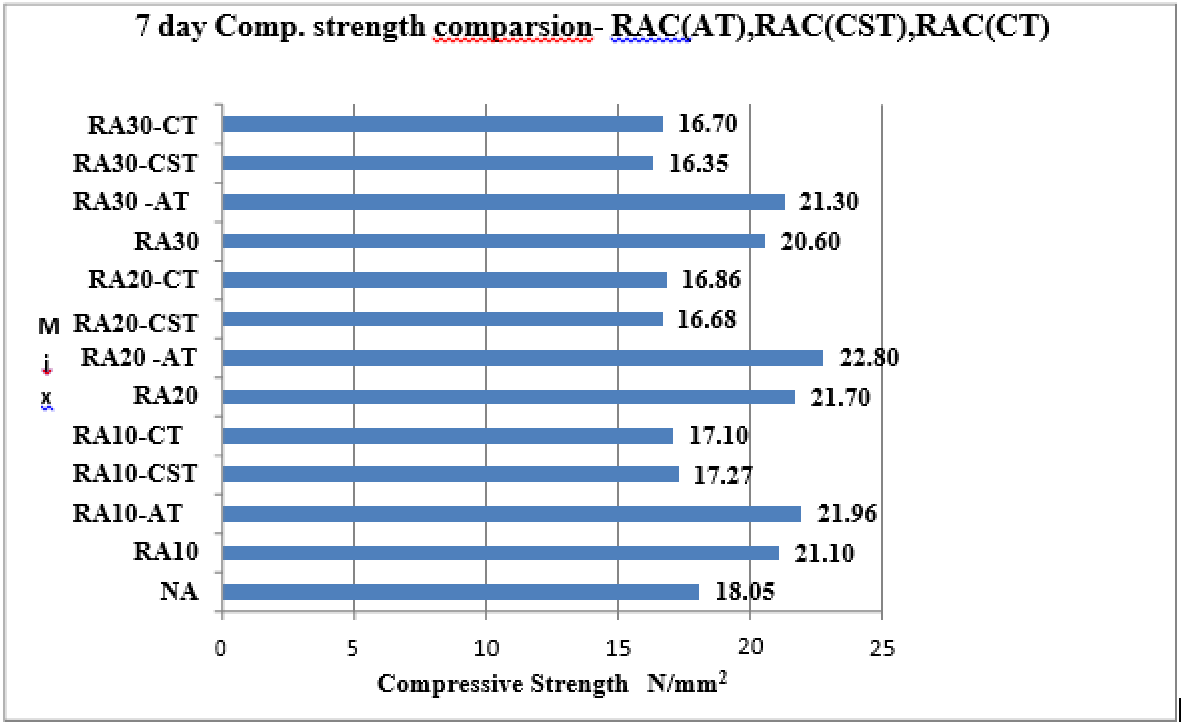



**Figure 3.2-day strength comparison- RAC (AT), RAC (CST), RAC (CT)**

### 3.2.3 Flexural Strength and Splitting Tensile Strength of RAC

The tests were prepared and carried out on above 19 various concrete mixes so that the flexural strength and splitting tensile strength of concrete M20 Grade concrete with varied replacement percentages of recycled coarse aggregate and fine aggregate could be studied. Tests of flexural strength are carried out in accordance with IS: 516-1959. Beam specimens used to test flexural tensile strength had dimensions of 100 millimeters on all three dimensions (mm). Both seven and twenty-eight days were spent curing the specimens in water. The beam specimen being tested for flexure strength is only supported by two rollers with a diameter of 4.5 centimeters. The flexural tensile strength of the beam specimen is determined by determining the ratio between the estimated bending moment and the section modulus of the beam. Figure 4.12 depicts the apparatus used for the tensile test as well as the flexure test. In accordance with IS 5816-1999, a test of the split tensile strength of concrete was carried out. Castings were made of cylinders with a diameter of 150 mm and a length of 300 mm. The samples were aged for a total of twenty-eight days. The compression testing machine has a capacity of 3000 KN, and here is where the tensile test is carried out.

