Utilization of Solid Waste Materials as Aggregates in M25 Grade Concrete

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Abstract-*Extensive laboratory experimentation has been carried out to analyze the performance of M25 concrete made by partially replacing aggregates with waste materials like construction debris, leather waste, PVC waste, cast iron waste. The resultant concrete has been tested for parameters like a slump, unit weight, compressive strength, flexural strength and split tensile strength and compared with conventional plain cement concrete. It has been observed that the use of waste materials results in the formation of light weight concrete. A considerable increase in the strength of concrete has been observed when the coarse aggregates are fully or partially replaced with construction debris and cast iron waste. However, a reduction in workability of the concrete mix has been observed in some cases. When the coarse aggregates have been replaced with PVC waste in small percentage by weight, the resultant concrete shows the fair value of compressive strength and good workability. However, on the partial introduction of leather waste in place of sand, the concrete passed the slump test but failed dreadfully in a compressive strength test. The study shows that the use of recycled waste materials in concrete is an effective method to deal with the scarcity of natural aggregates. Their use can also solve the problem of their disposal. Hence, their utilization is a beneficial proposition which is economical and environment friendly as well.*

Key Words: Construction debris, leather waste, PVC waste, cast iron waste, strength.

1. INTRODUCTION

There is an evident need to recycle and reuse the solid waste materials being generated in order to reduce their stockpiling and harmful environmental effects. The construction industry, in particular, is notorious for the creation of vast amounts of waste. It is only sensible that this industry should do more to develop new ways of bringing waste that can potentially be recycled back into the production line. Because concrete is the most widely used construction material in the world today, the

Present study focuses on a specific component that accounts for 80% of the volume of concrete, that is, aggregates. Aggregates are becoming increasingly scarce in urban areas. That means that aggregates have to be transported from longer distances into the urban areas, which is where most buildings are constructed. Stringent environmental laws and growing public awareness towards a more sustainable society have driven organizations and governments to search for a replacement to aggregates.

In particular, this study examines the compressive strength of concrete made with recycled aggregates. The goal is to identify if concrete made from recycled aggregates can perform qualitatively as conventional concrete. A considerable amount of research has been carried out with different types of materials. The present study investigates the performance of concrete made from recycled aggregates such as concrete debris, PVC waste, leather waste and cast iron waste from various industries.

Overall, the purpose of this study is to increase the awareness about the scarcity of aggregates in the metropolitan areas and to present alternatives that can be used in place of conventional aggregates. Due to the diminishing amount of aggregates extracted from nature, the use of recycled aggregates creates an opportunity to preserve natural resources and offers and assists the pursuit of a greener planet for the present and future generations.

2. OBJECTIVES

The following objectives have been undertaken before the commencement of the study:

2.1. The design of M25 grade concrete mix.

2.2. Determination of workability using slump test.

2.3. Determination of compressive strength of concrete.

2.4. Determination of flexural strength of concrete.

2.5. Determination of split tensile strength of concrete.

3. LITRETURE REVIEW

Wang, Zureick and Cho(1994) - The study was carried out to evaluate the use of recycled fibers from carpet industrial waste for reinforcement of concrete at 1 and 2 volume % fractions. Compressive, flexural, splitting tensile and shrinkage tests were performed.

Meyer (2002) - Author has reviewed numerous by-products of industrial processes with pozzolanic properties which can be a substitute partially for cement, such as fly ash and ground granulated blast furnace slag. Also, applications of other recycled materials in concrete production have been suggested.

Ghailan (2005) - The author reported that natural aggregate is the main source of aggregate used in concrete work in Iraq. Synthetic aggregate is also used in limited scale around the world. An industrial solid waste is produced from iron and steel industry. It was physically treated and fully inspected and incorporated in concrete as coarse aggregate.

Siddique, Khatib and Kaur (2008) - The authors have carried out an extensive review of solid waste management in context with concrete technology. They reported that numerous waste materials are generated from manufacturing processes, service industries and municipal solid wastes.

Zega and Maio (2011)- Authors reported that the usage of waste materials for the development of new products is a global trend undergoing rapid development. Recycling materials allow for a more efficient life cycle and contribute to environmental protection.

Ahmed (2013)- Authors have reported the properties of concrete containing recycled coarse aggregate (RCA) sources from local construction and demolition (C&D) wastes and fly ash (FA) sourced from Western Australia (WA). The RCA were used as 25, 50, 75, and 100% (by weight) replacement of natural coarse aggregate (NCA).

