STUDY ON PARTIAL REPLACEMENT OF PULVERISED PLASTIC AS FINE AGGREGATE IN RIGID PAVEMENTS

Vakkar[1], Dr. Rakesh Gupta[2], Er. Neeraj Kumar[3]

[1]*M. Tech Scholar, SRMIET Khora Bhura Ambala*
[2]*Professor and Director, Department of Civil Engineering, SRMIET Khora Bhura Ambala*
[3] *Assistant Professor and Head of Civil Engineering Department, SRMIET Khora Bhura Ambala*

---***---

Abstract - The Indian concrete industry is today consuming millions of tonnes of concrete every year and it is expected to increase further in upcoming years. All the materials required to produce such huge quantities of concrete come from the earth's crust, thus depleting its resources every year creating ecological strains. On the other hand, human activities on earth produce solid wastes in considerable quantities including industrial wastes, agricultural wastes and other wastes from rural and urban societies. Disposal of such solid wastes involves economic issues as well as ecological and environmental considerations. The plastic is one of the recent engineering materials which have appeared in the market all over the world. Some varieties of naturally occurring thermoplastics were known to Egyptians and Romans who extracted and used these plastics for various purposes. Plastics were used in bath and sink units, corrugated and plain sheets, floor tiles, joint less flooring, paints and varnishes and wall tiles. There has been a steep rise in the production of plastics in last 30 to 40 years. Major part of total waste is plastic products, which deserves special attention on account of non- biodegradable property which is creating a lot of problems in the environment. There is however now increase in awareness regarding the utilization of plastic as a useful building material in our country.

1. INTRODUCTION

Concrete, usually Portland cement concrete (for its visual resemblance to Portland stone), is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over time—most frequently in the past a lime-based cement binder, such as lime putty, but sometimes with other hydraulic cements, such as a calcium aluminate cement or Portland Cement. It is distinguished from other, non-cementitious types of concrete all binding some form of aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder. When aggregate is mixed with dry Portland cement and water, the mixture forms a fluid slurry that is easily poured and molded into shape. The cement reacts with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete. Concrete is one of the most frequently used building materials. Its usage worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed $600 billion in revenue by 2025.

2. REQUIREMENTS OF A PAVEMENT

An ideal pavement should meet the following requirements:

I Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
II Structurally strong to withstand all types of stresses imposed upon it.
III Adequate coefficient of friction to prevent skidding of vehicles.
IV Smooth surface to provide comfort to road users even at high speed.
V Produce least noise from moving vehicles.
VI Dust proof surface so that traffic safety is not impaired by reducing visibility.
VII Impervious surface, so that sub-grade soil is well protected.
VIII Long design life with low maintenance cost.

3. TYPES OF PAVEMENTS

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

4. REVIEW LITERATURE

Ali et. al., (1998) an experimental study is being conducted to evaluate the effects of incorporating crumb rubber, very fine tire rubber particles, into Portland cement concrete. The objective of the study is to evaluate the effects of rubber aggregate into portlant cement concrete (PCC) properties. Initially, the rubber content replacing fine aggregates into the concrete mix was investigated by examining the concrete failure characteristics and the amount of energy absorbed during testing.

Khan, A and Nehdi M. (2001) this paper emphasizes another technically and economically attractive option, which is the use of recycled tire rubber in portland cement concrete. Preliminary studies show that workable rubberized portland cement concrete (rubcrete) mixtures can be made provided that appropriate percentages of tire rubber are used in such mixtures. Achievements in this area are examined in this paper, with special focus on engineering properties of rubcrete mixtures. These include: workability, compressive strength, split-tensile strength, flexural strength, elastic modulus, Poisson's ratio, toughness, impact resistance, sound and heat insulation, and freezing and thawing resistance.

C. Ferreire et. al., (2003) present study focuses on existing practices related to the reuse of Municipal Solid Waste (MSW) fly ash and identifies new potential uses. Nine possible applications were identified and grouped into four main categories: construction materials (cement, concrete, ceramics, glass and glass–ceramics); geotechnical applications (road pavement, embankments); "agriculture" (soil amendment); and, miscellaneous (sorbent, sludge conditioning).