**FIGURE 3.3 Tensile strength test**

The results of the flexural strength and splitting tensile strengths are shown in figures 3.4 and 3.5, respectively, and are shown for M40 and M50 grade concretes. The concretes that were created using recycled aggregate obtained a flexural and splitting strength that was comparable to or somewhat less than that of the control concrete. This was notably true in the situation where 50% of the fine aggregate was replaced. The manufacturing of concrete using recycled fine aggregate in place of natural fine aggregates has an adverse effect on the qualities in question. Only the concrete that was prepared with 30% fine RA was successful in obtaining or matching the control concrete's level of flexural strength.

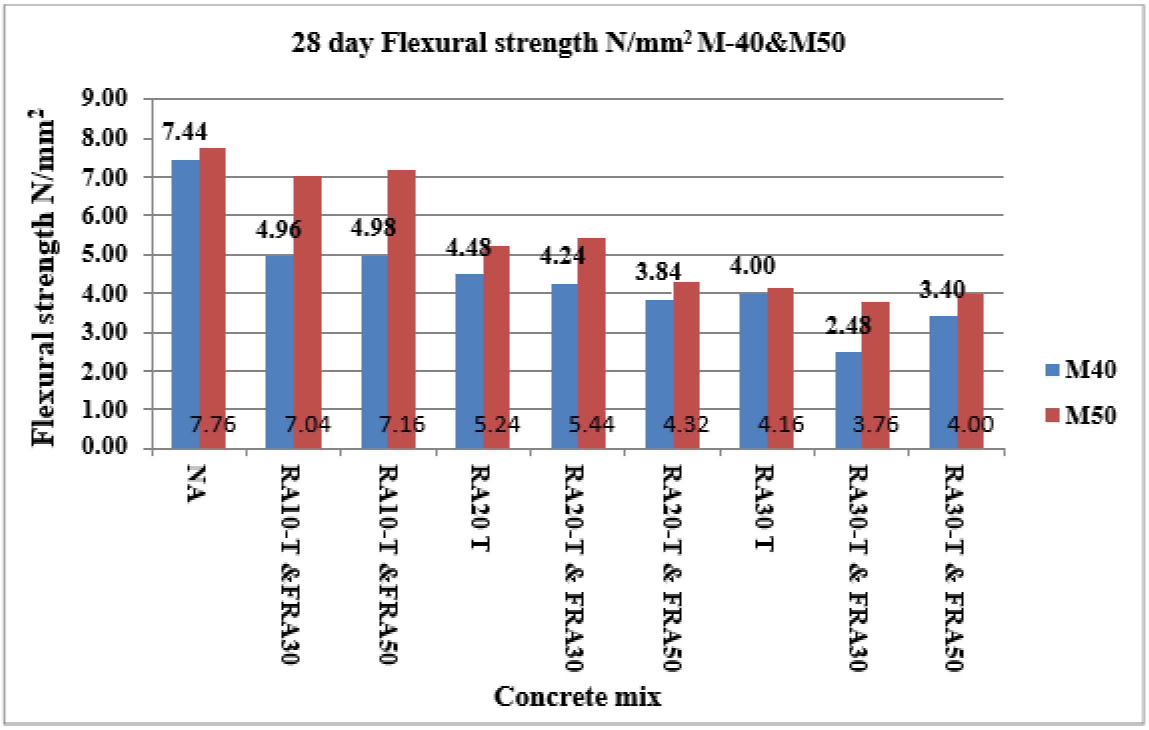
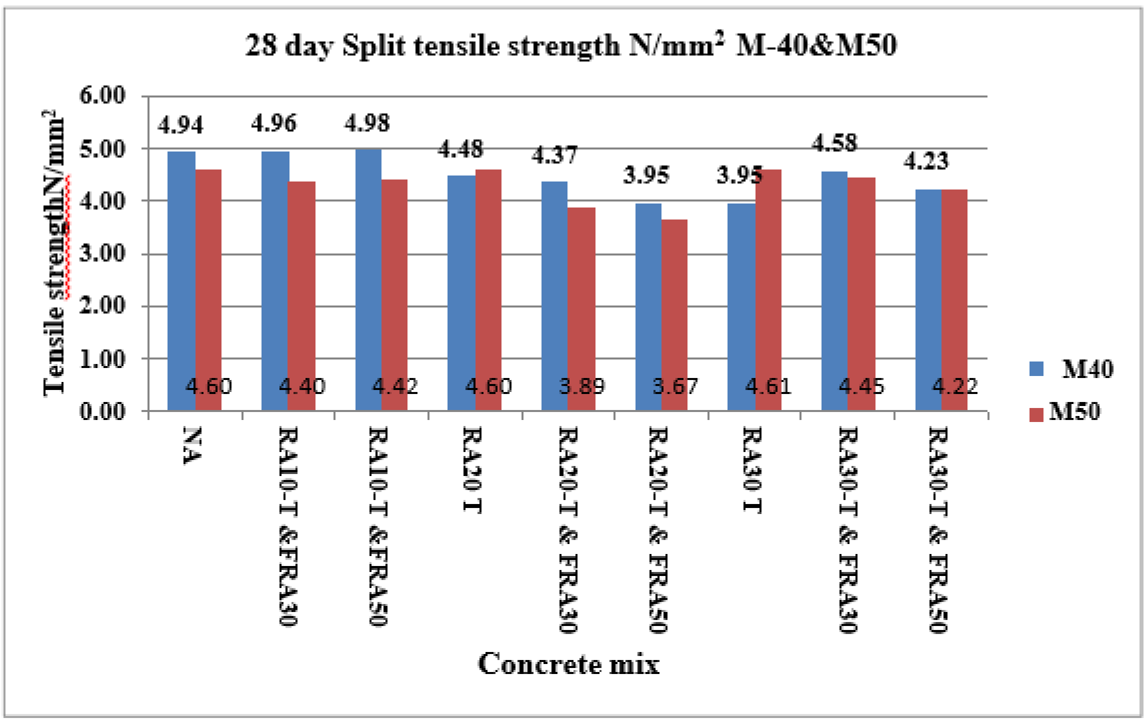



