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Enhancement of Higher Performance Concrete (Hpc) By Using Waste Tyre Rubber Powder and waste Plastic in Modified Road Construction Process

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Abstract-Now-a-days it is necessary to utilize the wastes effectively with technical development in each field. The old abandoned tyres from cars,trucks,farm and construction equipment and off-road vehicles are stockpiled throughout the country. This leads to various environmental problems which include air pollution associated with open burning of tyres and other harmful contaminants like (polycyclic aromatic hydrocarbon, dioxin, furans and oxides of nitrogen) and aesthetic pollution. They are non-biodegradable; the waste tyre rubber has become a problem of disposal. This paper is intended to study the feasibility of waste tyre rubber as binding material in bitumen, the waste tyre rubber is used with aggregate in different layer and also on the top surface layer mixed with bitumen in percentage and carried out different test result based on it, finding through it the difference in result by forming normal and rubber pavement and calculate the increase in strength of road pavement and also economically achieve.This is not only minimizes the pollution occurred due to waste tyres but also minimizes the use of conventional aggregate which is available in exhaustible quantity.

Keywords: Rubber aggregate, Crumb rubber, bitumen, Marshal stability test.

I. INTRODUCTION

Concrete is a widely used material throughout the world. Concrete, usually Portland cement concrete is a composite material composed of fine and coarse aggregate bonded together with cement (cement paste) that hardens over time. When aggregate is mixed together with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and moulded into shape. The cement reacts chemically 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 super plasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. The use of sustainable materials in construction industry is gaining popularity, as environmental preservation is becoming a primary societal concern globally. The use of waste rubber materials in sustainable concrete production is a relatively new concept and gradually gaining a lot of interest in recent years. The newly produced material would definitely pave the way for a greener environment, even though the idea is still in its conceptual phase due to lack of technical knowledge in its behaviour in concrete. Since the origin of waste rubber materials varies, their mechanical properties may fluctuate over a wide range. Therefore, proper guideline on the use of rubber in producing concrete and mortar is yet

to be established. Aggregate is one of the major constituted of the
concrete. Main strength of the concrete comes from the coarse aggregate and fine aggregate which acts as filler in between the structure of the concrete. Cement acts as a binder.

Rubber-based products; especially used rubber tyres from vehicles fill a significant portion of landfill spaces among all the waste materials. This is due to its non-degradable or non-decomposed characteristics consisting of small molecular weight additives, such as adhesives, stabilizers, colorants, plasticizers, and other fibers. These small but destructive molecular weight additives from discarded waste rubber tyres may leach to the soil surface and cause severe environmental and soil pollution. Usually a rubber tyre that is discarded or disposed at the end of its service life consists less than 1% abraded rubber. However, the main component in a tyre consists of 41% mixed synthetic and natural rubber. Therefore, a huge amount of waste is being generated every year from waste rubber tyre. Consequently, many unwanted pests, rats, and mosquitoes can make their breeding ground in these huge piles of waste rubber materials.

1.Cement Concrete Replacement

Cement concrete is the most commonly used building material in the world. It is plastic and malleable when it is mixed, strong and durable when hardened. The workability, strength, durability and the cost effectiveness make cement concrete a popular material in the construction industry. Strength and durability are essential properties of concrete that govern a wide range of structural abilities including permeability resistance, toughness, energy absorption and impact resistance. Conventional cement concrete is not much efficient with reference to durability and performance. On the downside, cement concrete is vulnerable to deterioration unless specific precautionary measures are taken during its design and production.

2.High Performance Concrete High Performance Concrete (HPC) is prepared by using a specific combination of cement, SCMs, mineral & chemical admixtures determined through many trial batches/mix designs to meet a specific performance requirement for a given application. The performance criteria are achieved by ensuring proper mix, transportation, placement and curing. In recent years, the usage of HPC has increased in various structural applications like high-rise buildings, bridges, masonry applications, parking lots, residential buildings and pavement construction etc.

It is well known that relatively low strength and elastic properties of concrete are due to the heterogeneous microstructure of the material, particularly the porous and weak transition zone that exists at the cementpaste and aggregate interface. The mechanical properties of concrete can be improved by densification and strengthening of the transition zone. This can be achieved by reducing the quantity of mixing water and increasing the cement content without compromising the workability by adding powerful cement dispersant like superplasticizer.

