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Utilization of Recycled Wastes as Ingredients in Concrete Mix

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Abstract- ***Laboratory experimentation was carried out to analyze the performance of M25 concrete made by partially replacing aggregates with waste materials like construction debris, PVC scrap and leather waste. The resultant concrete was tested for parameters like weight, compressive strength, slump and workability 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. There is a considerable increase in the compressive strength of concrete when the coarse aggregates are fully or partially replaced with construction debris. However a minor reduction in workability of the concrete mix was observed. When the coarse aggregates were replaced with PVC scrap in small percentage by weight, the resultant concrete shows fair value of compressive strength and the workability. But with the partial introduction of leather waste in place of sand in concrete, the concrete passed workability test but it failed completely in compressive strength test and gave almost zero strength. Hence, except leather waste other materials like construction debris and PVC scrap performed well as full or partial replacement for concrete aggregates and can find suitable application in construction industry as alternative to conventional materials. Uses of such waste materials will not only cut down the cost of construction, but will also contribute in safe disposal of waste materials. Apart from the environmental benefits, the addition of such wastes, also improves certain properties of resultant concrete.***

Keywords: M25 Concrete, compressive strength, flexural strength and workability.

I. INTRODUCTION

In the present scenario, no construction activity can be imagined without using concrete. Concrete is the most widely used building material in construction industry. The main reason behind its popularity is its high strength and durability. Today, the world is advancing too fast and our environment is changing progressively. This has created what we call the biggest problem of the world, industrial waste and debris accumulation. Hence there is a need to recycle these waste into something more useful and environment friendly. To achieve this, major emphasis must be laid on the use of waste from various industries. Research into new and innovative use of waste materials being undertaken world-wide and innovative ideas that are expressed are worthy of this important subject.

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Research concerning the use of by-products to augment the properties of concrete has been going on for many years. In the recent decades, the efforts have been made to use industry by-products such as fly ash, silica fume, ground granulated blast furnace slag (GGBS), glass cullet, metakaolin etc., in civil constructions. Many highway agencies, private organizations and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability and performance of using waste materials in construction.

The potential applications of industry by-products in concrete are as partial aggregate replacement or as partial cement replacement, depending on their chemical composition and grain size. The use of these materials in concrete comes from the environmental constraints in the safe disposal of these products. These studies try to match societal need for safe and economic disposal of waste materials with the help of environmental friendly industries, which needs better and cost-effective construction materials. In this study, construction debris, PVC scrap and leather waste were used to augment various properties of concrete.

II. WASTE GENERATION IN INDIA

A. Construction debris

1. General Construction and demolition waste is generated whenever any construction/demolition activity takes place. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc. These wastes are heavy, having high density, often bulky and occupy considerable storage space and are mostly unsuitable for disposal by incineration or composting.

2. Generation of debris Waste is generated at different stages of construction process. Concrete and masonry constitute more than 50% of waste generated by the construction industry. Waste during construction activity relates to excessive cement mix or concrete left after work is over, rejection/ demolition caused due to change in design or wrong workmanship etc. Estimated waste generation during construction is 40 to 60 Kg/m^2. Similarly, waste generation during renovation/ repair work is estimated to be 40 to 50 kg/m^2. The highest contribution to waste generation is due to demolition of buildings. Demolition of Pucca and Semi-Pucca buildings, on an average generates 500 & 300 kg/m^2 of waste respectively. The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum [10]. Quantities of different constituents of waste that arise from construction industry in India are estimated as follows:

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Table.1. Quantity of different construction debris/waste generated in million tons per annum

Constituent	Quantity Generated (In Million Tons/Annum)
Soil, Sand & gravel	4.20 to 5.14
Bricks & Masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.30
Wood	0.25 to 0.30
Others	0.10 to 0.15

B. PVC scrap

1. General The word 'Plastic' means substances which have plasticity and accordingly, anything that is formed in a soft state and used in a solid state can be called a plastic. Plastics can be separated into two types. The first type is Thermoplastic, which can be melted for recycling in the plastic industry. The second type is Thermosetting Plastic.

This plastic cannot be melted by heating because the molecular chains are bonded firmly with meshed crosslink. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin and silicone. Polyvinyl Chloride, commonly abbreviated as PVC, is a thermoplastic polymer. It is a vinyl polymer constructed of repeating vinyl groups having one of their hydrogen's replaced with a chloride group. It can be made softer and more flexible by the addition of plasticizers, the most widely used being phthalates. Polyvinyl chloride is the third most widely produced plastic, after polyethylene and polypropylene. PVC is widely used in construction because it is cheap, durable and easy to assemble. PVC production is expected to exceed 40 million tons by 2016.

