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Concrete That Makes Use of Recycled Demolition Debris as Coarse Aggregate

Nazir Ahmad Siddiquie
Bachelor of Engineering, Department of Civil Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India.

Sheikh Ahsanul Haque
Bachelor of Engineering,
Bachelor of Engineering, Department of Civil Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India.

Tridip Krishna Maitra Tamal
Bachelor of Engineering, Department of Civil Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India.

M. Saranya
Assistant Professor,
Department of Civil Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India.

Abstract: The aggregate used in building is currently in low supply. Forty percent of all garbage is generated by the construction industry every year. Landfill problems and other environmental dangers result from this. Several environmental concerns and landfill difficulties can be mitigated by using recycled concrete aggregate in place of natural aggregate. The experimental outcomes of using recycled concrete aggregate as opposed to natural concrete aggregate are presented in this research. In both recycled and ordinary concrete, the fine aggregate is entirely natural. The aggregate was salvaged from the demolition of two buildings in Padappai. The M25 variety of concrete always uses the same w/c ratio, maximum aggregate size, and mix proportion. Strength changes in recycled aggregate concrete are studied when tested at 7, 14, and 28 days.

Keywords: Recycled Demolished, Concrete, Waste, Aggregate in Concrete.

INTRODUCTION

The Minoan civilization (c. 2000 B.C.) was responsible for the discovery of concrete. Around 300 BC, while the Roman Empire was still in its early stages, the people of Rome discovered that by combining volcanic ash with lime mortar, they could create a hard, water-resistant material called concrete [7]. One of the most significant parts of global trash is debris from construction and demolition. Making and constructing with concrete requires a massive quantity of aggregates. After a structure has served its purpose for as long as it can be, it will be torn down and its debris sent to a landfill. It's very difficult to locate a vast area suitable for garbage dumps [8-12]. However, natural aggregates used in construction are being depleted due to ongoing mining and quarrying activities. The 23.75 million tonnes of C&D garbage generated each year in India is expected to more than treble during the next seven years [13]. In wealthy nations, C&D garbage, especially concrete, is considered a valuable resource. The need of maintaining the specified compressive strength of recycled concrete in second-generation concrete has been emphasised by recycling projects [14]. In order to primarily focus on compressive strength, this research evaluates the available literature on the use of recycled concrete as aggregates in concrete. It suggests a method for utilising recycled concrete aggregate without reducing the quality of the finished product [15-19].

Demolition, maintenance, and replacement of concrete and masonry buildings is increasing in importance everywhere, but especially in emerging nations. Demolition debris can be recycled into aggregates for use in other engineering projects, solving both issues effectively [20]. The feasibility of using demolition debris as coarse aggregates in fresh concrete is investigated in this study [21]. In my research paper, I use experimental learning to explore the feasibility and reusing of demolished waste concrete for new construction by evaluating the properties of the constituents of concrete, including the demolished concrete wastes, which shall be used as coarse aggregates in new concrete to make high-strength concrete [22-25].

Motivation

Concrete is the most popular building material worldwide because of its durability and ability to withstand weather conditions while minimising environmental impacts. Due to its widespread application, concrete production accounts for around 5% of annual greenhouse gas emissions, making it on par with the aviation industry. Released greenhouse gases, such as carbon dioxide, have a major impact on global warming [26-29]. The manufacture of concrete can also contribute to the gradual depletion of natural resources, which can have devastating effects on the environment if not addressed [30]. In order to deal with the massive volumes of demolition debris left over from the war and to produce raw material for reconstruction, aggregate recycling was first used in Germany after World War II [31-35]. The demand-supply imbalance in the construction industry may be narrowed through the recycling of aggregate material from building and demolition debris [36-41]. The reduction in the extraction of raw materials, the decrease in transportation costs, and the decrease in environmental impact caused by the tremendous amount of dust particles produced during their excavation, manufacturing, and transportation are additional arguments in favour of adopting a recycling strategy in the face of growing waste management issues (figs. 1 and 2) [42-45].