II. MATERIALS AND METHODS

1. General

In this chapter the details of the experimental investigations carried out is described. It describes the materials used in the investigation, properties, test specimen details, experimental set-up and procedures adopted to determine the mechanical characteristics of concrete with OPC, fly ash and tyre rubber. The physical and chemical properties of the materials used in the investigation are also presented

2.Materials used in Investigation

2.1.Cement

Cement plays a major role in the concrete; it acts as the binder and forms a cohesive mix which develops strength over a period of time. In the present study 53 grade Ordinary Portland Cement conforming to IS 12269:2013 was used. The properties of cement was tested as per IS 4031-1996 (reaffirmed 2005) & IS 4032-1985(reaffirmed 2005). The physical and chemical properties of cement are given in Table 4.1 and Table 4.2 respectively. Figure 1 shows the major chemical constituents of OPC.

Table 1: Physical properties of Cement.

Sl. No	Physical Properties	Test Result	Requirements as per standards
1	Fineness (% retained on 90-μm	8.2	10
2	Normal Consistency (%)	28	25-35
3	Initial Setting Time (minutes)	33	30 (minimum)
4	Final Setting Time (minutes)	420	600 (maximum)
5	Compressive Strength of 75 mm	53.6	53 (minimum)
6	Specific Gravity	3.15	3.15

Table 2: Chemical composition of Cement

Chemical content	Value %
Calcium Oxide (CaO)	60.81
Silica (SiO_2)	19.5
Alumina (Al_2O_3)	4.12
Iron oxide(Fe_2O_3)	6.06
Magnesia(MgO)	1.52
Alkalis (Na_2O)	0.05
Alkalis (K_2O)	0.28
Sulphur Anhydrite(SO_3)	2.48
Total Loss on Ignition	3.41
Insoluble Residue	1.51
Chloride	0.01

2. Fly Ash

Class F fly ash obtained from Bhatinda thermal power plant, India was used in this work. The physical properties and chemical composition of fly ash are given in Table 4.3 and Table 4.4 respectively. Figure 4.2 shows the major chemical constituents of fly ash.

Table 3: Physical properties of Fly Ash

Sl no	Characteristic	Value
1	Specific gravity	2.20
2	Specific surface area (m^2/g)	1.24
3	Moisture content (%)	0.20
4	Wet density (gram/cc)	1.75
5	Turbidity (NTU)	459
6	pH	7.3

3.Silica Fume

Silica fume is a very fine powder. When used to produce high performance concrete, silica fume is typically 4-15% of the cement weight. The physical and chemical properties are listed in Table 4.5 and Table 4.6 respectively.

Table 5: Physical properties of Silica Fume

Physical Property	Result
Physical state	Micronized Powder
Odour	Odourless
Colour	White
Appearance	White colour powder
Peak density	0.76 gm/cc
pH of 5% solution	6.90
Specific Gravity	2.63
Moisture	0.058%
Water absorption	55 ml/100gm

Table 6: Chemical properties of Silica Fume

Chemical	Percentage (%)
Silica (SiO_2)	99.56
Alumina (Al_2O_3)	0.043
Ferric Oxide (Fe_2O_3)	0.040
Calcium Oxide (CaO)	0.001
Magnesia (MgO)	0
Sodium Oxide (Na_2O)	0.003
Potassium Oxide (K_2O)	0.001
Titanium Oxide (TiO_2)	0.001
Loss on ignition	0.015

4. Fine Aggregate

Local river sand which is available in Chennai was used as fine aggregate in the concrete. The fine aggregate used in the investigation complied with the requirements of IS 383-1970 (reaffirmed 2002). The river sand conforming to grading Zone III of IS 383-1970 (reaffirmed 2002) was used as fine aggregate. The sand was tested as per the procedure given in IS 2386:2002(Part-3) in the laboratory. The details of physical properties of fine aggregates are given in Table 4.7.

Table 7: Physical properties of fine aggregate

Sl.No.	Test Particulars	Value
1	Specific Gravity	2.39
2	Fineness Modulus	2.4
3	Bulk Density(kg/m^3)	1780
4	Size (mm)	Below 4.75
5	Water Absorption (%)	0.93

5. Coarse Aggregate

Crushed granite stone of size between 12.5 mm and 20 mm were used as coarse aggregate. The coarse aggregate used in the investigation complied with the requirements of IS 383: 2016. In the present investigation, locally available crushed blue granite stone aggregate of size between 20mm and 12.5mm was used. The physical properties of the coarse aggregates are given below in Table 4.8.