Bahoria, Parbat, Nagarnaik, and Waghe (2013)- Authors have utilized waste plastic of fabric form shapes in various percentages in concrete mixtures as a modifier, in order to reduce the propagation of micro cracks. This study insures that reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics.

YI, LI and XU (2013) - Authors reported that in China, large amounts of construction waste produced by the large-scale urban construction, the new rural construction and road construction currently, among which waste concrete is the largest. Waste concrete is permanent garbage that cannot be broken down by the environment itself through natural circulation. This makes the recycling of Waste concrete a necessity, which is not only a good solve to the environmental problems caused by Waste concrete but also a good way to protect the mine gravel and other natural resources.

Senhadji, Escadeillas, Benosman, Mouli, Khelafi, and Kaci (2015)- Authors have used non-biodegradable plastic aggregates made of polyvinylchloride (PVC) waste, obtained from scrapped PVC pipes, as a partial replacement to conventional aggregates in concrete. For this purpose, a number of laboratory prepared concrete mixes were tested, in which natural sand and coarse aggregates were partially replaced by PVC plastic waste aggregates in the proportions of 30, 50, and 70% by volume (granular classes 0/3 and 3/8).

Kurup and Kumar (2016)- Authors have studied the influence of electronic waste as an additive in concrete. Electronic waste (e-waste) in concrete is the new revolutionary concept of sustainable concrete because it reduces the environmental pollution and solid waste problem. In this paper, the extracted outer casing insulation of electrical wire was made into fibers.

Özalp, Yilmaz, Kara, Kaya and Şahin (2016)- Authors have investigated the utilization criteria of the recycled aggregates gained from construction and demolition wastes, in the production of various ready-mixed and precast concrete elements. Within this scope, construction and demolition waste materials were selectively separated to have homogeneous concrete wastes in the recycling plant.

Ren and Zhang (2016)- The study investigates complete recycling and utilization of waste concrete, both the aggregates and the fines from crushing, to produce new concrete through geopolymerization. Based on previous studies and considering the workability of the new geopolymer concrete (GPC), 25% waste concrete fines (WCF), and 75% Class-F fly ash (FA) were used as the geopolymer cement source material, $NaOH/Na_2SiO_3$ solution as the alkaline activator, and the aggregates (both coarse and fine) from waste concrete crushing as the aggregate.

4. MATERIALS AND METHODOLOGY

4.1 Cement

The cement used for this experiment is OPC (43Grade) Conforming to IS 8112-1982 and has the following properties which have been experimentally determined at the time of use:

Table-1: Physical Properties of Cement

S.No.	Physical Properties	Values Determined in Laboratory
1.	Specific Gravity	3.07
2.	Fineness (%)	3.5
3.	Standard Consistency (%)	34
4.	Initial Setting Time (minutes)	45
5.	Final Setting Time (minutes)	240
6.	Soundness (mm)	2

4.2 Aggregates

The size of the aggregate, particle shape, color, surface texture, density(heavyweight or lightweight), impurities, all of which have an influence on the durability of concrete, should conform to IS 383–1970.The size of coarse aggregates used are 20mm and that of fine aggregates are of ZONE-II as given

Table-2: Physical properties of sand

S.No.	Physical Properties	Values Determined in Laboratory
1.	Specific Gravity	2.67
2.	Water Absorption (%)	1.020
3.	Moisture Content (%)	0.155
4.	Bulking (%)	2.48
5.	Fineness Modulus	2.715
6.	Grading Zone	II

Table-3: Physical properties of aggregates

S.No.	Physical Properties	Values Determined in Laboratory
1.	Specific Gravity	3.01
2.	Water Absorption (%)	3.806
3.	Moisture Content (%)	0.806
4.	Fineness Modulus	7.36
5.	Nominal Size (mm)	10

4.3 Concrete debris

Concrete debris has been obtained from left over pile heads and has been recycled to 10 mm of average particle size. These recycled aggregates have been used as a replacement to conventional coarse aggregates. Physical properties of recycled concrete debris aggregates (RCDA) have been determined by carrying out tests for specific gravity, water absorption, moisture content and fineness modulus as per the specifications of IS 2386(Part 3):1963 and IS 2386 (Part 1):1963.The nominal size of different proportions of RCDA (25%, 50%, 100%) in conventional aggregates has been observed to be 12.5 mm.