Amit Goel and Animesh Das (2004) India is undergoing through a large no of projects.This paper presents some emerging road materials and innovative application concepts which will promising for future developments.

Tarun R. Naik and Rafat Siddique (2004) studies show that workable rubberized concrete mixtures can be made with scrap-tire rubber. This paper presents an overview of some of the research published regarding the use of scrap-tires in portland cement concrete. The benefits of using magnesium oxychloride cement as a binder for rubberized concrete mixtures are also presented. The paper details the likely uses of rubberized concrete.

Chi-Sun Poon and Dixon Chan (2006) paper presents an investigation on the cause of the self-cementing properties by measuring X-ray diffraction patterns, pH values, compressive strength and permeability of various size fractions of the FRCA obtained from a commercially operated construction and demolition waste recycling plant. Their influence on the overall sub-base materials was determined. The results indicate that the size fractions of <0.15 and 0.3–0.6 mm (active fractions) were most likely to be the principal cause of the self-cementing properties of the FRCA.

Mehmet Gesoğlu and Erhan Güneyis (2007) study presented herein has been carried out in order to investigate the strength development and chloride permeability characteristics of plain and rubberized concretes with and without silica fume. For this purpose, two types of tire rubber, namely crumb rubber and tire chips, were used as fine and coarse aggregate, respectively, in the production of rubberized concrete mixtures which were obtained by partially replacing the aggregate with rubber.

Rafat Siddique et. al., (2008) in this paper presents a detailed review about waste and recycled plastics, waste management options, and research published on the effect of recycled plastic on the fresh and hardened properties of concrete. The effect of recycled and waste plastic on bulk density, air content, workability, compressive strength, splitting tensile strength, modulus of elasticity, impact resistance, permeability, and abrasion resistance is discussed in this paper.

N. Oikonomou and S. Mavridous (2009) applications where tyres can be used and where the addition of tyre rubber has proven to be effective in protecting the environment and conserving natural resources include the production of cement mixtures, road construction and geotechnical works. Recycling of tyres in the applications mentioned above represents a suitable means of disposal for both environmental and economic reasons.

Manasseh Joel (2010) suitability of Crushed granite fine (CGF) to replace river sand in concrete production for use in rigid pavement was investigated. Slump, compressive and indirect tensile strength tests were performed on fresh and hardened concrete.28 days Peak compressive and indirect tensile strength values of 40.70N/mm2 and 2.30N/mm2 respectively was obtained, with the partial replacement of river sand with 20% CGF, as against values of 35.00N/mm2 and 1.75N/mm2 , obtained with the use of river sand as fine aggregate. Based on economic analysis and results of tests, river sand replaced with 20% CGF is recommended for use in the production of concrete for use in rigid pavement. Conservation of river sand in addition to better ways of disposing wastes from the quarry sites are some of the merits of using CGF.

Pasetto et. al., (2010) this paper presents the results of an investigation to verify the suitability of an industrial waste material, known as Electric Arc Furnace (EAF) steel slag, for recycling in the lithic matrix of cement bound granular material for road foundations. A preliminary study of the chemical, leaching, physical and mechanical properties of the EAF steel slag was followed by the mix design, based on Proctor compaction, compression and indirect tensile tests. Mechanical characterization of the mixtures was completed with the elastic modulus evaluation, through ultrasonic tests.

M. Sivaraja et. al. (2010) in his paper "Mechanical Strength of Fibrous Concrete with Waste Rural Materials" focuses on various mechanical properties of concrete specimens made by mixing the plastic fibers in concrete. The volume fraction of waste was varied from 0. 5% to 1.5%.

R. Lakshmi and S. Nagan (2011) in his paper "Investigations on Durability Characteristics of E-plastic Waste Incorporated Concrete" presents the results of an investigation to study the performance of concrete prepared with E-plastic waste as part of coarse aggregate. An effort has been made to detail a systematic study of compressive strength of concrete with various proportions of E-waste as coarse aggregate in concrete. The test results showed that a significant improvement in compressive strength was achieved in the E-plastic concrete compared to conventional concrete.