Table 8: Physical properties of coarse aggregate

Sl.No.	Test Particulars	Value
1	Shape	Angular
2	Specific gravity	2.9
3	Bulk density (kg/m^3)	1691
4	Size (mm)	12.5 to 20
5	Water Absorption (%)	1.4

6. Tyre Rubber

Waste tyre rubber pieces were collected from the local market of Kolkata. The pieces were cleaned with soap water and rinsed with clean water. After drying under sun at open place, both faces of the tyre pieces were rubbed with hard wire brush to make surfaces as rough. Tyre may be divided into two types – car and truck tyres. Car tyres are different from truck tyres with regard to constituent materials (e.g. natural and synthetic rubber). In the present study the old rubber from heavy vehicles, such as truck tyre was used. The chipped rubber samples were obtained by cutting the tyre manually. The scrap tyre rubber chips passing through the 20 mm sieve size were used in the study. The tyre rubber used for this investigation is shown in Plate 3.1

Fig 1. Chipped rubber

7. Water

In the present investigation, clean potable tap water as per the requirement IS456-2000 was used for mixing of the concrete and curing. The Physico-chemical properties of potable water are shown in Table 4.9 and also mansion the maximum permissible limit as per IS 456-200 (Reaffirmed 2005).

Table 9: Properties of water

Types of Solids	Content in Potable water	Max. Permissible Limits (IS456-2000)
Organic	130	200
Inorganic	610	3000
Sulphate	180	400
Chloride	380	2000
Total dissolve solid	880	2000
pH	7.2	<6.0

All parameters are expressed in mg/lit. except pH value

III. METHODOLOGY

The research work was divided into three phases. In phase I, the mechanical properties such as workability, compressive strength and tensile strength of concrete with 0%, 5%, 10% and 15% chipped rubber aggregate as partial replacement for coarse aggregate were determined. It is observed that a rise in the percentage of substitution of chipped rubber beyond 10% reduces 56 the compressive strength.

As a result, an investigation into the flexural behavior of the RC beam with 5% and 10% coarse aggregate replacement with chipped rubber was carried out. The crack pattern; load- deflection behaviour, moment-curvature and ductility of the RC beam were studied. A durability study on rubber aggregate concrete was also done by immersing a concrete cube in a 5% H_2SO_4 solution as per ASTM C-267. A total of 233 specimens were tested in the phase I. All the specimens were tested after 7 days and after 28 days of curing. Phase I studies show that compression strength, tensile strength and ultimate capacity of load carrying for the RC beam are reduced beyond 10% by the substitution of coarse aggregate with chipped rubber. In order to enhance the strength of concrete, in phase II studies, 40% of the cement was replaced with fly ash and 5% silica was added by weight of cement along with 5% rubber aggregate for replacement of coarse aggregate. It is termed as Modified Rubber Concrete. In phase II cubes, cylinders, and prisms were cast to determine compressive strength, flexural strength, tensile strength and durability against acid, heat and salt, water absorption, and mass loss/gain. Concrete cubes and cylinders were immersed in acid, salt and subjected to a temperature of 150°C for 3 hours to study the durability properties of modified rubber concrete. The modulus of elasticity of modified rubber concrete was also found using a compressometer. The crack pattern, load- deflection behavior, moment-curvature and ductility of the RC beam made from modified rubber concrete were also studied. In phase II, a total of 158 specimens were tested.

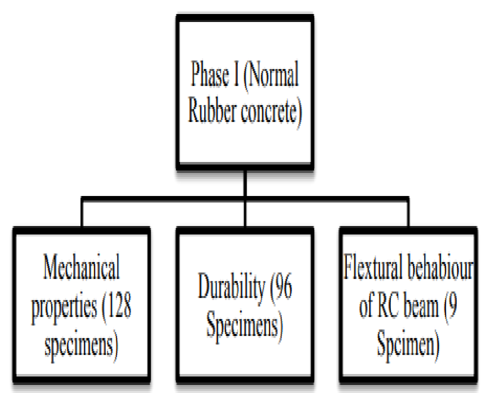

Fig 2. Methodology

1 Preparation Of Test Specimens And Curing

1.1. Concrete Mix Design

The test results of the materials were used to design the concrete mix as per the recommendations of IS 10262:2009. The grade of concrete used in the present investigation was M 50. Table 3.13 shows the mix proportion.

Table 10 Mix proportions

Grade of concrete	Target strength (N/mm²)	W/c ratio	Mix proportion
M20 (control mix)	56.60	0.5	1:1.4:3.1
M20 (with admixture)	56.60	0.48	1:2.36:2.93
M20(with fly ash)	56.60	0.48	1:1.9:2.40

1.2 Preparation of Test Specimens

Total 5 types of mix proportion were prepared with 0, 5, 10, and 15 percentage of rubber replacing the coarse aggregate for the first phase. Workability, compressive strength, tensile strength, and flexure strength was found out.

Table 11Shows the specimens designation.