4.4 Leather waste

Leather waste has been collected from nearby industries and recycled by pulverizing it to 1.18 mm of average particle size. Leather waste is a very lightweight material and has an egligible affinity towards water hence only sieve analysis tests have been performed on different percentages (5%, 10%, 100%) of leather waste in fine aggregates. The grain size distribution has been shown in Figure 3.6. Fineness modulus values have been determined as per the specifications of IS 2386(Part 1):1963 and observed as 2.632, 2.82 and 3.77 at 5%, 10%, 100% replacement of fine aggregates respectively.

4.5 PVC waste

PVC waste has been collected from nearby industries and recycled by pulverizing it to 4.75 mm of average particle size. PVC is a very lightweight material and has an egligible affinity towards water hence only sieve analysis tests have been performed on different percentages (5%, 10%, 100%) of PVC in coarse aggregates. The grain size distribution has been shown in Figure 3.7. Fineness modulus values have been determined as per the specifications of IS 2386(Part 1):1963 and observed as 7.28, 7.213 and 5.89 at 5%, 10%, 100% replacement of coarse aggregates respectively.

4.6 Cast Iron waste

Cast Iron Waste (CIW) has been procured locally from nearby industries. The material was in powder form having a density of about 1967.79 kg/m^3. Physical properties of CIW have been determined by carrying out tests for specific gravity and fineness modulus as per the specifications of IS 2386(Part 3):1963 and IS 2386 (Part 1):1963. The values of specific gravity and fineness modulus have been observed to be 4.50 and 2.65 respectively.

4.7 Methodology

Mixing of concrete: Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc. Cubes of 150 mm x 150 mm x 150 mm dimension have been casted to perform the compression tests. The concrete is poured into the mould and tempered properly to remove any voids After 24 hours moulds have removed and test specimens have been put into a water tank for curing.

These specimens are tested by compression testing machine at intervals of 7,14 and 28 days curing as Load has been applied gradually at the rate of 140 kg/cm^2 per minute till the failure of the cube. The ratio of load at the failure and area of specimen gives the compressive strength of concrete. Test for compressive strength has been carried out on the cubes as per the specifications of IS 516-1959.

Flexural strength is the stress in the material before it yields. It is also known as bend strength. The centre point loading method has been used to check the flexural strength of concrete beams. For this purpose, a total of 20 beams of dimensions 100 mm x 100 mm x 500 mm have been casted. These specimens are tested by flexure testing machine at intervals of 7 and 28 days curing. The samples have been tested immediately after removal from the curing tank. The load has been applied gradually at the rate of 400 kg per minute till the failure. The tests have been conducted as per the specifications of IS 516-1959.

The split tensile strength of concrete is required for the design of concrete structural elements subject to transverse shear, torsion, shrinkage and temperature effects. Its value is also used in the design of pre-stressed concrete structures, liquid retaining structures, roadways and runway slabs. A total of 20 cylinders of diameter 150 mm and length 300 mm have been casted. Tests have been conducted at the recognized ages of the test specimens, the most usual being 7 and 28 days. Specimen have been tested immediately on removal from the water. Surface water and grit has been wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips. The load has been applied without shock and increased continuously at a nominal rate within the range 1.2mm^2/min to 2.4mm^2/min. The tests have been conducted as per the specifications of IS 5816-1999.

5. EXPERIMENTAL RESULTS AND DISCUSSIONS

Compressive strength: Tests for compressive strength have been carried out on 90 cubes as per the specifications of IS 516-1959.The 28 Days compressive strength of PCC has been observed to be28.72 N/mm^2.It shows that RCDA and natural aggregates perform better when used in combination. The variation of the compressive strength of RCDA concrete with age is shown in Figure 1. For PLW, a catastrophic failure has been observed at all percentages. The variation of the compressive strength of PLW concrete with age is shown in Figure 2.

No significant change in the value of compressive strength of concrete has been observed at 5% addition of PVC as a replacement to natural coarse aggregates. However, at 10% addition of PVC as an aggregate, a slight decrease in compressive strength has been observed. The variation of the compressive strength of PVC concrete with age is shown in Figure 3.