Fig. 1: Collection of demolished concrete

Fig. 2: Recycling of demolished concrete

One of the main waste sources in the European Union (EU), Asia, and many other regions is debris from construction and demolition. In India, for instance, it is estimated that each citizen generates about 520 kg per year of core trash (defined as materials retrieved from demolished structures or civil engineering infrastructure). Germany and the Netherlands have the highest at over 700 kg/person/year, while Sweden, Greece, and Ireland have the lowest at around 200 kg/person/year [46-49]. Not to mention the massive amounts that are discarded illegally. As a result, the problem of C&D waste has gone global and demands long-term answers [50-55]. In order to maximise economic and environmental benefits, it is now generally understood that there is a great potential for reclaiming and recycling demolished material for use in value-added applications. Low-value waste is converted into secondary construction materials by recycling enterprises in several countries, including South Africa. These commodities include a wide range of aggregate grades, road materials, and aggregate fines [56].

These materials are commonly used in the building of inexpensive roads, retaining walls, low-quality concrete, drainage systems, and brick and block structures. While it is true that there is a need to increase the use of RCA, it is important to keep in mind that aggregate used in concrete must adhere to all applicable standards [57]. The divide between these groups must be bridged in small chunks, and RCA must be integrated into structural concrete over time. In a similar vein, controlling the waste processing and subsequent sorting, crushing, separating, and grading of the aggregate used in the concrete building industry calls for a great deal of care and attention. There is a lot of room to grow this sector and find more applications for C & D waste, which is already routinely recovered and reused in several industrialised countries (mostly as fill, drainage, and sub-base materials). Further, a sustainable C&D waste management plan is required, as are efforts to promote recycling for use in value-added applications [58].

Scope And Objective

The significance of our work can be gleaned from its scope and primary goal. Our project's scope and goals are outlined in further detail below; This pilot project will test the viability of using recycled concrete aggregate to completely replace traditional coarse aggregate. Because replacing fine aggregate with concrete dust raises the water requirement of concrete, reducing its strength, only coarse aggregates are used in recycling. Cement powder surrounding recycled aggregates raises the amount of water needed to achieve the necessary workability [59].

Objective

- The goal is to evaluate RCA concrete against standard concrete in terms of compressive strength.
- The goal of this study is to evaluate RCA concrete against standard concrete in a split tensile test.
- The goal of this study is to evaluate RCA concrete's flexure strength against that of regular concrete.
- The goal is to find the optimum RCA content for usage in concrete.
- The purpose of this research is to analyse and contrast the characteristics of newly placed concrete made with RCA and traditional concrete.

Literature Review

Nearly one hundred percent of the aggregate was replaced, and the new concrete's qualities were evaluated. When compared to concrete constructed with new particles, the recycled kind clearly fell short. Concrete constructed with aggregates crushed at age three days displayed superior qualities than concrete prepared with aggregates of the other crushing ages [1]. The effects of crushing age were mild [60-65].

The aggregate used in the recycled concrete passed the IS sieve at 40mm and was retained at 4.75mm. Natural stone chips of a consistent nominal size were used to create controlled concrete. To achieve the appropriate degree of workability, regular tap water was dosed with a superplasticizer [Conplast SP 430 (M)]. In this investigation, three different mixtures were made, with either no RCA, 50% RCA, or 100%

RCA used to replace natural aggregates. After allowing the cast concrete to cure for 28 days, its strength was evaluated. The specific gravity and the water absorption and crushing and impact and abrasion values of recycled concrete aggregate were found to be lower and considerably higher, respectively. In addition, the tensile strength of concrete made using recycled material depends mostly on compressive strength [2], just as concrete made with natural aggregate [66].

