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An Experimental Study on Partially Processed Recycled Coarse Aggregate in Concrete

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Abstract
In the present work RCA is used as a replacement of natural aggregate in manufacturing of concrete. This report aims to find the possibility of the usage of recycled coarse aggregate mixed with natural aggregates, based on better understanding of behavior of recycled aggregate in concrete structures experiments on fresh and hardened concrete based on different days of curing. The literature review provides an overview of sustainability and key performance indicators, the material properties of RCA both as an aggregate and in concrete, concrete mixture and proportioning designs with RCA, performance of existing RCA pavements, and the implementation of RCA highlighting some examples where RCA has been used successfully. Use of recycled aggregate (RA) in concrete can be useful for environmental protection and economical terms. Recycled aggregates are the materials for the future. It is well known fact that it is giving little lower strength than natural aggregate concrete. Though, if it is used up to 15% of replacement by weight, than it can give almost similar strength to that of natural aggregate concrete and around 45% of replacement by weight with some admixture also give satisfactory result. As test is also conducted for 30%, 60% and 100% replacement by weight, where result not up to mark of desire strength. Hence it was necessary to improve strength of recycled aggregate concrete for higher recycled aggregate content.

Keywords: Natural Aggregate (NA), Recycled Aggregate Concrete (RAC), Recycled coarse Aggregate (RCA), Recycled Aggregate (RA).

INTRODUCTION

Rapid growth in population and economic development in developing countries has led to a huge demand for infrastructure development. Extensive increase in the construction creates immense depletion of natural resources. Moreover, the progression of industrialization and urbanization demands massive renewal of old built facilities which generate huge amounts of construction and demolition (C&D) waste. Current construction industry faces the dual problem of diminishing natural resources and burgeoning C&D wastes. Recycling of C&D wastes into new construction can alleviate both the problems simultaneously. In the C&D debris, where the waste concrete percentage is very high, the reuse of old concrete as a source of aggregate has emerged as an attractive alternative to natural aggregates (NA) in concrete. Demolished building wastes, concrete road bases, rejected precast concrete members, unused concrete in concrete mixing plants and tested specimens from different laboratories are the sources of waste concrete.The last 100 years have seen a massive population growth and with the advent of rapid industrialization and urbanization of developing countries the strain on natural resources has been increasing exponentially. Thus, as need of the hour, the idea of sustainable development was introduced in Rio summit in the year 1992. It was found that, the economic activity is to be carried out in a manner which is in harmony with earth's ecosystem. The construction industry is the sector with the most environmental impact as it consumes large amount of natural resources, energy and generation of huge amount of waste. Since, concrete is the most used material in the construction industry, owing to its versatility and easily alterable properties, sustainability in the construction industry can be improved by minimizing the environmental impact of concrete.

The demand of aggregates will double over the course of next two to three decades if present rate of consumption of aggregates and concrete continues. Most of this natural resource consumption takes place in developing countries such as China, India, and Brazil etc. China produces more than half of the total cement while India stands second with 7% of total cement production in the world. China and India are two countries which are seriously challenging the environmental as per the current status. Thus, as the demand for concrete increases, the depletion of natural resources is eminent. Hence, work on green and sustainable technologies has been the focus in the early 21st century. As per rule 2016 Government of India in waste management says that construction and demolition waste should be separated and now you cannot be directly dispose in sanitary landfills. So that use of RA is more important for sustainable development.

2. LITERATURE REVIEW

Víctor Revilla-Cuesta, Marta Skaf b, Flora Faleschini& others (2020) Self-compacting concrete manufactured with recycled concrete aggregate. In this review paper, current and past research articles on the design of self-compacting concrete with recycled concrete aggregate, both by itself and in combination with other wastes, are summarized and assessed. Research is presented into recycled concrete aggregate properties and the mix-design of the self-compacting concretes that contain them, as well as relevant results on the fresh state (workability, rheology), the hardened state (compressive strength, splitting tensile and flexural strength, modulus of elasticity, density, and porosity), durability (resistance to aggressive agents), long-term properties of concrete (shrinkage, creep), and structural elements manufactured with selfcompacting concrete containing recycled concrete aggregate. The results under review reaffirm that the incorporation of recycled concrete aggregate can produce a suitable self-compacting recycled concrete, on the basis of careful designs that are essential for successful performance.

Abhijit Mistri ,Sriman Kumar Bhattacharyya & others (2019) Methods of mitigation of these weaknesses through various treatments have been reported. This review has a special focus on India, a country that generates one of the world's highest quantity of C&D waste. After analysing all the treatment methods, the authors summarize that the strengthening of attached mortar (AM) technique is better than removing of AM, which is also cost-effective, eco-friendly and sustainable.

