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Utilization of Construction & Demolition Waste as Coarse Aggregate in Rigid Pavement Construction

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Abstract: The main objective of this research is to investigate the possibility of utilizing construction & demolition waste aggregate in rigid pavement construction. In the present study compressive strength of concrete at 7, 14, and 28 days was checked, and this concrete is prepared by mixing cement, sand, aggregate, and water. In a further study, coarse aggregate is replaced by aggregates obtained from C&D (Construction & Demolition) waste, and then M35 mix design concrete is prepared. From the result obtained in the present experimental investigation, it was found that the desired strength concrete can be obtained from replacing the conventional coarse aggregate with recycled aggregate obtained from C&D waste with a substitution rate of 20 %. Thus the use of C&D waste in concrete manufacturing will not only solve the problem of availability of material but also reduces the cost of the construction and problems caused due to dumping of C&D waste. The utilization of C&D waste in the construction industry also ensures sustainable development in an environmentally friendly manner by the conservation of natural resources.

Keywords: Compressive Strength; Construction & Demolition Waste; Recycled Aggregate; Road Construction; Rigid Pavement

I. INTRODUCTION

A pavement is a structure consisting of superimposed layers of processed materials above the natural soil surface, whose primary function is to distribute the vehicular loads to the stable strata below the normal ground level lies at a considerable depth. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements (Mathew, 2009).

Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavements layers reflect the deformation of the lower layers on to the surface of the layer (Anusha & Avinash, 2017). Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. In rigid pavement, the load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium; assuming the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading. Compare to the flexible pavement, rigid pavement is placed either directly on the prepared sub-grade or a single layer of granular or stabilized material. Construction of rigid pavement is now-a-days most widely used in the road construction industry. Rigid pavement has a life span of 40 years compared to the bituminous which has 10 years life span. Also, rigid pavement distributes load much more widely than the flexible pavement (Chandra, 2017). Rigid pavement requires little maintenance; whereas bituminous roads need frequent repairs due to damage occurred by traffic and weather. The main disadvantage of rigid pavement requires high initial cost for rectification compare to bitumen roads as the entire concrete slab needs to be replaced when it damages(Jain et al., 2013).

Because of the continuous use of construction material has led to a fast decrease in natural available resources. Today we are faced with an important consumption and a growing need for aggregates because of the growth in industrial production, the situation has led to a fast decrease of available resources. (Hebhoub et al., 2011a) With the advancement of technology and on-going research in development, the use of various materials other than conventional material has been increased. Now-a-days in the road construction works, waste is being used as a substitute for the conventional materials; gives the same strength and bearing capacity to concrete. This type of wastes comes from mining sites and thermal power plants (Miller & Collins, 1976).

In India, Road Construction works have witnessed a significant change over the last few decades due to the adoption of advanced technology, new as well as improved construction methods, the involvement of private firms with huge finances, changes in policies, and willing to provide better infrastructure facilities by the government. Utilization of waste/recycled material in construction works has several merits: cost reduction, reduction in disposal/waste/dumpling load, promoting recycling of waste material, natural resource conservation, pollution reduction, and many other environmental benefits.

This will not only ensure that the construction industry follows the path of sustainability but also addressing the problem of resource scarcity (Bakash et al., 2013). Nearly 12 million tons of CD (construction & demolition) waste is being produced annually in developing nations like India. In major parts of the world, the population explosion in urban areas has lead to the exploitation of natural resources due to fast-growing construction works. The utilization of CD waste as a construction material will not only reduce the burden on landfill sites but also help in the conservation of natural resources (Jagadeesh & Rao, 2018).

