Concrete mix design by replacing natural aggregates with recycled aggregates

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Abstract

The construction industry is experiencing a shortage of natural aggregate, which is a crucial component of construction materials. As a result, this industry generates 40% of the total waste produced each year, which leads to environmental hazards and landfill problems. To address this issue, one possible solution is to replace natural aggregate with recycled concrete aggregate. By doing so, we can decrease landfill disposal, conserve primary resources, reduce transportation costs, and promote sustainable development. Therefore, it is necessary to examine the structural properties of recycled aggregate concrete, as it is a readily available and cost-effective alternative to natural resources .

The main focus is to obtain mix proportion of recycled and natural aggregates using IS code method The paper presents information about the material properties of the aggregates that were tested, and discusses the mix design process and testing outcomes.

Keywords: *Recycle coarse aggregate concrete, IS Code mix design method,slump test, compressive strength test.*

1. Introduction

Concrete is a composite material that consists of fine and coarse aggregates, water, and cement as a binder. The presence of coarse aggregates contributes significantly to the heterogeneity of the material, as they occupy the majority of its volume. Despite its many advantages, such as durability, cost-effectiveness, and high compressive strength, the use of traditional concrete made from virgin aggregates and ordinary Portland cement has proven to be environmentally unfriendly. This is due to the depletion of natural resources, increasing disposal problems, and high energy consumption in quarrying activities. Nonetheless, concrete remains the most widely used construction material worldwide, with applications in various civil engineering works such as infrastructure, buildings, defense installations, and environmental protection.

To be appropriate and flexible for changing environmental conditions, concrete needs to be designed in a way that preserves resources and safeguards the environment.To achieve this, it is crucial to focus on utilizing waste and byproducts in cement and concrete for new constructions to reduce costs and promote efficient use of energy.
The disposal of large amounts of demolished concrete at various construction sites has become a significant problem in urban areas. However, this concrete can be easily recycled and repurposed as an aggregate in new concrete.

Recycling and reusing concrete waste is essential to preserve the environment and effectively utilize resources. It helps to reduce the environmental impact by limiting the need for landfilling and exploitation of natural resources. Concrete, a composite construction material composed of cement, sand (fine aggregate), gravel (coarse aggregate), and water, has been a leading construction material for over a century. It is estimated that global concrete production is about 2.5 tons per capita, or 1 m3. By 2025, the worldwide use of naturally obtained aggregates is projected to be around 10-13 billion tons, while the amount of construction and demolition waste generated is increasing significantly worldwide each year.

The extensive use of naturally sourced aggregates and the rising amounts of construction and demolition waste are leading to significant environmental problems and undermining society's aspiration for a cleaner and less polluted environment.

In the past, the vast majority of construction materials were obtained from natural sources and the waste generated from demolished buildings was often disposed of in unregulated open areas. However, the growing amount of solid waste, particularly from construction and demolition activities, has become a significant environmental challenge. Such waste now constitutes a major portion of total solid waste production.

1.2 Advantages of Recycled Aggregate

The expansion of infrastructure due to population growth has led to an increase in demand for aggregate, resulting in a decline in natural resources. Using recycled waste concrete as aggregate can help reduce the need for virgin aggregate from quarries and preserve natural resources, leading to environmental benefits.

Reduction in Costs and Energy Consumption: Recycling concrete waste helps to save natural aggregates and reduces the environmental impact of their exploitation and transportation. The transportation and delivery involved in concrete production contribute significantly to pollution, second only to carbon emissions from cement manufacturing. The use of recycled concrete aggregates can decrease transport needs, resulting in cost and environmental benefits. Additionally, strategically locating mobile crushing plants can further reduce the distance required to transport recycled aggregates, making it a viable option for larger construction projects.