R. Kandasamy and R. Murugesan (2011) in his paper "Fibre Reinforced Concrete Using Domestic Waste Plastics as Fibres" describes about the attempt that has been made in the present investigations to study the influence of addition of polythene fibers (domestic waste plastics) at a dosage of 0.5% by weight of cement. The properties studied include compressive strength and flexural strength. The studies were conducted on a M20 mix and tests have been carried out as per recommended procedures of relevant codes. Addition of 0.5% of polythene (domestic waste polythene bags) fiber to concrete increases the cube compressive strength of concrete in 7 days to an extent of 0.68%,increases the cube compressive strength of concrete in 28 days to an extent of 5.12%, Increases the cylinder compressive strength of concrete in 28 days to an extent of 3.84%,increases the split tensile strength to an extent of 1.63%; and the increase in the various mechanical properties of the concrete mixes with polythene fibers is not in same league as that of the steel fibres.

K. Ramadevi and R. Manju (2012) in her paper "Experimental Investigation on The Properties of Concrete with Plastic PET (Bottle) Fibres as Fine Aggregate" studied the use of PET (polyethylene terephthalate) bottles as the partial replacement of aggregate in Portland cement. Concrete with 1%, 2%, 4%, and 6% PET bottle fibres for fine aggregate were produced and compared against control mix with no replacement. It was observed that the compressive strength increased up to 2% replacement of the fine aggregate and it gradually decreased for 4% and 6% replacement.

5. SCOPE AND OBJECTIVE OF STUDY

This work seeks to study properties of pulverized plastic replace with aggregate in concrete, with scope and objectives are on next page:

I. Several design concrete mixes with different percentages (i.e. 0%, 14%, 24%, and 34%) of plastic waste on the strength criteria of M40 concrete will be casted into desire shapes and sizes as per the requirement of the tests.

II. Compressive strength of concrete with or without Plastic waste for 14 days and 28 days will be observed.

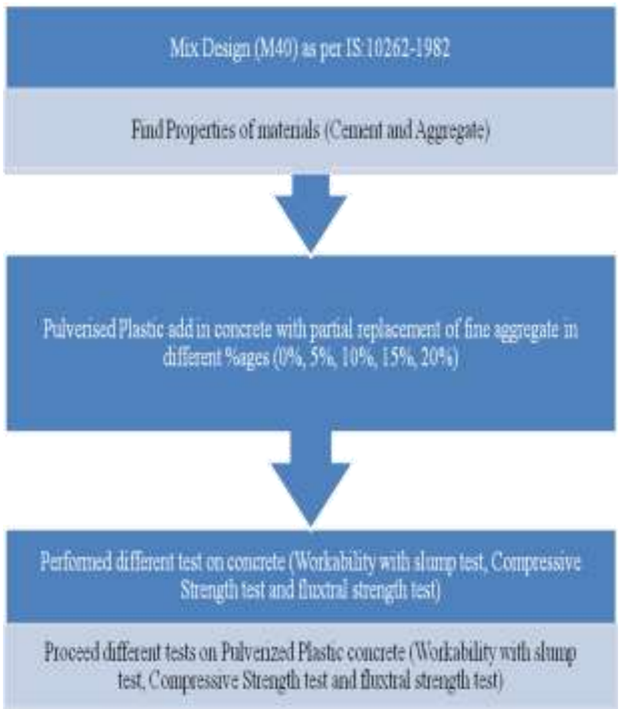
III. As partial substitute for the fine aggregate (sand) in concrete composites.