Cubes, beams, and cylindrical specimens were made by altering variables such as the water-cement ratio and the amount of polymer (from 2.5% to 10% by parts weight of cement), while keeping the volume of steel fibre in the concrete at 0.5%. Compared to natural aggregate, recycled material excels in three key areas: specific gravity, absorption capacity, and fineness modulus. The mechanical resistance of recycled aggregates, measured by crushing strength, impact value, and abrasion value, is much more than that of conventional aggregates. The addition of polymer-steel fibre to recycled concrete boosts its compressive strength, but only slightly. At 90 days, polymer steel fibre recycled aggregate concrete outperforms both conventional and recycled aggregate concrete in split tensile strength and flexure strength. Polymer concrete is more suited for earthquake-resistant construction because it has a larger area under the stress-strain curve, demonstrating its high toughness properties. The addition of 10% polymer and 0.5% steel fibre to concrete increases its adaptability compared to both recycled aggregate concrete and traditional concrete [4].

The research showed that RCA's water absorption was around 3-5 times higher than the similar natural aggregates, and its density was roughly 3- 10% lower, all due to the bonded cement paste. According to the data, there was no discernible difference in the concrete's strength for a given RCA content across four distinct RCA samples [5].

Recycled aggregates are suitable in concrete manufacturing, and Naik. et al. [3] sheds some information on their creation, characteristics, and applicability. The limitations of recycled aggregate concrete are also examined, along with its qualities and applications. According to the results, recycled aggregates are better at absorbing water, but they are weaker and less dense than natural aggregates.

Sixty percent of the recycled aggregates and forty percent of the crushed stone chips are used to create the recycled aggregate concrete. Aggregates for concrete mixing are kept at a surface-saturated dryness. Recycled aggregate concrete has slightly less workability than regular concrete. Although recycled aggregate concrete has a slightly lower compressive strength than regular concrete, it can still be employed in both plain and reinforced concrete applications. Recycled and conventional concrete, which consists of 60% recycled aggregate and 40% crushed natural stone chips, is nearly in the middle of the pack when it comes to workability and strength. Therefore, this sort of concrete is only appropriate next to traditional concrete [6] from the perspectives of economy and performance.

Material Collection

Concrete's raw materials undergo a battery of tests to establish its suitability as a building material. Cement, coarse aggregate, fine aggregate, and water make up the synthetic material known as concrete [67]. In order to improve some characteristics of concrete, we introduced a synthetic additive (silica fume) in this experiment. Cement, M-sand, recycled aggregate, coarse aggregate, and an artificial additive are all part of the mix [68]. The mechanical properties of the recycled aggregate, including specific gravity, water absorption, abrasion resistance, Aggregate Impact Value, and Aggregate Crushing Value, were determined in order to verify the use of demolition debris as coarse aggregates in concrete in the recently built project [69-72].

- Cement

- Fine aggregate
- Recycled aggregate
- Coarse aggregate
- Admixture- silica fume
- Water

The control mix in this study was created with a compressive strength of 25 MPa in mind, as per IS10262:1986. Compressive strength, Split tensile strength, and Flexural strength are all tested at 7, 14, and 28 days on the cast cubes. Using technique, the wet material was layered into the mould, and then compressed with 25 whacks from a 4.5 kg rammer on a level, firm surface [73-76]. The number and amount of samples are based on the types of tests being conducted. The mould was levelled with a straight edge, and the surplus mixture was scraped out. After twenty-four hours, the mould and its contents were taken out of the room. The specimen was marked with identifiers so that it could be quickly and easily referred to [77].

Cement: Ordinary Portland Cement is the type most often used (OPC). In accordance with Indian Standard (IS) 12269, 53-grade Ordinary Portland Cement (OPC) is used. It's a strong adhesive and cohesive power that, when combined with water, fine aggregate, coarse aggregate, and a little bit of sand, cures into a solid mass of stone. Since cement is mostly responsible for concrete's strength, choosing the right kind of cement is crucial. Cement's characteristics are shown in the following table [78-83].