Land Preservation: Recycling concrete waste helps to save natural aggregates and reduces the environmental impact of their exploitation and transportation. The transportation and delivery involved in concrete production contribute significantly to pollution, second only to carbon emissions from cement manufacturing. The use of recycled concrete aggregates can decrease transport needs, resulting in cost and environmental benefits. Additionally, strategically locating mobile crushing plants can further reduce the distance required to transport recycled aggregates, making it a viable option for larger construction projects.

1.3 Objectives of study:

- To discover different construction wastes which can be well utilized inconcrete making.

  To replace natural coarse aggregate by the recycled coarse aggregate in various percentages (0%, 50% and 100%)

- To study and compare the mechanical properties compressive strength of hardened concrete specimens with and without recycled aggregates.
- To develop some alternative economic construction materials which will also environment friendly.
- To find out the optimum content of RCA that can be feasibly used in normal construction practice.
- To reduce the impact of waste materials on environment.
- To carry out different tests on RCA and NA, and compare their results.

1.4 Properties of Recycled Aggregate

Density
The lower density of recycled concrete aggregate is attributed to the less dense adhered mortar compared to the underlying rock in natural aggregate.

In a saturated surface dry state, the relative density of recycled concrete aggregate is typically 7-9% lower than that of natural aggregate.

Porosity
The porosity of natural aggregate is typically low, leading to a lower water absorption rate. However, due to the greater porosity of the adhered mortar on recycled concrete aggregate, it can hold more water within its pores than natural aggregate.

Water Absorption
Almost double than natural aggregate.

2. LITERATURE REVIEW

Ravande Kishore, Kalidas (2022)-The research on the replacement potential of recycled coarse aggregates in concrete has been ongoing for many years. It has been established that despite the quality of recycled coarse aggregates affecting the properties of Recycled Aggregate Concrete (RAC), it is still possible to produce concrete equivalent to that made with natural coarse aggregates. This paper aims to investigate the use of recycled coarse aggregates in ternary blended cement concretes and demonstrate that they can be a viable alternative in structural concrete. The objective is to evaluate the compressive strength of concrete made with recycled coarse aggregates, supplementary cementitious materials (fly ash and alccofine), and a high-range water-reducing polycarboxylate ether based chemical admixture. The research aims to recommend an optimal replacement ratio of natural coarse aggregates with recycled coarse aggregates in ternary blended cement concrete. Two different grades of concrete, 40MPa and 60MPa, were studied with varying replacement ratios of natural coarse aggregates with recycled coarse aggregates.

P.C. Yong (2022) In the study, RECYCLE CONCRETE AGGREGATE was used, which was obtained from site-tested concrete samples. The samples were 14-day concrete cubes taken from a local building site after compression testing, and then they were split into required sizes. Approximately 200 Kg of recycled concrete aggregate was utilized for the research. The outcomes indicate that recycled concrete aggregate is capable of producing good quality concrete. Furthermore, the compressive strength of recycled concrete aggregate is higher than that of natural recycled aggregate. In terms of split tensile strength, wet density, and flexural strength test, recycled concrete aggregate is comparable to regular concrete.

M.C Neil (2021):- On the study of recycle concrete aggregate, which includes its properties, effects, and large-scale production. Several tests, such as compressive strength, splitting tensile strength, crack width and spacing, modulus of rupture and elasticity, and structural performance of recycle concrete aggregate cubes, were conducted to analyze its properties. The study concludes that the properties of recycle concrete aggregate can vary based on different materials and admixtures used in production, but it can still be used as a viable option for building structural concrete.

Dr. K. Ramadevi & Dr. R. Chitra (2021): The researchers conducted a study on using recycled aggregates in concrete by replacing natural coarse aggregate with proportions of 0%, 30%, 60%, and 100% for a mix proportion of m-25. The results showed that there was not a significant difference in strength between ordinary concrete and concrete with 30% replaced aggregate. However, as the percentage of aggregate replacement increased, there was a consistent increase in strength. This is because the recycled aggregates obtained from recycling concrete have a higher angularity, absorption, and specific gravity than natural coarse aggregate, which improves the load carrying capacity of the concrete and increases its strength.