IV. To present a comparative study on the Mechanical and Physical properties of Plastic waste incorporated concrete.

V. To determine the percentage of plastic which gives more strength when compared to control concrete.

Now a day our environment is suffer with many harmful materials which couldn't dispose off. Some techniques were implemented by government for dispose off those materials like plastic. The materials used in the present investigation are:

I. Cement – OPC 53 grade conforming to is 12269 – 1987
II. Fine aggregate – Natural sand – is 383 – 1970
III. Coarse aggregate – Crushed 20 mm maximum size – is 282 – 1970
IV. Plastic waste material
V. Portable water



Methodology flow diagram used for this dissertation work

6. MIX DESIGN

The selection of mix materials and their required proportion is done through a process called mix design. There are number of methods for determining concrete mix design. The methods used in India are in compliance with the BIS (Bureau of Indian Standards). The objective of concrete mix design is to find the proportion in which concrete ingredients-cement, water, fine aggregate and coarse aggregate should be combined in order to provide the specified strength, workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2000. The specification of a concrete mix must therefore define the materials and strength, workability and durability to be attained. IS:10262-1982 gives complete guidelines for design of concrete mix. In this study, six batches of mixes were determined. The mixes was taken with (1:1.83:2.6, w/c=0.41). The natural fine aggregate was replaced by pulverized plastic fine aggregate with the ratio of 0%, 5%, 10%, 15% and 20%. The properties such as compressive strength with cube mould and beam mould.

7. Pulverized Plastic

Polyvinyl Chloride (PVC) is used as a partial substitute for the fine aggregate (sand) in the concrete composites. The plastic waste is acquired from various scrap vendors. PVC is a major plastics material which finds widespread use in building, transport, packaging, electrical/electronic and healthcare applications. PVC is a very durable and long lasting construction material which can be used in a variety of applications, rigid or flexible, white or black and a wide range of colours in between. Due to its very nature, PVC is used widely in many industries and provides very many popular and necessary products. PVC can be clear or coloured, rigid or flexible, formulation of the compound is key to PVC's. PVC can be plasticised to make it flexible for use in flooring products. Unlike other thermoplastics which are entirely derived from oil, PVC is manufactured from two starting materials;

I. 57% of the molecular weight derived from common salt
II. 43% derived from hydrocarbon feedstock's (increasingly ethylene from sugar crops is also being used for PVC production as an alternative to ethylene from oil or natural gas)

PVC's major benefit is its compatibility with many different kinds of additives, making it a highly versatile polymer. PVC can be plasticized to make it flexible for use in flooring products. Rigid PVC, also known as PVC-U (the U stands for "unplasticised") is used extensively in building applications such as window frames and cladding. Its compatibility with additives also allows for the possible addition of flame retardants although PVC is intrinsically fire retardant because of the presence of chlorine in the polymer matrix. PVC has excellent electrical insulation properties, making it ideal for cabling applications. Its good impact strength and weatherproof attributes make it ideal for construction products.PVC can be clear or coloured, rigid or flexible, formulation of the compound is key to PVC's "added value".

Pulverised Plastic material used in concrete

General properties of the rigid PVC material.

Property	Value
Density	1380 kg/m^3
Specific Gravity	1.40
Young's modulus	2900-3300 MPa
Tensile strength	50-80 MPa
Melting point	212 ^{o}C
Vicat temperature	85 ^{o}C
Water absorption	0.04-0.4
Linear expansion coefficient	8.10^{-5} /K
Specific heat	0.25 BTU

8. MIX PROPORTION

The ratio of pulverized plastic to total aggregate (by weight) is termed as the PP weight replacement with fine aggregate. The mix proportion of the concrete are given in Table: 3.7 in which FA - Fine Aggregate, CA - Course Aggregate, PP - Pulverized Plastic.

9. SPECIMENS CASTING

The mix M40 chosen with design proportion (1:1.83:2.6, w/c=0.41). The concrete mix was prepared using fine aggregate obtained from partial replacement of fine aggregate with Pulverized plastic from an old waste material (collected from scrap shop located at Chandigarh industrial area) Mix with proportional amount of natural fine and coarse aggregate were prepared and used to cast the specimens.

Cube mould

In all the above mentioned mixes workability was measured by slump test, compaction factor test and flow table test. The test specimens were (150mm x 150mm x 150mm) cubes and beam mould (700mm x 150mm x 150mm) for compressive strength and flexural strength test. The specimens were cast according to IS: 516-1959. The specimens were tested at the age after 14 days curing and 28 days curing. The compaction is very important in respect of strength. In this study compaction is done with vibrator. The aggregates used were in saturated and surface-dry condition.