2. Generation of PVC Plastic waste constitutes a significant portion of the total Municipal Solid Waste (MSW) generated in India. It is estimated that approximately 10 thousand Tons per Day (TPD) of plastic waste is generated. Among the various types of plastics, the largest component of the plastic waste is low density polyethylene/linear low density polyethylene (LDPE) at about 23%, followed by 17.3% of high density polyethylene, 18.5% of Polypropylene, 12.3% of Polystyrene, 10.7% Polyvinyl chloride, 8.5% Polythylene Terephthalate and 9.7% of other types [10].

C. Leather waste

1. General Leather is a durable and flexible material created via the tanning animal skin. It can be produced through different manufacturing processes, ranging from cottage industry to heavy industry. Leather can be oiled to improve its water resistance. This supplements the natural oils remaining in the leather itself, which can be washed out through repeated exposure to water. Frequent oiling of leather, with mink oil, keeps it supple and improves its lifespan dramatically. In general, leather is sold in four forms which are full-grain leather, top-grain leather, and corrected-grain leather and split leather. Leather is a product with high environmental impact, most notably due to:

- the impact of livestock
- the heavy use of polluting chemicals in the tanning process
- severe air pollution due to the transformation process

One ton of hide or skin generally leads to the production of 20 to 80 m^3 of turbid and foul-smelling wastewater including chromium levels of 100–400 mg/L, sulfide levels of 200–800 mg/L and high levels of fat and other solid wastes, as well as notable pathogen contamination. With solid wastes representing up to 70% of the wet weight of the original hides, the tanning process comes at a considerable strain on water treatment installations. Tanning is especially polluting in countries where environmental norms are lax, such as in India - the world's 3rd largest producer and exporter of leather, where the higher cost associated to the treatment of effluents leads to environmental dumping to save on costs.

Vegans and animal rights activists boycott the use of all items made from leather, believing the practice of wearing animal hides is unnecessary and cruel in today's society. Animal rights groups such as PETA have called for boycotts and encourage the use of alternative materials such as synthetic leathers. Many pseudo-leather materials have been developed, allowing those who wish to wear leather-like garments to do so without actually wearing leather. One example of this is vegan microfiber, which claims to be stronger than leather when manufactured with strength in mind [9].

III. MATERIALS & METHODS

Concrete mixes were designed as per Indian Standards [3][5][7][8] by incorporating various percentages of recycled aggregates. Natural aggregates were replaced with 100%, 75% and 25% of recycled debris (20mm average particle size), 10% and 5% with PVC and 10% and 5% with pulverized leather waste. Physical properties of 43-Grade cement were determined as per Indian Standards [4] are reported in Table 2.

Table 2. Physical properties of cement

S.No.	Physical Property	Value 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
7	28 days Compressive Strength (N/mm^2)	42.7

The sand used as fine aggregates was locally procured. It was first sieved through 4.75 mm IS sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The physical properties are reported in Table 3.

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Table 3. Physical Properties of sand

S.No.	Physical Property	Value 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

Gravels used as coarse aggregates were locally procured having average particle size of 20 mm. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The physical properties are reported in Table4.

Table 4. Physical properties of coarse aggregates

S.No.	Physical Property	Value determined in laboratory
1.	Apparent Specific Gravity	3.01
2	Water Absorption (%)	3.806
3	Moisture content (%)	0.806
4	Fineness Modulus	7.36

Recycled concrete aggregates used were obtained from left over pile heads crushed to 20 mm average particle size. These debris aggregates were used to replace natural coarse aggregates. Physical properties of recycled concrete debris and aggregates partially replaced with recycled concrete debris are reported in Table 5.

Table 5. Physical properties of construction debris

S.No.	Physical Property	Values determined in laboratory		
		100% Debris	50% Debris+ 50% aggregates	25% Debris + 75 % aggregates
1.	Apparent Specific Gravity	2.66	2.83	2.92
2	Water Absorption (%)	5.22	4.33	4.206
3	Moisture content (%)	0.60	0.703	0.75
4	Fineness Modulus	8.19	7.27	7.57

PVC wastes were collected from nearby industries. Fineness modulus for PVC has been observed as 5.94, 7.213 and 7.28 for 100% PVC, 10% PVC mixed with 90% aggregates and for 5% PVC mixed with 95% aggregates respectively.