**FIGURE 3.4 Flexural strength for M40 & M50 grade**




**FIGUR E 3.5. strength for M40 & M50 grade**

## 4. CONCLUSIONS

Experiments conducted on reused aggregates have shown that coarse and fine reused aggregates may be utilized to produce concrete of a quality that is comparable to new concrete.

- Recycled aggregate concrete with thirty percent of its coarse aggregate replaced by recycled material has a compressive strength that is comparable to that of natural aggregate concrete. After undergoing abrasion treatment, acid treatment, and treatment with cement slurry, it was discovered that recycled aggregate concretes had compressive strengths that were equivalent to those of natural aggregate concrete.
- When it comes to removing the connected mortar and increasing the performance of recycled aggregate, abrasion treatment of recycled aggregate is superior to chemical treatment and treatment with cement slurry in terms of both efficiency and suitability.
- Utilizing fifty percent fine recycled aggregates and thirty percent coarse recycled aggregates as a substitute yields compressive strength and tensile strength that are equal to those of conventional concrete after 28 days in concrete grades M20, M40, M50, and M70.
- The workability of concrete mixes made with recycled aggregate is lower than that of concrete mixes made with natural aggregate. In the instance of concrete mix using just thirty percent treated coarse recycled aggregate concrete, a suitable usable concrete has been generated.
- The addition of super plasticizer, on the other hand, makes it possible for concrete made with 30% coarse recycled aggregate and 50% fine recycled aggregate to have a workability that is equivalent to that of conventional concrete made with natural aggregates.
- When compared to the theoretical value presented in IS 456, the experimental elastic modulus for natural aggregate concrete is comparable to the code value. On the other hand, the values are slightly lower in the M20, M40, and M50 grades for concrete that contains 30% recycled coarse aggregates and 50% recycled fine aggregate, but these values are still greater than those derived by BS and ACI.
- There is the potential to realize a cost advantage of 10% in this location by favoring the use of recycled aggregates material rather than natural resources. This can save money to a certain level.