Sand, gravel, and crushed stone are all examples of aggregates, which are inert granular materials that can be used as filler or as a standalone product. Additionally, they are raw ingredients that are required to make concrete. Aggregates, the smaller, loose particles that make up most of a concrete mix, must be clean, firm, and strong to prevent the deterioration of the concrete from absorbed chemicals or coatings of clay and other fine elements [84-87].

Fine aggregate, often known as sands, can be extracted from either land or sea. Natural sand or broken stone, with most particles smaller than 9.5 millimetres in size, are typical examples of fine aggregates. These, like coarse aggregates, can come from either new or previously used materials. The choice of fine aggregate also matters because its effect on concrete strength varies with the amount of water used [88].

Coarse aggregates are any particles with a diameter larger than 4.75 millimetres, typically falling between 9.5 millimetres and 37.5 millimetres. Primary, secondary, or recycled sources are all acceptable. Primary, or "virgin," aggregates, can be acquired either on land or at sea. Coarse aggregates can be obtained from the sea, like gravel, or from the land, like crushed rock. Most coarse aggregate for concrete comes from gravel, with crushed stone making up the rest [89].

Aggregates from demolished concrete buildings are collected and processed to create repurposed aggregates. The concrete mix for this endeavour makes use of the proposed recycled aggregates. Grading is used to achieve uniformity in the recycled aggregates. Recycled angular aggregates with a 20 mm size are chosen as a partial replacement per the standard.

Properties of Recycled Concrete Aggregate Particle Size Distribution: Tests on Recycled Aggregate: Crushed recycled concrete aggregate and natural aggregates undergo sieve analysis in accordance with IS 2386. The particle size distribution is optimised by crushing and screening recycled coarse aggregate down to a range of sizes. After recycling, the percentage of fine particles smaller than 4.75 millimetres ranged from 5 to 20 percent, depending on the quality of the concrete that had been demolished in the first place. Primary, secondary, and tertiary crushing are the best ways to acquire the highest quality natural aggregate. In the case of recycled aggregate, however, the same result can be achieved by primary and secondary crushing. Even using recycled material, the efficiency of the single crushing process remains unchanged. The particle shape analysis of recycled aggregate shows that its particles are quite comparable to those of natural aggregate made from crushed rock. In most cases, the specifications for aggregate in concrete can be fulfilled by recycled material.

Results for the specific gravity of recycled concrete aggregate in a saturated surface dry condition ranged from 2.30 to 2.58, which is lower than expected but still acceptable. Segregation, honeycombing, and a decrease in concrete yield can occur if the specific gravity is less than 2.4.

- Weight in air = 2005g
- SDD saturated surface dry weight = 2123.5g
- Weight in water = 1257.6g
- Volume = SDD weight – weight in water=2123.5 – 1257.6 = 865.9g

Sp.gravity of RCA =

$wt.in\ air$

$volume$

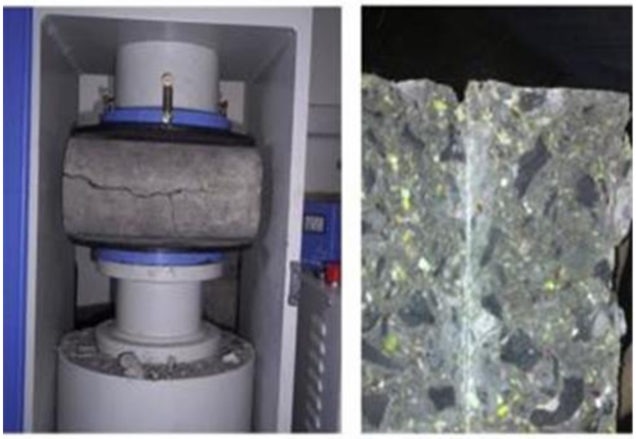
= 2005g 865.9g

= 2.31

Crushed stone aggregate with old mortar adhering to it makes up the RCA from demolished concrete, and its water absorption ranges from 1.5% to 7%, which is higher than that of natural aggregates. So, it seems like the water absorption tests went well.