Zhanggen Guo a, Tao Jiang a, Jing Zhang a, Xiangkun Kong a, Chen Chena,c , Dawn E. Lehman (2019)-Mechanical and durability properties of sustainable self-compacting concrete with recycled concrete aggregate and fly ash, slag and silica fume. This research aims to maximize the content of supplementary cementitious material (SCM) and recycled concrete aggregate (RCA) in self-compacting concrete (SCC) by using a combination of fly ash, slag and silica fume. A sustainable SCC was proposed by substantially substituting natural aggregates with RCA and cement with SCM. A total of 23 mixes, including binary, ternary and quaternary mixes were prepared. Binary mixes were prepared with fly ash and ternary mixes were prepared with fly ash and slag incorporating RCAs (50% and 100%) and high volumes of SCMs (50%, 75%) were prepared. The mechanical and durability properties of RA-SCC were investigated. Quaternary mixes were blended with fly ash, slag, silica fume. The mechanical and durability properties were studied. The effect of RCA and SCM was investigated as well as using a combination of fly ash, slag and/or silica fume. The test results indicate that the proposed combination of fly ash, slag and silica fume can compensate for the detrimental effect of RCA and significantly improve the mechanical and durability properties of SCC with RCA, thus optimize the sustainability performance of SCC by minimizing cement and natural resources content.

3. MATERIAL AND METHODOLOGY

A. CEMENT

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials, clay predominates and in calcareous materials calcium carbonate predominates. Portland cement is manufactured by grinding together calcareous (limestone, chalk, marl, etc.) and argillaceous (shale or clay) materials in approximate proportion of 2:1 and other silica, alumina or iron oxide bearing materials. Portland cement referred as (Ordinary Portland Cement) is the most important type of cement. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. The grade indicates the compressive strength of cement at 28 days tested according to IS: 4031- part IV (Methods of physical tests for hydraulic cement) and show OPC 53 grade.

Figure 1: OPC 53 grade.

B.COARSE AGGREGATE (IS : 460-1962)

Generally, aggregates occupy 70% to 80% of the volume of concrete and have an important influence on its properties. They are granular materials, derived for the most part from natural rock (crushed stone, or natural gravels) and sands. In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft and porous rock can limit strength and wear resistance, and sometimes it may also break down during mixing and adversely affect workability by increasing the amount of fines. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in the present work.

C. FINE AGGREGATES (IS: 460-1962)

The material which passes through 4.75 mm sieve is termed as fine aggregate. Usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as a fine aggregate.

D. RECYCLED COARSE AGGREGATE (As Per coarse aggregate IS : 460-1962)

Recycled aggregates comprise of crushed, graded inorganic particles processed from the materials that have been used in the construction and demolition concrete debris. Locally available recycled coarse aggregate having the maximum size of 20 mm was used in the present work. These materials were obtained from a building which was 20-25 years old. The density of RA is found lower than the NA because of the porous and less dense residual mortar lumps that is adhering to its surfaces. The aggregates were properly graded according to the Indian standard codes and then mixed with the respective natural aggregate in appropriate percentages. The use of fine recycled aggregate below 2 mm is uncommon in recycled aggregate use age because of the high water demand of the fine material smaller than 150 μm, which lowers the strength and increases the shrinkage significantly.

E. WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, tap water is used for both mixing and curing purposes.

4. RESULT OF COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is affected by both the aggregate properties, and the characteristics of the new cement paste that is developed during the maturing of concrete. The potential strength of concrete is partially a function of aspects related to mix proportioning such as cement content, water/cement ratio and choice of suitable aggregate but also a function of proper curing when chemical bonding develops. The w/c ratio, proper compaction and adequate curing, affect the development of concrete microstructure, and also affect the amount, distribution and size of pores. The bond that is developed when concrete hardens is the aggregate-paste bond, which is both physical and chemical. The presumption is that recycled aggregate concrete might develop an even weaker chemical bond with cement paste, as the chemical composition of the aggregate is different from those of commonly used natural aggregates and the re-bonding of some elements in cement paste residue can take place. The most important parameters of the aggregate affecting compressive strength are its shape, texture, maximum size and the strength of coarse aggregate which is one of the dominant factors in classification of concrete aggregate. The decrease of compressive strength due to increase of recycled aggregate percentage can be explained as follows: The recycled aggregate is covered with hardened cement paste, which is very weak layer, so the compressive strength of recycled aggregate itself is weak. The hardened cement paste on recycled aggregate is high in water absorption consequently no enough residual water is present to complete all the quantity cement reaction. This leads to poor compaction, consequently not well compacted concrete. There were some impurities in the recycled aggregate like wood, glass, bricks, etc. which could not be removed completely which affected the bond in general adversely. (For the entire chart table compressive strength in N/mm2 and concrete age in days)

Table 1: Compressive strength values.