Leather waste was collected from nearby industries and then pulverized to replace fine aggregates. Fineness modulus for leather waste has been observed as 3.77, 2.82 and 2.632 for 10% leather waste mixed with 90% fine aggregates and for 5% leather waste mixed with 95% fine aggregates respectively. Design mixes were prepared by incorporating physical properties of materials confirming to Indian Standards and the resulting ratios of water, cement, fine and coarse aggregates were reported in Table 6. Physical properties of all materials are as per specifications of IS Codes [6].

Table.6 Mix design for various types of concrete casted

S.No.	Type of concrete	Mix Design			
		Water (Litres)	Cement (kg)	Sand (kg)	Coarse aggregates (kg)
1.	PCC	0.46	1	1.34	2.86
2.	100% Debris as coarse aggregates	0.59	1	1.34	2.48
3.	50% Debris + 50% coarse aggregates	0.58	1	1.34	2.67
4.	25% Debris + 75% coarse aggregates	0.58	1	1.34	2.75
5.	5% PVC + 95 % coarse aggregates	0.46	1	1.34	2.86
6.	10% PVC + 90% coarse aggregates	0.46	1	1.34	2.86
7.	5% Leather waste + 95 % fine aggregates	0.46	1	1.34	2.86
8.	10% Leather waste + 90% fine aggregates	0.46	1	1.34	2.86

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The performances of PCC and concrete designed by incorporating recycled waste materials was evaluated in terms of strength and workability by performing slump test, compressive strength test and flexural strength test [1][2]. The following results have been observed;

A. Fresh concrete properties

It has been observed that there is a significant decrease in weight of concrete when recycled waste materials were used as aggregates.

However a decrease in value of slum is observed. Values of weight and slump for various types of concrete are reported in Table 7.

Table 7. Values of weight and slump for various types of concrete

S.No.	Type of concrete	Weight (Kg)	Slump (mm)
1.	PCC	7.92	94
2.	100% Debris as coarse aggregates	7.53	78
3.	50% Debris + 50% coarse aggregates	7.64	84
4.	25% Debris + 75% coarse aggregates	7.78	86
5.	10% PVC + 90% coarse aggregates	7.65	92

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6.	5% PVC + 95 % coarse aggregates	7.87	91
7.	10% Leather waste + 90% fine aggregates	6.27	79
8.	5% Leather waste + 95 % fine aggregates	7.08	82

B. Compressive strength

A significant increase in compressive strength was observed when natural aggregates were replaced with recycled concrete aggregates. However a decrease in compressive strength was observed when natural aggregates were replaced with PVC aggregates but characteristic strength was achieved successfully. Very poor results were shown by concrete in which fine aggregates were replaced by pulverized leather waste. Values of compressive strength for various percentages of recycled wastes were reported in Table 8 and variation of compressive strength with age of concrete is shown in Fig.1.

Table 8. Compressive strength for various types of concrete

S.No.	Type of concrete	Average Compressive Strength (KN/m^2)		
		7 Days	14 Days	28 Days
1.	PCC	19.48	20.67	28.72
2.	100% Debris as coarse aggregates	19.97	23.67	31.28
3.	50% Debris + 50% coarse aggregates	20.58	24.17	32.37
4.	25% Debris + 75% coarse aggregates	21.58	27.2	33.14
5.	10% PVC + 90% coarse aggregates	17.97	19.57	26.76
6.	5% PVC + 95 % coarse aggregates	19.76	20.94	28.87
7.	10% Leather waste + 90% fine aggregates	0.042	0.6348	0.938
8.	5% Leather waste + 95 % fine aggregates	5.72	6.97	9.07