Recycled aggregate has a lower bulk density than natural aggregate. The mix proportion suffers as a result of the lower bulk density, leading to disappointing outcomes.

Values of Impact: Recycled aggregate is less resilient than natural aggregate to a variety of mechanical treatments. Crushing and impact values for concrete wear surfaces, according to IS 2386 part (IV), must not exceed 30 and 45 percent, respectively. Recycled aggregate passes the BIS specification limit for crushing and impact values. The results of the crushing and impact test indicate that recycled aggregate can be used for purposes aside from wearing surfaces (fig.2).



The RCA reclaimed from demolished concrete ranges in water absorption from 1.5% to 7%, which is higher than natural aggregates. The RCA consists of crushed stone aggregate with old mortar adhering to it. Thus, the outcomes with regard to water absorption are commendable.

Bulk density is another area where recycled aggregate excels above its raw aggregate counterpart. Because of this, the outcomes are disappointing; the mix proportion suffers as a result of lower bulk density.

Values of ImpactRecycled aggregate is less resilient to a variety of mechanical forces than its natural counterpart. Crushing and impact values for concrete wearing surfaces should not exceed 30 and 45 percent, respectively, in accordance with IS 2386 part (IV). Recycled aggregate meets the strict limits set by BIS requirements in terms of crushing and impact values. It has been determined through crushing and impact testing that recycled aggregate can be used in settings other from worn surfaces.

Solution

Stipulations for mix design concrete

Grade designation = M25

Type of cement = OPC 53 grade conforming to IS8112 Max. nominal size of aggregate = 20mm

Min. cement content = 300 Kg/m^3 Max. water cement ratio = 0.5 Workability = 50-100mm (slump)

Exposure condition = Mild (for RCC) Method of concrete placing = hand mix Degree of supervision = Good

Type of aggregate = crushed angular aggregate Max. cement content = 450 Kg/m^3

Test data for materials (to be determined in the laboratory)

The specific gravity of cement = 3.15

The specific gravity of coarse aggregate = 2.84 Specific gravity of fine aggregate = 2.64

Procedure for the mixed design of M25 grade

Target strength for mix proportioning,

$ftarget = fck + 1.65 * S$

Where,

F'ck = target average compressive strength at 28 days Fck = characteristic compressive strength at 28 days

S = standard deviation

As per table I of IS:10262-2009 S = 4N/mm2

Therefore,

Ftarget = 25 + 1.65*4 = 31.6N/mm2

Selection of water/ cement ratio

From Table 5 of IS456 Max., the water-cement ratio= is 0.5. So, the selection of water content

from Table 2, max. Water content =186 litres (25 to 50mm slump range) for 20mm more aggregate.

Estimated water content for 100mm slump= 186+(3/100)*186 =191.6 litres

Calculation of cement content

Water cement ratio = 0.5

Cement content= 191.6/5=383.2 kg/m3 From table 5 of IS456

Min. cement content for mild exposure condition= 300kg/m3

383.2 kg/m3 > 300 kg/m3, hence.OK

Proportioning of the volume of coarse aggregate and fine aggregate content.

Table 3. The volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone II) for a water cement ratio of 0.45 is 0.60

In the present case, the water-cement ratio is 0.5. Therefore, the coarse aggregate volume must be increased to decrease the FA content.