COMPRESSIVE STRENGTH TEST (Mpa)				
MIX	**7 DAYS**	**14 DAYS**	**28DAYS**	**56 DAYS**
NA	**22.46**	**31.50**	**34.96**	**35.02**
RCA 15	**20.50**	**28.82**	**32.03**	**32.15**
RCA 30	**19.20**	**27.07**	**30.08**	**30.20**
RCA 45	**17.59**	**24.52**	**27.25**	**27.26**
RCA 60	**15.88**	**23.12**	**25.69**	**25.70**
RCA 100	**15.88**	**23.12**	**25.69**	**25.70**

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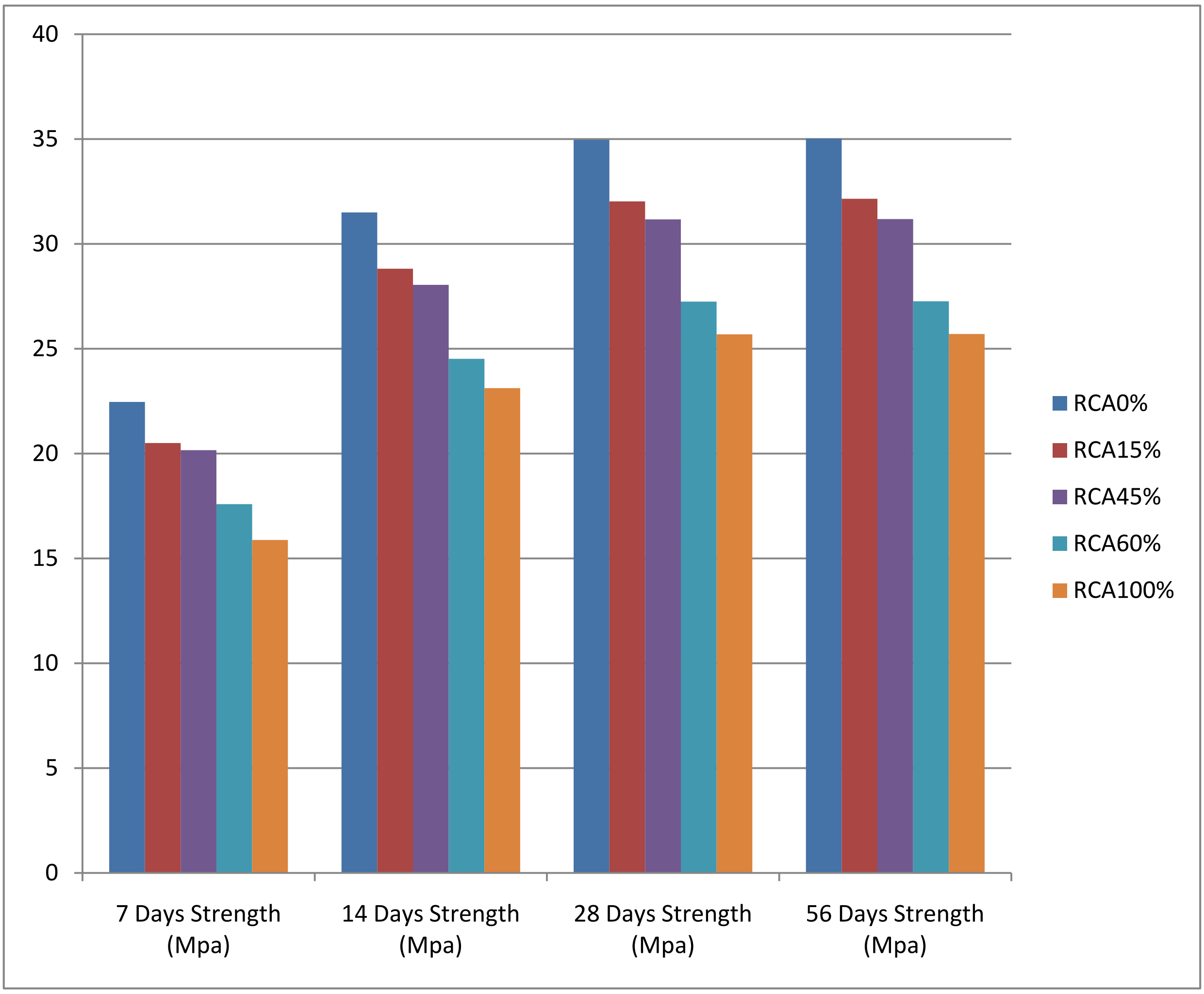

Figure 2: Comparison of Compressive Strength of Grade M35 with Different Percentage of RCA.