Natural aggregate consists of rock fragments that are used in their natural state or are used after mechanical processing such as crushing, washing, and sizing (Kulkarni et al., 2015). Quarried or excavated stone that has been crushed and screened to the desired standard particle size and make them suitable to use in construction works are crushed stone aggregates (Joanna, Hydzik-Wiśniewska Anna, Łukasz, & Sebastian, 2018). Artificial aggregates are sometimes produced for special purposes (Priyadharshini et al., 2012). Recycled aggregate is derived from crushing inert construction and demolition waste. It may be classified as recycled concrete aggregate (RCA) when consisting primarily of crushed concrete or more general recycled aggregate (RA) when it contains substantial quantities of material other than crushed concrete. The characteristic of recycled aggregates could be different from its parent concrete because the parent concrete was designed for its purposes such as permeable, durable, and high strength concrete. Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. Reinforcing steel and other embedded items, if any, must be removed, and care must be taken to prevent contamination by other materials that can be troublesome, such as asphalt, soil and clay balls, chlorides, glass, gypsum board, sealants, paper, plaster, wood, and roofing materials (PCA, 2019). In general, recycled aggregates without any processing are being used in many types of general bulk fill, Bank protection, Base or fill for drainage structures, Road construction, Noise barriers, embankments etc., while after processing of recycled aggregates, can be used in pavements, shoulders, median barriers, sidewalks, curbs, and gutters, Bridge foundations, Concrete bases, Bituminous concrete (Steven et al., 2002).

In this paper, an attempt has been made to access the utilization of waste materials collected from construction and demolition waste as coarse aggregate in concrete production. Utilization of waste generated from construction and demolition activities not only solves the problem of material availability and economical feasibility but also helps in maintaining environmental sustainability by waste reduction.

II. METHODOLOGY

The Methodology adopted for the present study is depicted in the figure given below:

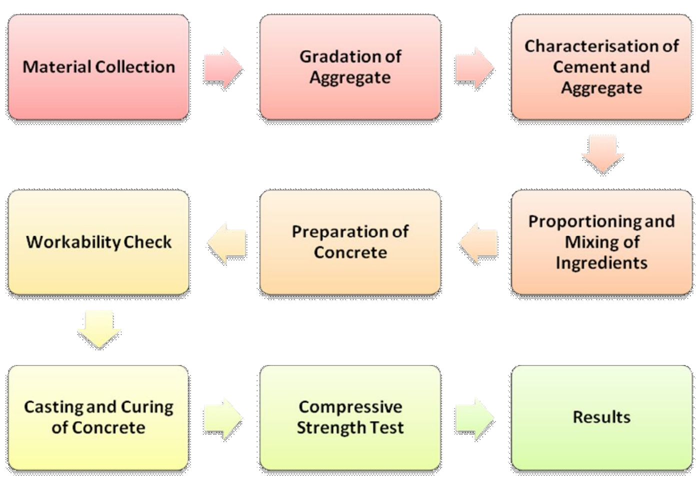

Figure 1: Methodology Adopted

III.EXPERIMENTAL STUDY AND LABORATORY TESTS

In this study, natural coarse aggregate is replaced by aggregates collected out of construction and demolition waste and then designed mix concrete is prepared by mixing cement, aggregate, water, and sand. For the present study, compressive strength as a prime variable for quality assessment of concrete was checked at 7, 14, and 28 days. For preparing the concrete of desired strength, the material like cement of OPC grade 43 conforming to IS: 8112-2013, the conventional coarse aggregate of size 10 – 20 mm, the recycled aggregate of size 10 – 20 mm, sand Particle of size below 4.75 mm and potable tap water free from any kind of impurity was used in this study (BIS, 2013).

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For experimental work the waste material (construction and demolition waste) was collected from the construction and demolition site of the classroom turned into a pharmacological laboratory, located inside the Mewar University Campus. As per the requirement and specification recommended by IS: 383-1970, segregation of material was done to extract the usable material as coarse aggregates (BIS, 1970).