As the W/C ratio is lower by 0.1. The proportion of the volume of coarse aggregate is increased by 0.02(at the rate of ± 0.01 for every ±0.05 change in the w/c rate. Therefore, The corrected proportion of the volume of CA for a w/c ratio of 0.5= 0.62. Therefore, the volume of coarse aggregate=0.62*0.90=0.558 (the vol. reduced by 10% for pumping), the volume of fine aggregate content = 1-0.558=0.442

16m3

1 1000

Vol.of all aggregate= a-(b+c)

=1-(0.122+0.1916) = 0.6864m3

Mass of CA = vol.of all aggregate * vol.of CA* sp.gravity of CA*1000

= 0.6864*0.558*2.84*1000=1087.75kg

Mass of FA= vol.of all aggregate* vol.of FA*sp.gravity of FA*1000

= 0.6864*0.442*2.64*1000 = 800.94kg

Concrete mix proportions

Hence, we have taken the standard ratio of M25 garage concrete (i.e. 1:1:2) for casting specimens.

Mix Proportion

The water absorption range for RCA sourced from demolished concrete is between 1.5% and 7%, which is higher than that of natural aggregates. RCA is made up of crushed stone aggregate with old mortar adhering to it. Because of this, we have achieved desirable water absorption outcomes.

When compared to natural aggregate, recycled aggregate has a lower bulk density. As a result, the mix proportion suffers from lower bulk density, leading to undesirable outcomes.

Values of Impact: When compared to natural aggregate, recycled aggregate is less resilient to a variety of mechanical operations. The IS 2386 section (IV) specifies maximum crushing and impact values of 30 and 45 percent for concrete wearing surfaces and non-wearing surfaces, respectively. Recycled aggregate passes the BIS limit tests for crushing and impact values. The crushing and impact test results show that recycled aggregate can be used in places outside wear areas.

- Only regular and standard concrete types can use this method of mix proportioning.
- There is no such thing as air in concrete.
- The proportioning is done so that the concrete has the desired characteristics, such as workability of fresh concrete and durability requirements, by a certain age.

Testing of Specimens

The concrete cube test's compressive strength gives a general sense of the material's properties. If the concrete has been poured correctly, it will pass this test. The compressive strength of concrete in commercial and industrial buildings is typically higher than the 15–30 MPa range used in residential construction. Compressive strength in concrete is influenced by numerous variables, including water-cement ratio, cement strength, concrete material quality, manufacturing quality control, etc. A cube or cylinder is used for the compressive strength test. A concrete cube or cylinder is the preferred test specimen according to many standard standards. The compressive strength of cube concrete specimens is often tested using a compression Testing Machine (CTM). One of the most fundamental and crucial characteristics of concrete is its tensile strength. The tensile strength of concrete can be measured using the splitting tensile strength test on a concrete cylinder. Because of its brittle composition, concrete is not designed to withstand tension. When tension is applied to concrete, cracks appear. In order to calculate the force at which concrete members could break, it is important to measure the material's tensile strength. The tensile strength of concrete can be measured using the splitting tensile strength test on a concrete cylinder. The material underwent a split tensile strength test according to IS5816-guidelines. 1999's For this experiment, 100mm 200mm cylinders were employed. The samples were evaluated at 7, 14, and 28 days. The cylindrical specimen was set up horizontally on the testing apparatus.

Conclusion

Reducing the need to dump hundreds of thousands of tons of trash and making up for a lack of natural aggregates can be accomplished through the prudent use of recycling and repurposing construction waste. Recycled aggregates used in concrete are advantageous in technical, environmental, and financial terms. The bulk density, crushing and impact values, and water absorption of recycled aggregate are all higher than those of natural aggregate. Up to a 30% replacement of NCA with RCA increases the compressive strength of recycled aggregate concrete by up to 15% compared to that of natural aggregate concrete. The initial concrete from which the aggregates were extracted also has a role in the variation. Concrete mixes performed well when coarse aggregate was replaced with RCA at percentages between 10 and 30 percent of native coarse aggregate. As a mineral additive, silica fume improved the interfacial zone between the new and old mortar bonded to RCA, serving as a micro filler to boost RAC's effectiveness. Overall, the large-scale testing revealed that when looking at a complete structural member, RCA can still be used to build structural concrete, despite the fact that RCA can be lower grade aggregate and negatively affect concrete material qualities.

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