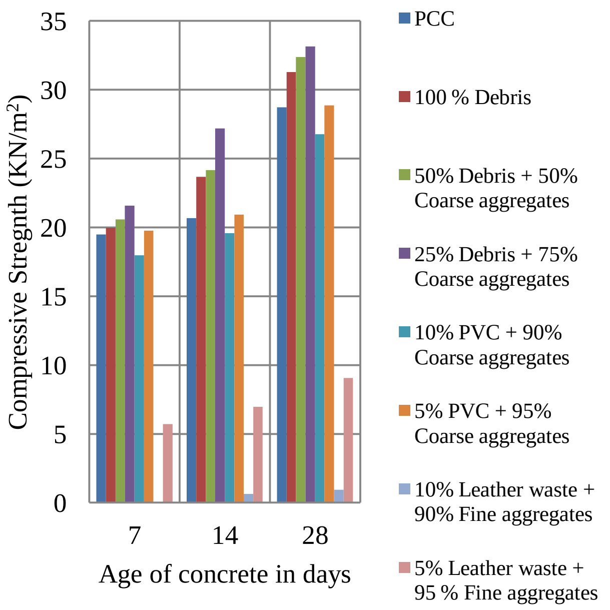

Fig.1. Variation of compressive strength in KN/m^2 with age of concrete in days

C. Flexural strength

Table 9 shows values of flexural strength determined by performing 3-Point method. A significant increase in flexural strength was observed when natural aggregates were replaced with recycled concrete aggregates. However a decrease in flexural strength was observed when natural aggregates were replaced with PVC aggregates. Very low flexural strength has been shown by concrete in which fine aggregates were replaced by pulverized leather waste. Values of flexural strength for various percentages of recycled wastes were reported in Table 9 and variation of flexural strength with age of concrete is shown in Fig.2.

Table 9. Flexural strength for various types of concrete

S.No.	Type of concrete	Average Flexural Strength (KN/m^2)		
		7 Days	14 Days	28 Days
1.	PCC	2.85	3.11	4.61
2.	100% Debris as coarse aggregates	2.89	3.18	4.69
3.	50% Debris + 50% coarse aggregates	2.58	3.72	4.81
4.	25% Debris + 75% coarse aggregates	3.46	3.91	5.04
5.	10% PVC + 90% coarse aggregates	2.21	2.77	3.98
6.	5% PVC + 95 % coarse aggregates	2.41	3.19	4.42
7.	10% Leather waste + 90% fine aggregates	0.03	0.24	0.381
8.	5% Leather waste + 95 % fine aggregates	1.22	1.43	1.68

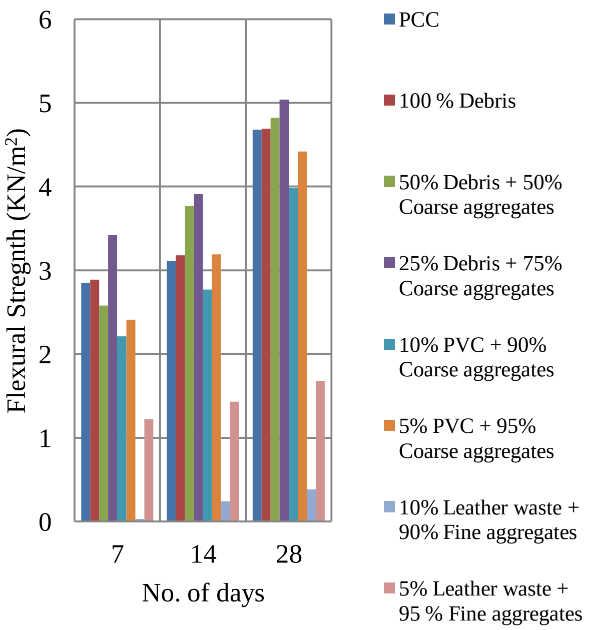

Fig.2. Variation of flexural strength in KN/m^2 with age of concrete in days

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V. CONCLUSIONS

Following conclusions are drawn on the basis of experimental investigation carried out in this study.

- Use of waste materials results in the formation of lightweight concrete.
- There is a considerable increase in the compressive strength as well as flexural strength of concrete when the aggregates are fully or partially replaced with construction debris. However maximum strength was shown by concrete mix having 25% recycled debris aggregates and 75% natural aggregates.
- A small reduction in workability of resultant concrete has been observed. And based on the observed values of slump the resultant concrete is recommended to be used in R.C.C beams, slabs, columns and retaining walls.
- The production cost decreased remarkably.
- In construction debris concrete, there is a minor reduction in workability of the concrete mix.
- Melting point of plastics is low, so it cannot be used in furnaces.
- Leather mixed concrete failed completely in compressive and flexural strength test.
- Use of such waste materials not only cuts down the cost of construction, but also contributes in safe disposal of waste materials.
- Plastics production involves the use of potentially harmful chemicals, which are added as stabilizers or colorants. Many of these have not undergone an environmental risk assessment and their impact on human health and the environment is currently uncertain.

Hence, except leather waste other materials like construction debris and PVC scrap performed well as full or partial replacer of concrete aggregates and can find suitable application in construction industry as alternative to conventional materials.

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