In this experiment program test specimens of M35 concrete mix were prepared to have a constant water-cement ratio of 0.35. The physical properties of cement are presented in Table 1. The concrete was prepared by replacing the natural coarse aggregate by recycled aggregate. Replacement was done in different proportions such as 0%, 20%, 40%, 60%, 80% and 100% by weight. The physical properties of natural coarse aggregate and recycled coarse aggregate are presented in Table 2. All the material was mixed manually in the desired proportion as per the requirement and concrete mixes were prepared. The mix proportions are presented in Table 3. Concrete cubes of size 150 mm × 150 mm × 150 mm were cast by filling the molds with concrete in three layers and each layer was compacted with the help of a vibrating Table as per procedure defined in Indian standard IS: 516-1959 (BIS, 1959). All specimens were de-molded after 24± 1h of casting and cured in water at room temperature until their testing was done.

IV. RESULTS & DISCUSSION

The characterization of cement, natural aggregate, and recycled aggregate were done before the preparation of the concrete mix by performing various tests in the laboratory. the workability check of the fresh concrete was done before casting of concrete cubes by using a slump cone and compaction factor test. for determination of compressive strength, 150 mm × 150 mm × 150 mm cube specimens were tested under compression testing machine or CTM.

Table 1: Observed Properties of Cement

Sr. No.	Test	Result
1.	Specific Gravity	3.15
2.	Initial Setting Time	40 - 45 min
3.	Standard Consistency	33P

1) *Aggregate Impact Value Test:* The aggregate impact value indicates resistance offered by aggregates to sudden impact or shock, which may be different for the gradually applied compressive load. The impact value presented in Table 2 shows that natural coarse aggregate and recycled aggregate is strong enough to be used in rigid pavement.
2) *Los Angeles Abrasion Test:* Los Angeles abrasion test shows the aggregate toughness and abrasion resistance such as Crushing, degradation, and disintegration. From the results, it is clear that natural coarse aggregate is stronger but recycled also have sufficient strength to be used as aggregate in the rigid pavement.
3) *Specific Gravity and Water Absorption:* The observed value of Specific gravity and water absorption for natural coarse aggregate and recycled are presented in table 2 Aggregates having low specific gravity are generally weaker than those with higher specific gravity values and water absorption shall not be more than 0.6 per unit by weight. From the result, it is clear that recycled aggregates are weaker than natural aggregates. Since the recycled aggregates were obtained from construction and demolition waste consisting of crushed, broken, and fragmented material with old mortar adhering it owing to lower specific gravity and high water absorption characteristics.

Table 2: Observed Properties of Natural Coarse Aggregate and Recycled Coarse Aggregate

Sr. No.	Property	Natural Aggregate	Recycled Aggregate
1.	Specific gravity	3.08	2.72
2.	Water absorption	0.63%	1.95%
3.	Impact value	6.17%	18.76%
4.	Abrasion Resistance	12.79%	28.32%

Table 3: Mix Proportion Details

Mix Designation	Mix of RA (%)	Water content (in liter)	Cement (in kg)	Sand (in kg)	Natural Coarse Aggregate (in kg)	Recycled Coarse Aggregate (in kg)
NC (Control Concrete)	0%	3.15	9.00	4.5	9.00	0.00
RC20	20%	3.15	9.00	4.5	7.20	1.80
RC40	40%	3.15	9.00	4.5	5.40	3.60
RC60	60%	3.15	9.00	4.5	3.60	5.40
RC80	80%	3.15	9.00	4.5	1.80	7.20
RC100	100%	3.15	9.00	4.5	0.00	9.00

4) *Workability:* The workability of fresh concrete being a measure of consistency is an important characteristic of quality control in concrete production. For workability checks, an empirical test such as the slump cone test was performed. Table 4 suggests that the workability of the concrete got reduced with the increment in replacement of natural coarse aggregate by recycled aggregates. The decrease in the workability of the concrete mix was due to the high water absorption rate of recycled aggregate. The low workability of the concrete is suitable for pavement construction.