## REFERENCES

[1]. Kumar M, Malay N, Kujur J. Study of natural carbonation of concrete incorporating marble dust. Proceedings of the Institution of Civil Engineers–Construction Materials. 2018; 171(2), pp. 85-92.

[2]. André, A. et al., 2014. Durability performance of concrete incorporating coarse aggregates from marble industry waste. Journal of Cleaner Production, 65, pp.389–396.

[3]. Kumar M, Kujur J, Chatterjee R, Chattopadhyaya S, Sharma S, Dwivedi SP, Saxena A, Rajkumar S, Anand A. Corrosion Zones of Rebar in High-Volume Fly-Ash Concrete through Potentiodynamic Study in Concrete Powder Solution Extracts: A Sustainable Construction Approach. Advances in Civil Engineering. 2022 Mar 24; 2022.

[4]. Anson-cartwright, M., 2011. Optimization of Aggregate Gradation Combinations to Improve Concrete Sustainability Optimization of Aggregate Gradation Combinations to Improve Concrete Sustainability,

[5]. Binici, H. et al., 2008. Durability of concrete made with granite and marble as recycle aggregates. Journal of Materials Processing Technology, 208(1–3), pp.299–308.

[6]. Kumar M, Sinha AK, Kujur J. Mechanical and durability studies on high-volume fly-ash concrete. Structural Concrete. 2021 Jan; 22: E1036-49.

[7]. Ergün, A., 2011. Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete. Construction and Building Materials, 25(2), pp.806–812.

[8]. Binici, H. et al., 2008. Durability of concrete made with granite and marble as recycle aggregates. Journal of Materials Processing Technology, 208(1–3), pp.299–308.

[9]. Hebhoub, H. et al., 2011. Use of waste marble aggregates in concrete. Construction and Building Materials, 25(3), pp.1167–1171.

[10]. Mishra, A. et al., 2013. Green cement for sustainable concrete using marble dust. International Journal of ChemTech Research, 5(2), pp.616–622.

[11]. Ceylan, H., & Manca, S., 2013. Evaluation of Concrete Aggregate Marble Pieces. SDU Journal of Technical Science, 3, pp.21–25.

[12]. André, A. et al., 2014. Durability performance of concrete incorporating coarse aggregates from marble industry waste. Journal of Cleaner Production, 65, pp.389–396.

[13]. Abdul, A. et al., 2014. An Experimental Study on the Availability of Solid Waste of Mines and Quarries as Coarse Aggregate in Concrete Mixes. Journal of Engineering Sciences Assiut University Faculty of Engineering, 42(3), pp.876–890

[14]. Bureau of Indian Standards (BIS), 1991. Specification for Portland pozzolana cement- BIS: 1489(Part-1)-1991, New Delhi, India.,

[15]. Bureau of Indian Standards (BIS), 1997. Specification for coarse and fine aggregates from natural sources for concrete. BIS: 383, New Delhi, India; 1970.

[16]. Bureau of Indian Standards (BIS), 1991. Specification for Concrete Admixtures - Internet Archive- BIS: 9103-1991, New Delhi, India.

[17]. Bureau of Indian Standards (BIS), 1999a. Specification for Methods of Sampling and Analysis of concrete, BIS:1199-1659, New Delhi, India,

[18]. Bureau of Indian Standards (BIS), 2002. Specification for Methods of Tests for Strength of Concrete BIS: 516-1959, New Delhi, India.