Beam mould

The test procedures were followed as per relevant Indian standard specifications. The batching was done by weight.

10. Mixing and Compaction

The component materials were weighted on the weighting machine. The mixing was done with the help of machine. Cement, fine aggregate and coarse aggregate were thoroughly mixed in dry condition to get the homogeneous mix. Water was then added slowly to get a uniform mix. The mixing time was in the range of 4-5 minutes for all the mixes. Cast iron moulds were used for casting specimens. The specimens were cast according to IS: 516-1959. The compaction was done by vibrating the moulds for about 2 minutes using the table vibrator. Excess material was struck off using a rod. Top surface was given smooth finish using suitable floats and trowel. The concrete specimens were removed from the moulds after 24 hours. Specimens were kept in clean and fresh water for curing in water tanks and cured till testing. The cubes and beam specimens were tested after 14 days of curing and 28 days curing.

11. Curing

The test specimen should be stored in a place at temperature of 27° +/- 2°C for 24 +/- 0.5 hours from the time addition of water to the dry ingredients. After this period the specimen should be marked and removed from the mould and immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to the test. The water or solution in witch the specimens are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.

12. PROPERTIES OF FRESH CONCRETE (WORKABILITY)

A number of different methods are available for measuring the workability of fresh concrete, but none of them is wholly satisfactory. Each test measures only a particular aspect of it and there is really no method which measures the workability of concrete in its totality. However, by checking and controlling the uniformity of the workability it is easier to ensure a uniform quality of concrete and hence uniform strength for a particular job. In the present work, following tests were performed to find workability.

S. No.	Mix	W/C	%PP	Slump Value (mm)	Compaction Factor Value
1.	1:1.83:2.6:0.00	0.41	0	39	0.86
2.	1:1.74:2.6:0.09	0.41	5	36	0.84
3.	1:1.65:2.6:0.18	0.41	10	32	0.81
4.	1:1.55:2.6:0.28	0.41	15	27	0.78
5.	1:1.46:2.6:0.37	0.41	20	22	0.73

a) The Slump Test
b) The Compaction Factor Test
c) The Flow Test

In this study first two tests are done the values obtained from tests mentioned above.

13. TESTING PROCEDURE

After the specified period of curing the specimens were taken out of the curing tank and their surfaces were wiped off. The various tests were performed such as Compressive Strength of Cubes after 14 days of curing & 28 days curing.

14. Compressive Strength test

The specimens were tested at the age of 7 and 28 days. The cubes were tested on universal testing machine after drying at room temperature according to IS 516-1959.

Universal testing machine

The load was applied continuously without impacts and uniformly @140N/cm²/minute. Load was continued until the specimen failed and maximum load carried by the specimen was recorded. The cube compressive strength was obtained by considering the average of three specimens at each age.

15. Flexural Strength test

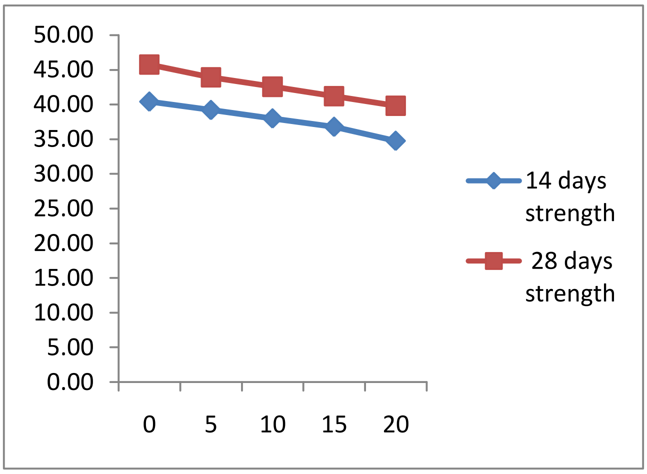
The beam mould shall is of metal, preferably steel or cast iron and the metal shall be of sufficient thickness to prevent spreading or warping. The mould shall be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimens without damage. The bed of the testing machine shall be provided with two steel rollers, 38mm in diameter, on which the specimen is to supported and these rollers shall be so mounted that the distance from centre to centre is 60cm for 15cm specimens.