Table 4: Workability of Design Mix Concrete

Mix Designation	NC (Control Concrete)	RC20	RC40	RC60	RC80	RC100
Mix of RA (%)	0%	20%	40%	60%	80%	100%
Slump Value	7	7	5	4	3	2

5) *Compressive Strength:* Compressive strength of concrete is the most prominent characteristic as it can provide comprehensive information about the quality of concrete because of the direct relationship with the other properties. The concrete cube specimens were cast and tested at 7, 14, 28 days and the results are presented in Figure 1. The compressive strength of the concrete mix containing 20% recycled aggregates was approximately equal to that of control concrete. The decrease in compressive strength in the concrete mix has 40%, 60%, 80% and 100% replacement of natural coarse aggregate with recycled aggregate are since recycled aggregate losses it strength because of very small fractures developed while breaking down the C&D waste material into small pieces and unevenness of the composition of the material. Improper bond action also gets developed due to different types of material that adhere to the surface of the recycled aggregate leads to a loss in strength characteristic of concrete.

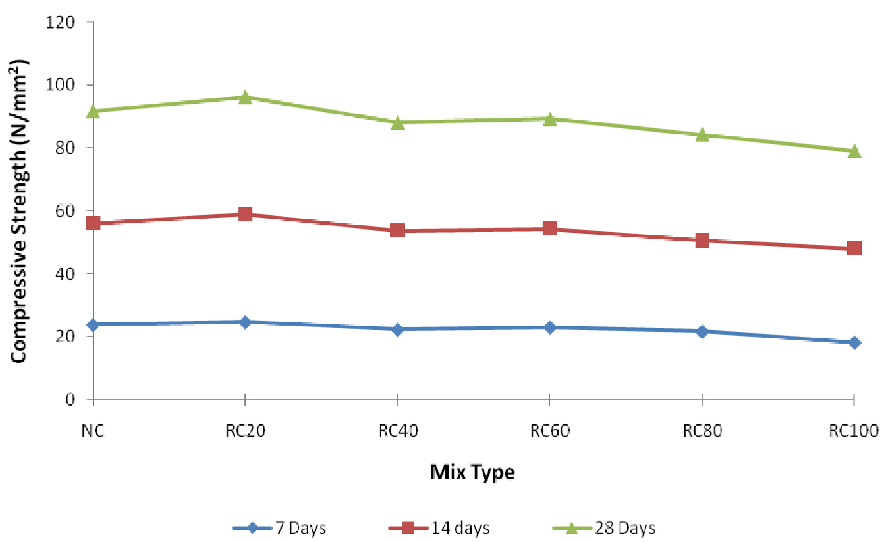

Fig. 1: Compressive Strength Test of Concrete at 7, 14 and 28days

V. CONCLUSIONS

The use of construction & demolition waste in road works not only results in a reduction in construction cost but also a very important environmental management tool for achieving sustainable development. On the other hand, recycling waste without properly scientific research and development can result in environmental problems greater than the waste itself. Therefore, many countries have still been working on how to re-use the waste material. Now-a-days the cost of material is increasing so if we use the waste material in the production of the concrete so we decrease the price. Exposing the waste material to the environment directly can cause problems to the environment as well as the flora and fauna present on the planet.

In the present study, replacement of natural coarse aggregate by recycled aggregates obtained from C&D waste in the M35 design mix concrete in the order of 0%, 20%, 40%, 60%, 80%, and 100% was done. The experimental result shows that the compressive strength of concrete prepared with recycled aggregate was found to be very much close to the concrete produced with conventional/natural aggregate up to 20% substitution rate after 28 days of concrete casting and after 20% compressive strength started decreasing. However, a replacement ratio of 100% can be used for minor works of lower importance. The impact value and Los Angeles abrasion test value are within limits as per BIS: 2386 (part IV), 1963 (BIS, 1963). From the result, it is also clear that recycled aggregates are weaker than natural aggregates but can provide considerable strength when used in concrete production. The use of waste and by-products as aggregates has potential because 75% of the concrete is composed of aggregates. The results of this study show that recycled aggregate can be used as a replacement of natural coarse aggregate in pavement construction.