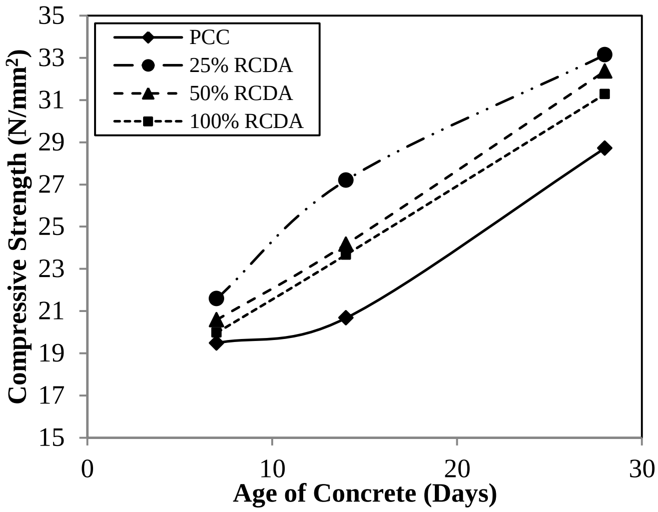

Fig-1: Variation of Compressive Strength with Age of Concrete for Different Percentages of RCDA

A significant improvement in the compressive strength of concrete has been observed on addition of CIW as a replacement to sand. The variation of the compressive strength of resultant concrete with age is shown in Figure 4.

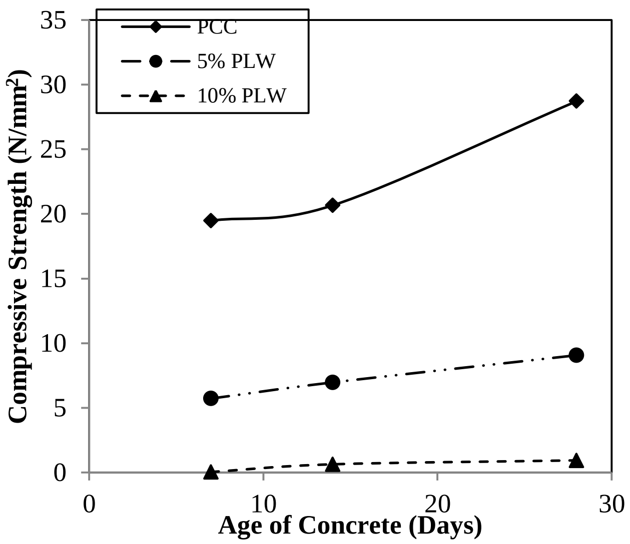

Fig-2: Variation of Compressive Strength with Age of Concrete for Different Percentages of PLW

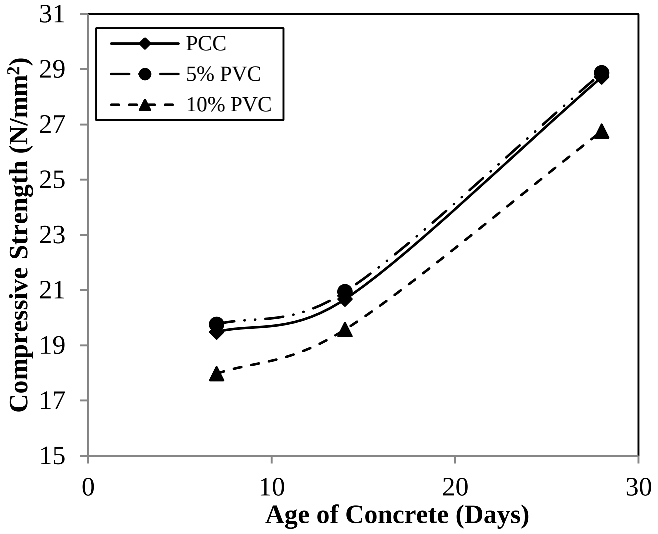

Fig-3: Variation of Compressive Strength with Age of Concrete for Different Percentages of PVC

Flexural strength: Tests for flexural strength have been carried out on 20 beams as per the specifications of IS 516-1959. The 28 Days flexural strength of PCC has been observed to be 4.708 N/mm^2.A significant increase in the flexural strength of concrete has been observed on addition of RCDA as a replacement to natural coarse aggregates. However, the maximum strength has been observed at 25% RCDA content and lowest at 100% RCDA content as aggregates.