S R Yadav (2020) : On the use of recycled concrete aggregate in concrete production and reviews existing literature on the subject, particularly in relation to compressive strength. The article proposes an approach for using recycled concrete aggregate without compromising the strength of the resulting concrete. The literature suggests that compressive strength is primarily affected by factors such as adhered mortar, water absorption, Los Angeles abrasion, aggregate size, strength of parent concrete, curing age, replacement ratio, interfacial transition zone, moisture state, and impurities. While some studies have suggested mix design procedures for recycled aggregates, a simple and cost-effective method for using demolished concrete and calculating mix composition based on % adhered mortar is yet to be developed. Despite extensive research on recycling, the construction industry still lacks an efficient and economical method of using recycled aggregates in second generation concrete.

Er. Rajdeep Singh Er. Gurtej Singh (2019): The study aimed to evaluate the physical properties of recycled aggregate in comparison to Indian Standards and to determine the effect of different proportions of recycled aggregate on concrete compressive strength. The tests were carried out according to Indian Standards, and the results indicated that although there were variations in physical properties between recycled and natural aggregate, they were within BIS specifications. The compressive strength test revealed that substituting 20% of natural aggregate with recycled aggregate had no significant effect on strength, while using 100% recycled aggregate resulted in compressive strength that was approximately 82% of that of natural aggregate.

3. MATERIALS AND METHODOLOGY

3.1 Cement

Type and Grade: PPC 43 GRADE
Specific gravity: 3.15

3.2 Fine Aggregate

Fine aggregate is the type of aggregate that can pass through a 4.75 mm IS sieve. The specific gravity of fine aggregate is 2.64.

The local quarry provided the coarse aggregate, which has a specific gravity of 2.835 and a maximum size of 40mm.

3.3 Recycled Coarse Aggregate: -

The recycle aggregate is brought from a demolished building site, having specific gravity 2.42.

3.4 Tests on Fine, Natural Coarse Aggregate and Recycled Coarse Aggregates:

- Specific Gravity Test
- Water absorption test for Coarse aggregate

3.5 Mix Design with natural aggregate

Mix Design for samples of M40 used as per IS10262:2019

- Grade Designation : M40
- Type of Cement : Portland Pozzolana Cement (43 grade).
- Maximum nominal size of aggregate : 20mm
- Minimum cement content : 300kg/m3
- Workability : 75mm
- Exposure condition: Moderate

- Degree of supervision: Good
- Type of coarse aggregate : Crushed, Angular
- Fine Aggregate Zone (confirmingIS383) : ZoneII
- Specific gravity of Coarse Aggregate : 2.835
- Specific gravity of Fine Aggregate : 2.64
- Specific gravity of Cement : 3.15
- Target mean strength : 48.25N/mm^2
- Maximum water cement Ratio : 0.55
- Adopted Water Cement ratio : 0.40

3.6 Calculated Mix Design

Detail of Mix Proportion

S.NO	Materials	Quantities
1	Water	143.685litres
2	Cement	359.213kg/m^3
3	Fine Aggregate	654.511kg/m^3
4	Coarse Aggregate	1361.961kg/m^3
5	Admixture (Superplasticizer)	3.6 litres
6	Calculated proportions	1.000 : 1.822 : 3.792

3.7 Mix Design with recycled coarse aggregate

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- Maximum nominal size of aggregate : 20mm
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- Degree of supervision: Good
- Type of coarse aggregate : Crushed, Angular
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- Specific gravity of recycled Coarse Aggregate : 2.42
- Specific gravity of Fine Aggregate : 2.64
- Specific gravity of Cement : 3.15

- Target mean strength : 48.25N/mm^2
- Maximum water cement Ratio : 0.55
- Adopted Water Cement ratio : 0.40

3.8 Calculated Mix Design

Detail of Mix Proportion

S.NO	Materials	Quantities
1	Water	143.685lit
2	Cement	359.213kg/m^3
3	Fine Aggregate	654.511kg/m^3
4	Recycled Coarse Aggregate	1170.74kg/m^3
5	Admixture (Superplasticizer)	3.6 lit
6	Calculated proportions	1.000 :1.822 : 3.25

3.9 Casting, Curing and Testing

This study includes testing of both fresh and hardened concrete cubes, which were cured for 7 days and 28 days. The cubes were removed from the molds after 24 hours of casting and placed in a curing tank. The compressive strength tests were conducted using a compression testing machine (CTM), and the results were analyzed according to the curing periods.