5. SPLIT TENSILE STRENGTH RESULTS

The split tensile strength also shows the similar pattern of results as the compressive strength results are showing in graph. Tensile strength of concrete ranges from 10 to 15 percent of the compressive strength. The decrease of compressive strength and spilt tensile strength due to increase of recycled aggregate percentage can be explained as follows:

The recycled aggregate is covered with hardened cement paste, which is very weak layer, so the compressive strength of recycled aggregate itself is weak. The hardened cement paste on recycled aggregate is high in water absorption consequently no enough residual water is present to complete all the quantity cement reaction. This leads to poor compaction, consequently not well compacted concrete. The existence of cement paste layer on recycled aggregate prevent integration of all aggregate ,and prevent enough bond between recycled aggregate and new cement paste.

Table 2: Split tensile strength values.

SPLIT TENSILE STRENGTH (Mpa)				
MIX	**7 DAYS**	**14 DAYS**	**28DAYS**	**56 DAYS**
NA	**2.12**	**2.72**	**3.52**	**3.6**
RCA 15	**1.62**	**2.07**	**2.82**	**2.84**
RCA 30	**1.53**	**2.10**	**3.02**	**3.06**
RCA 45	**1.38**	**2.56**	**3.28**	**3.29**
RCA 60	**0.84**	**1.67**	**2.81**	**2.84**
RCA 100	**0.23**	**1.78**	**2.56**	**2.63**

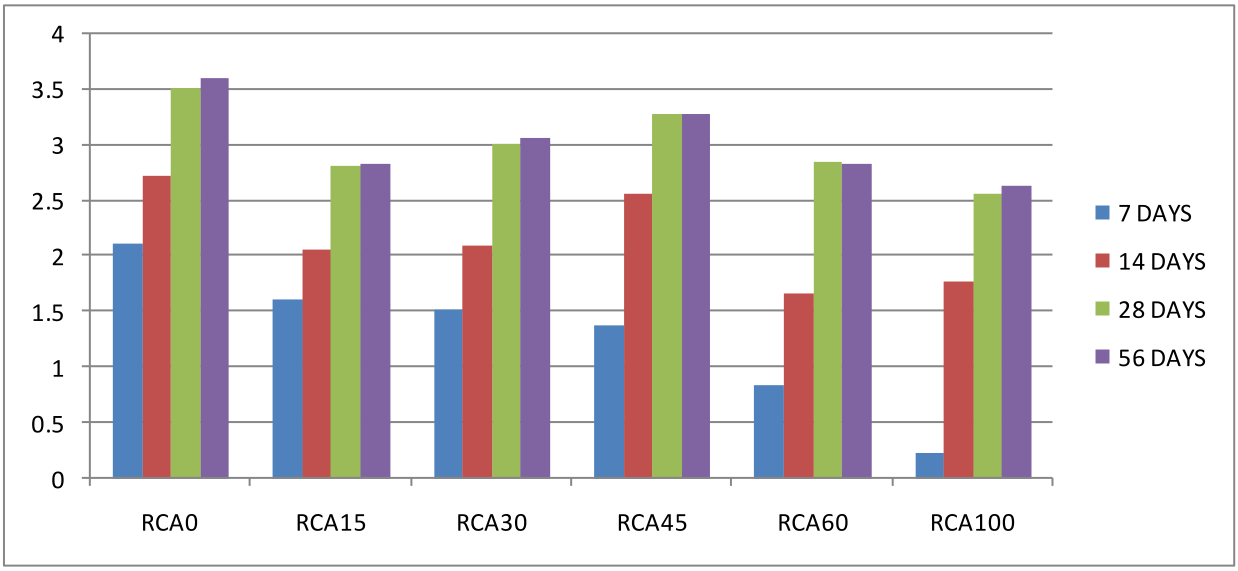

Figure 3: Split tensile strength vs. age in Mpa.

6. CONCLUSION OF THE STUDY

Experimental works on the use of recycled aggregates have proven that good quality concrete could be produced with recycled aggregates. The use of aggregates produced from recycled construction and demolition waste should be further promoted.

Based on the experimental investigation reported in the work, the following conclusions are drawn:

1. Water absorption of RCA was higher and specific gravity of is lower than the NCA. Attached cement mortar and voids in that are the basic reason behind such behavior.

2. The workability of recycled aggregate concrete mix is lower than natural aggregate concrete because recycled aggregate has more surface area.

3. The strength of concrete decrease with increase in the percentage of recycled aggregate, this can be due to the loose mortar around the recycle aggregate which do not allow the proper bonding between the cement paste and aggregate.

4. RCA based concrete with gives higher compressive strength than normal RAC. This may due to bonding between the old mortar and cement paste.

5. It was observed that the presence of recycled aggregates seemed to produce lower performance but useful in economic and sustainable construction purposes.

6. As impact and crushing value of aggregate shows that it can be used in pavement blocks and other construction also were aggregate is required.

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