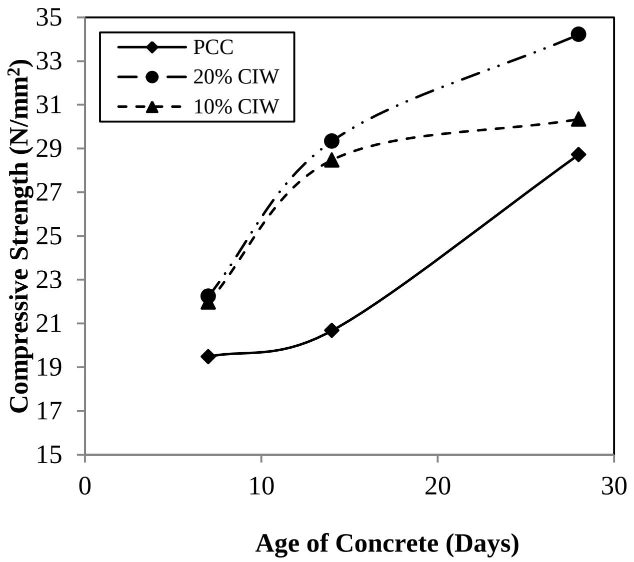

Fig-4: Variation of Compressive Strength with Age of Concrete for Different Percentages of CIW

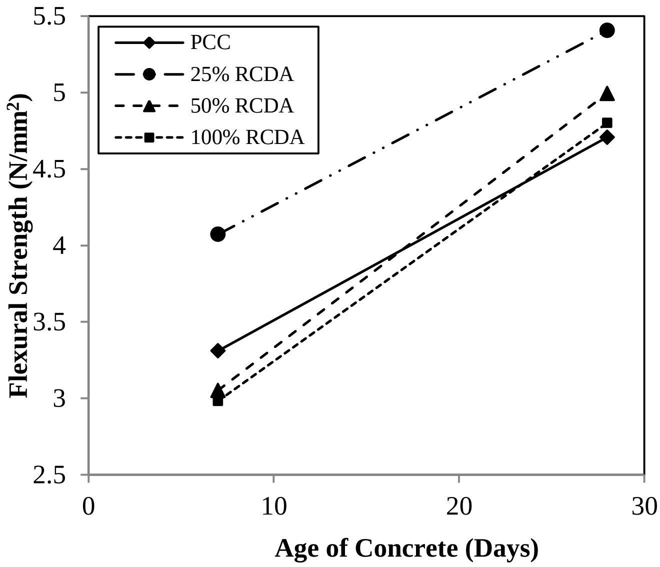

Fig-5: Variation of Flexural Strength with Age of Concrete for Different Percentages of RCDA

It shows that RCDA and natural aggregates also performs better in flexure when used in combination. The variation of the flexural strength of RCDA concrete with age is shown in Fig. 5.

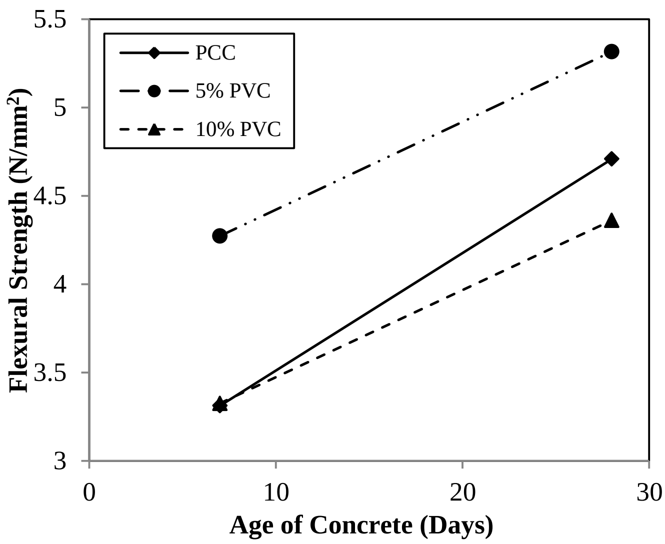

Fig-6: Variation of Flexural Strength with Age of Concrete for Different Percentages of PVC

No significant improvement in the value of flexural strength of concrete has been observed at 10% addition of PVC as a replacement to natural coarse aggregates. However, at 5% addition of PVC as an aggregate, an impressive increase in flexural strength has been observed. The variation of the flexural strength of PVC concrete with age is shown in Fig. 6.

No significant improvement in the flexural strength of concrete has been observed on addition of CIW as a replacement to sand. The variation of the flexural strength of resultant concrete with age is shown in Fig. 7.