4 RESULTS AND DISCUSSION

4.1 Test on fresh concrete:

Slump Cone Test

% Replacement of natural aggregate with recycled aggregate	Slump Value (mm)	Type of Slump
0%	105	True
50%	95	True
100%	100	True

4.2 Compressive Strength of Concrete Cubes

% Replacement of natural aggregate with recycled aggregate	Compressive strength (N/mm^2)	
	7days	28days
0%	30.20	44.09
50%	27.59	36.84
100%	23.78	31.87

4.3 Charts and figures of test

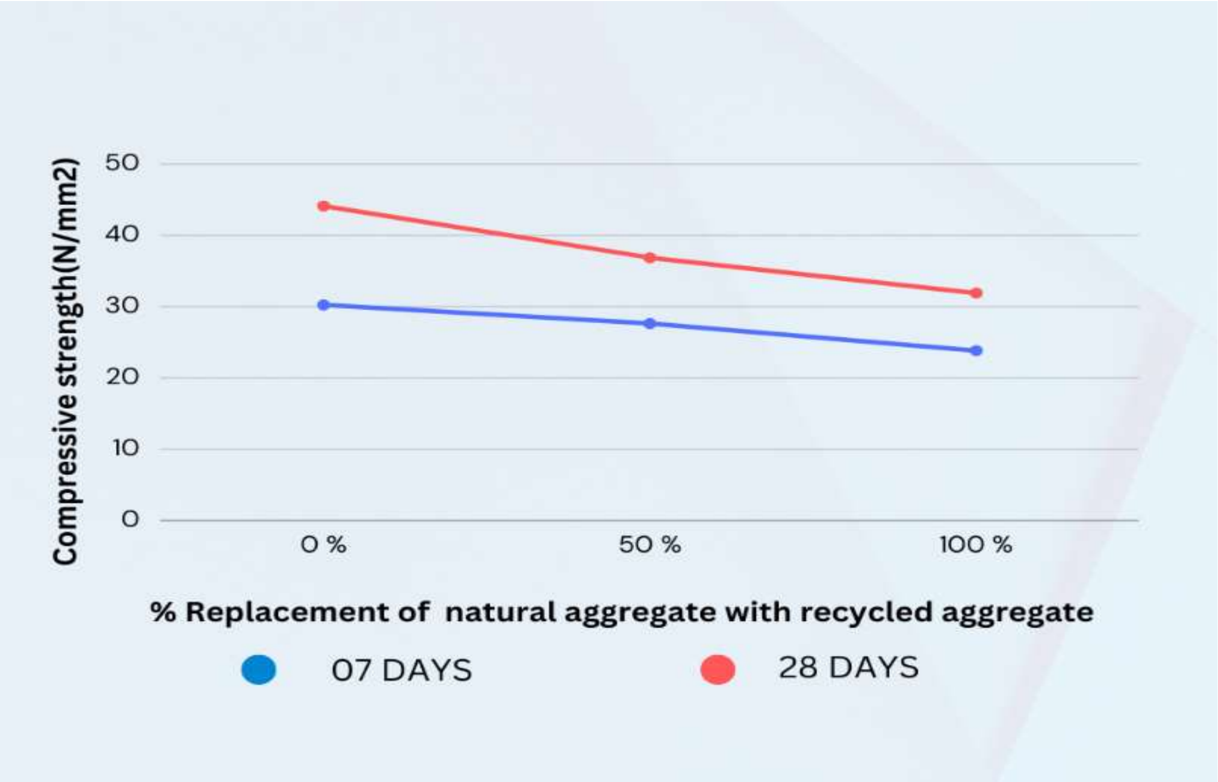

CHART 1:- Compressive Strength Of Concrete

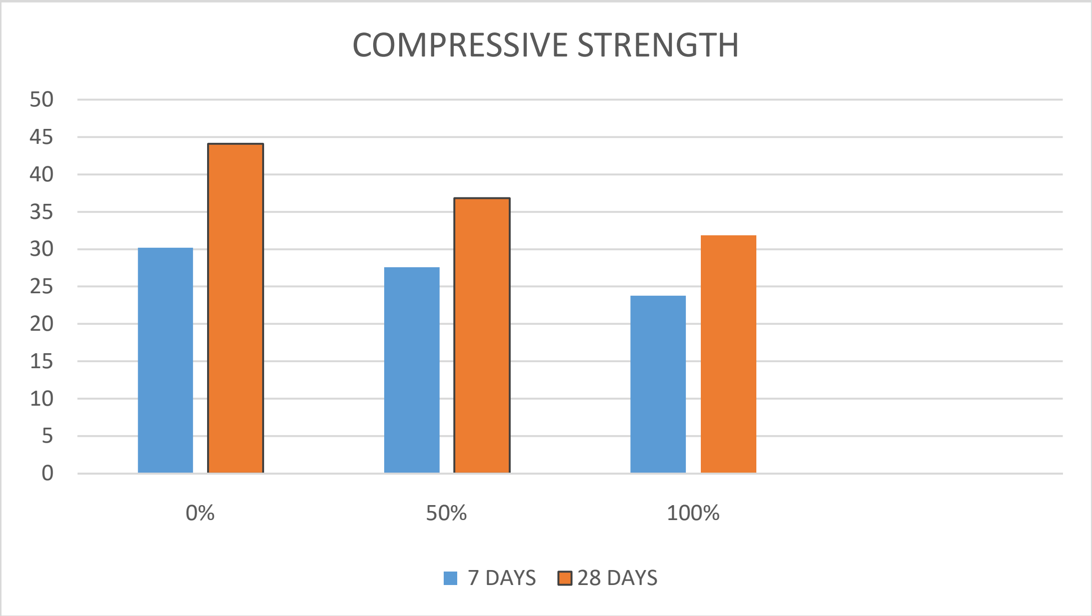

CHART 2:- Comparison of compressive strength of cubes after 7 days and 28 days with and without recycled coarse aggregate

Figure 1:- Concrete Cubes After Casting

Figure 2:- Compressive Strength Test

5. CONCLUSION

In this paper, IS code10262 mix design method was used. A total of eighteen concrete cubes with three RCA replacement ratios of 0, 50, and 100% and water cement ratio of 0.40 were produced, it consists of 10 to 20 mm size of natural and recycled coarse aggregates.

Mix proportion for M40 with recycled coarse aggregate obtained is 1.000 : 1.822 : 3.250 and Mix proportion for M40 with natural coarse aggregate obtained is 1.000: 1.822 : 3.792

As the specific gravity of recycled coarse aggregate is comparatively less than that of natural coarse aggregate the quantity of aggregate required to produce same amount of concrete is more.

Workability of concrete with all proportions and aggregate replacements is good and true slump is observed slump cone test .
The target compressive strength for M40 grade concrete is achieved up to 92% with 50% replacement of recycled coarse aggregate with natural aggregate.
The target compressive strength for M40 grade concrete is achieved up to 80% with 100% replacement of recycled coarse aggregate with natural aggregate.

So the use of recycled coarse aggregate can be done as valuable building materials in environmental & economical respects.
Recycle & reuse is an appropriate solution for the problem of dumping thousands of ton of demolition waste. The shortages of natural aggregates can be addressed by recycled aggregate.

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