Flexural testing machine

The load shall be applied through two similar rollers mounted at the third points of the supporting span that is spaced at 20cm centre to centre.the load shall be divided equally between the two loading rollers and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses. The load applied without shock and increasing continuously at a rate such that the extreme fiber stresses increase at approximately 7kg/sq.cm/min. that is at a rate of loading 400kg/min. The load increase until the specimen fails, and the maximum load applied to the specimen during the test to be recorded.

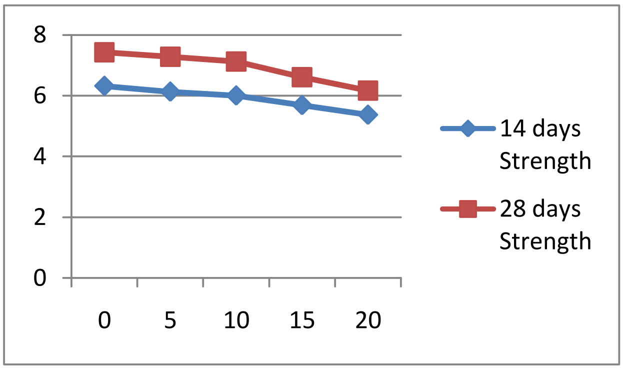
16. RESULTS AND DISCUSSION

The specimens were tested at the age of 14 days curing and 28 days curing. The cubes were tested on universal testing machine after drying at room temperature according to IS 516-1959.

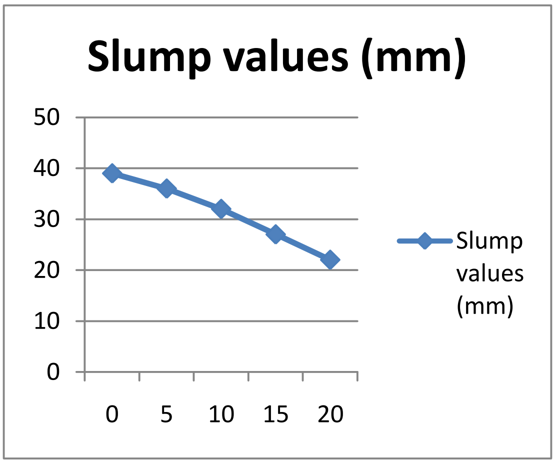


14 days Compressive strength compare with 28 days Compressive strength

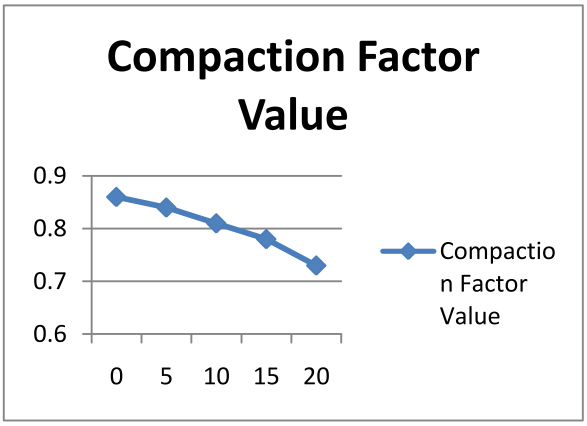
The specimens were tested at the age of 14 days curing and 28 days curing. The beams were tested with flexural testing machine after drying at room temperature according to IS 516-1959.



14 days Flexural strength compare with 28 days Flexural strength



Slump values with various percentage of PPC



Compaction factor with various percentage of PPC

17. CONCLUSIONS

Study on the partial replacement of fine aggregate with pulverized plastic in construction mix design proportion the following conclusions have been drawn based on the observations and discussion of test results:

I Compressive strength of Mix design without any replacement of fine aggregate is more than compressive strength observed with partially replacement of pulverized plastic. The compressive strength decrease 14% for 14 days curing and 13% for 28 days curing with the %age of pulverized plastic (20%).