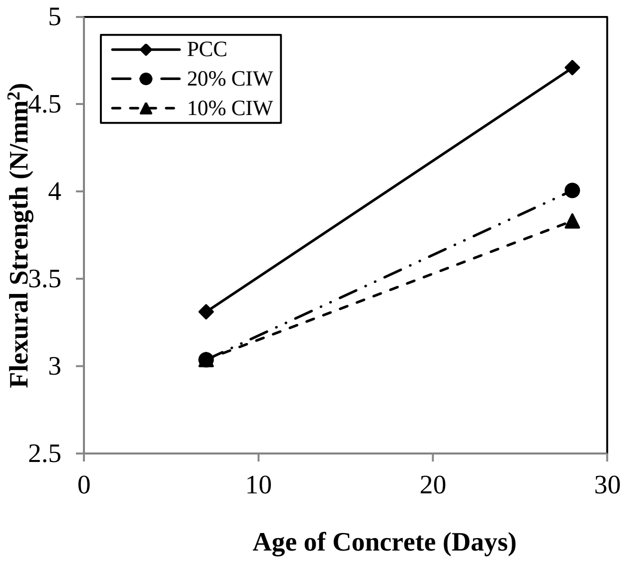

Fig-7: Variation of Flexural Strength with Age of Concrete for Different Percentages of CIW

Split tensile strength: Tests for split tensile strength have been carried out on 20cylinders as per the specifications of IS 5816-1999. The 28 Days split tensile strength of PCC has been observed to be 2.952 N/mm². A significant increase in the split tensile strength of concrete has been observed on addition of RCDA as a replacement to natural coarse aggregates. However, the maximum strength has been observed at 25% RCDA content and lowest at 100% RCDA content as aggregates. It shows that RCDA and natural aggregates also performs better in tension when used in combination. The variation of the split tensile strength of RCDA concrete with age is shown in Figure 8.

No significant improvement in the value of split tensile strength of concrete has been observed at 10% addition of PVC as a replacement to natural coarse aggregates. However, at 5% addition of PVC as an aggregate, a slight increase in split tensile strength has been observed. The variation of the split tensile strength of PVC concrete with age is shown in Figure 9.

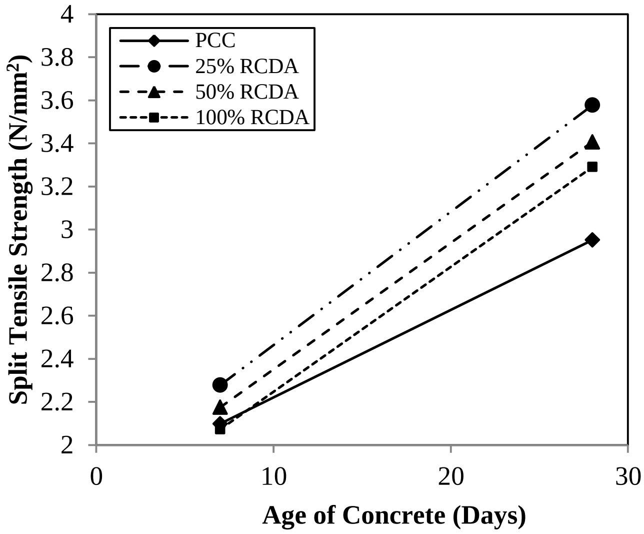

Fig-8: Variation of Split Tensile Strength with Age of Concrete for Different Percentages of RCDA

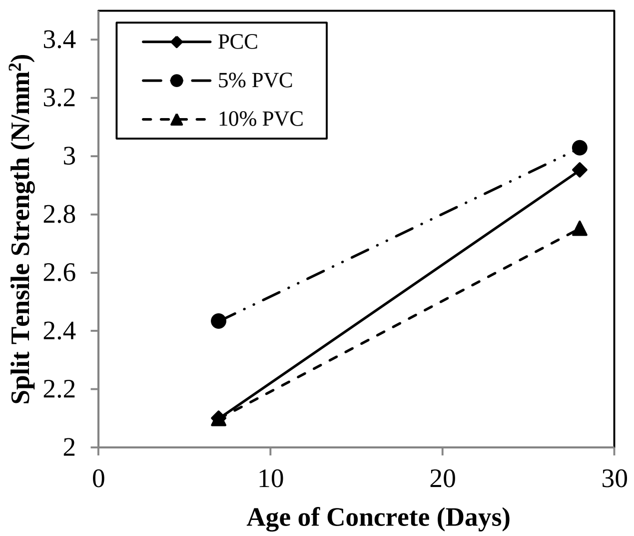

Fig-9: Variation of Split Tensile Strength with Age of Concrete for Different Percentages of PVC

A significant improvement in the split tensile strength of concrete has been observed on addition of CIW as a replacement to sand. The variation of the split tensile strength of resultant concrete with age is shown in

Figure 10.