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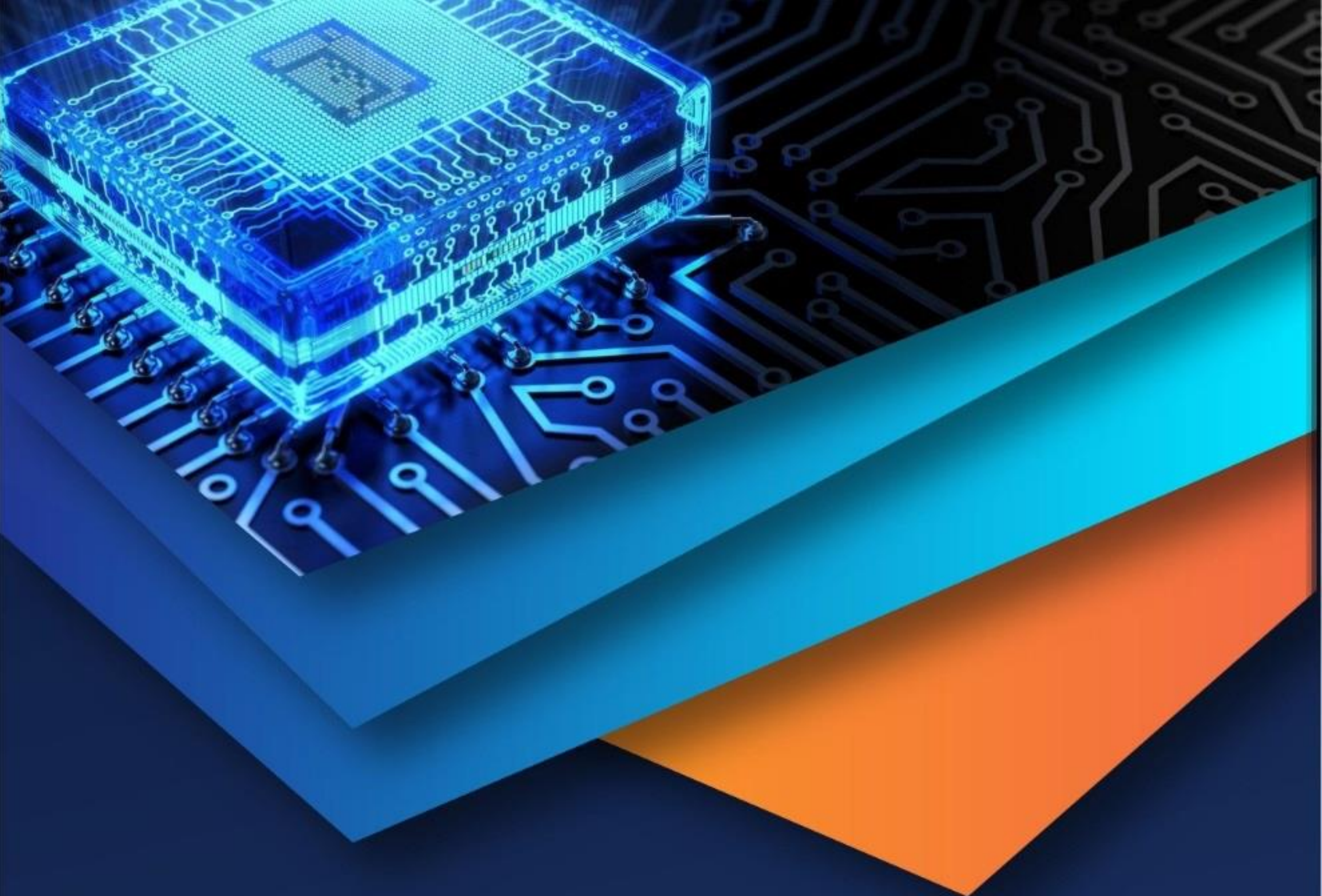

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