II Compressive strength is decreases with increases the partial replacements of fine aggregate with pulverized plastic percentages (0%, 5%, 10%, 15%, 20%).

III Flexural strength of Mix design without any replacement of fine aggregate is more than Flexural strength observed with partially replacement of pulverized plastic. The Flexural strength decrease 15% for 14 days curing and 17% for 28 days curing with the %age of pulverized plastic (20%).

IV Flexural strength is decreases with increases the partial replacements of fine aggregate with pulverized plastic percentages (0%, 5%, 10%, 15%, 20%).

V Economical and environmental pressures justify consideration of this alternative material source i.e. pulverized plastic from waste (scrap), in places where there is lesser-availability of natural aggregate or available sources of new rocks are inaccessible either because of high land values or zoning constrains.

VI It can be said that it is a creative and environment friendly solution to use any plastic waste as replacer of any content in concrete.

18. REFERENCES

1. Tarun R.Naik and Rafat Siddique.," Properties of concrete containing scrap-tire rubber." Elsevier of waste management, volume 24, issue 6, pp 563-569 (2004).

2. Manasseh JOEL.," Use of Crushed Granite Fine as Replacement to River Sand in Concrete Production." Leonardo Electronic Journal of Practices and Technologies, issue 17, pp 85-96 (2010).

3. Mehmet Gesoğlu Erhan Güneyis.," Strength development and chloride penetration in rubberized concretes with and without silica fume."Journal of Material and science, volume 40, issue9, pp 953-964 (2007).

4. C.Ferreire , A.Ribeiro and L.ottosen.," Possible applications for municipal solid waste fly ash." Journal of Hazardous Materials, volume 96, issue 2-3, pp 201-216 (2003).

5. Rafat Siddique, Jamel Khatib and Inderpreet Kaur.," Use of recycled plastic in concrete." Journal of Waste Management, volume 28,issue 10, pp 1835-1852 (2008).

6. Chi-Sun Poon and Dixon Chan." The cause and influence of self-cementing properties of fine recycled concrete aggregates on the properties of unbound sub-base." Journal of Waste Management, volume 26, issue 10, pp 1166-1172 (2006).

7. Ali, A-H and Goulias," Evaluation of Rubber-Filled Concrete and Correlation Between Destructive and Nondestructive Testing Results."Journal of ASTM International, volume 20,issue 1, pp 140-144 (1998).

8. Amit Goel and Animesh Das." Emerging Road materials and Innovative Applications."National Conference on Materials and Innovative Applications,pp 26-27 (2004).

9. N.Oikonomou S.Mavridous.," The use of waste tyre rubber in civil engineering works."Journal of

Sustainability of Construction Materials,pp 213-238 (2009).

10. Pasetto, Marco; Baldo, Nicola.," RECYCLING OF STEEL SLAGS IN ROAD FOUNDATIONS."Journal of ABSCO information services,volume 9 ,issue 6, pp 773-777 (2010).

11. Swaptik Chowdhury , Aastha Tashkant Maniar and Om. Suganya ." Polyethylene Terephthalate (PET) Waste as Building Solution." International Journal of Chemical, Environmental & Biological Sciences, volume 1, issue 2, pp 308-312 (2013).

12. Vignesh Kumar Nagarajan , S. Aruna Devi , S. P. Manohari and, M. Maria Santha.," Experimental Study on Partial Replacement of Cement with Coconut Shell Ash in Concrete." International Journal of Science and Research (IJSR), volume3, issue 3,pp 651-661 (2014).

13. Priyanka Asutkar, S.B.Shinde and Rakesh Patel.," Study on the behaviour of rubber aggregates concrete beams using analytical approach." International Journal of Engineering Science and Technology, volume20, issue 1,pp 151-159 (2017)

14. M.Iqbal Khan and Samir Dirar.," Novel lightweight concrete containing manufactured plastic aggregate." Journal of Construction and Building Materials, volume 148, issue 1,pp 386-397.(2017).