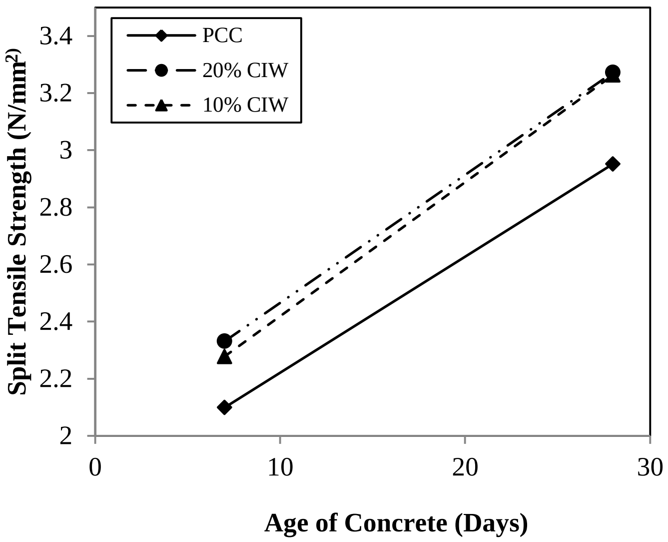

Fig-10: Variation of Split Tensile Strength with Age of Concrete for Different Percentages of CIW

On the careful assessment of results, it has been observed that concrete samples with 25% RCDA and 5% PVC performed well in all tests. These concrete variants can be used in reinforced construction works without the use of superplasticizers. Significant reduction in a slump has been observed for rest of the cases and hence can be used with superplasticizers. Utilization of leather waste in concrete production is not at all recommended.

6. CONCLUSION

The following conclusions are derived from this study:

- A significant increase in the compressive strength of concrete has been observed on addition of RCDA as a replacement to natural coarse aggregates. However, the maximum strength has been observed at 25% RCDA content and lowest at 100% RCDA content as aggregates. It shows that RCDA and natural aggregates perform better when used in combination.
- For PLW, a catastrophic failure has been observed at all percentages. The variation of the compressive strength of PLW concrete with age. Hence, utilization of leather waste in concrete production is not at all recommended.
- No significant change in the value of compressive strength of concrete has been observed at 5% addition of PVC as a replacement to natural coarse aggregates. However, at 10% addition of PVC as an aggregate, a slight decrease in compressive strength has been observed. It shows that PVC can be used along with natural aggregates while preparing concrete for common construction works.
- A significant improvement in the compressive strength of concrete has been observed on addition of CIW as a replacement to sand.
- A significant increase in the flexural strength of concrete has been observed on addition of RCDA as a replacement to natural coarse aggregates. However, the maximum strength has been observed at 25% RCDA content and lowest at 100% RCDA content as aggregates. It shows that RCDA and natural aggregates also performs better in flexure when used in combination.
- No significant improvement in the value of flexural strength of concrete has been observed at 10% addition of PVC as a replacement to natural coarse aggregates. However, at 5% addition of PVC as an aggregate, an impressive increase in flexural strength has been observed.
- No significant improvement in the flexural strength of concrete has been observed on addition of CIW as a replacement to sand.
- A significant increase in the split tensile strength of concrete has been observed on addition of RCDA as a replacement to natural coarse aggregates. However, the maximum strength has been observed at 25% RCDA content and lowest at 100% RCDA content as aggregates. It shows that RCDA and natural aggregates also performs better in tension when used in combination.
- No significant improvement in the value of split tensile strength of concrete has been observed at 10% addition of PVC as a replacement to natural coarse aggregates. However, at 5% addition of PVC as an aggregate, a slight increase in split tensile strength has been observed.
- A significant improvement in the split tensile strength of concrete has been observed on addition of CIW as a replacement to sand.
- The study shows that the use of recycled waste materials in concrete is an effective method to deal with the scarcity of natural aggregates. Their use can also solve the problem of their disposal. Hence, their utilization is a beneficial proposition which is economical and environment friendly as well.

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