Designation	Specification
RP 0	Control concrete with 0% rubber
RP 5	Control concrete with 5% rubber
RP 10	Control concrete with 10% rubber
RP 15	Control concrete with 15% rubber
F40S5R0	Specimen with 40% fly ash and 5% silica 0% CR
F40S5R5	Specimen with 40% fly ash and 5% silica 5% CR

1.3 Mechanical BehaviourOf Concrete With Rubber

Mix proportions were arrived at for concrete with 0, 5, 10, and 15 percentage of rubber replacing the coarse aggregate in the first phase. The mechanical behaviour of concrete with 0%, 5%, 10%, and 15% rubber replaced with coarse aggregate was investigated. Tests were conducted to determine the workability, compressive strength, splitting tensile strength, flexural strength and durability. The cubes were cast and tested at 7 and 28 days of curing.

1.4 Workability Test

Slump cone apparatus was used to find out the workability as per IS 7320:1974 (Reaffirmed 2008). Plate 3.2 shows workability of concrete mix in terms of slump value.

Fig 3. Slump cone test

1.5 Compressive Strength Test

Compression Testing Machine – 200 tons capacity was used to determine the compressive strength. The test was carried out as per the specifications of IS 516-1959 (Reaffirmed 2004). Concrete cubes of 150mmx150mm were cast and tested at 7 and 28 days of curing. The experimental set up for compressive strength test is shown in Plate.

1.6 Splitting Tensile Strength

Splitting tensile strength test on cylinder is an indirect test used for assessing the tensile strength of concrete in the laboratory and it is widely accepted. Splitting tensile strength test on concrete was performed on 300 mm long and 150 mm diameter concrete cylinder specimens curing as per the procedure specified in IS 5816:1999 (Reaffirmed 2004). Plate 3.4 shows the split tensile strength test set up.

1.7 Flexural Strength

Flexural strength is a measure of the resistance of the material to deformation. It is also indicative of the load at which cracks begin to develop. Flexural strength of concrete is expressed as Modulus of

Rupture. It is obtained by testing beams under symmetrical two-point loading according to IS 516-1959 (Reaffirmed 2004) in the Machine. Plate 4 shows Flexural strength test setup

Fig 4. Compression test on concrete cubes.

IV. RESULTS AND SIMULATION

1. Compressive Strength Test

Compressive strength off concrete cubes with without rubber aggregate was found out at 7days and 28 days of curing and tabulated in Table 5.3.

Fig 5. Failure of cube RP 5 It is observed that, compressive strength decreases as the rubber percentage increases.

A satisfactory level is found to be up to 5% replacement of coarse aggregate. Failure of specimen RP 5 is shown in Plate 4.1

4.2 Flexural Strength Test

Flexural strength was found out by testing prisms under symmetrical two-point loading according to IS 516:1959. Flexural strength of concrete specimens were tabulated in Table 5.5

Hypothesis:

- **H01:** There is no significant possibility of some kind of performance increase or decrease when rubber powder and waste plastic in modified road construction process is being used.
- **H1:** There is significant possibility of some kind of performance increase or decrease when rubber powder and waste plastic in modified road construction process is being used.

Table 12: Compressive strength

Specimen	Replacement of rubber aggregate (%)	7 days strength (MPa)	28 days strength (MPa)	Percentage reduction on w.r.t RP0 (28 days)
RP 0	0	48.8	58.2	-
RP 5	5	48.3	57.3	3.19%
RP 10	10	47.4	56.2	7.09%
RP 15	15	44.0	51.4	24.1%

Table 13: Spilt tensile strength with admixture

Specimen	Replacement of rubber aggregate (%)	7 days strength (MPa)	28 days strength (MPa)	Percentage reduction w.r.t RP0 (28 days)
RP 0	0	1.6	2.1	
RP 5	5	1.4	1.8	14.29%
RP 10	10	1.1	1.6	23.81%
RP 15	15	1.0	1.5	28.57%

one-tail		

Table 14: Flexural strength

Specimen	Replacement of rubber aggregate (%)	7 days strength (MPa)	28 days strength (MPa)	Percentage reduction w.r.t RP0 (28 days)
RP 0	0	3.3	4.6	-
RP 5	5	2.7	3.9	15.21 %
RP 10	10	2.6	3.8	17.39 %
RP 15	15	2.4	3.4	26.06 %

Table 15:Replacement of rubber Aggregate and days.

Replacement of rubber aggregate (%)	7 days strength (MPa)
0	48.8
5	48.3
10	47.4
15	44

Table 16:F-Test Two-Sample for Variances.

F-Test Two-Sample for Variances		
	Replacement of rubber	7 days strength
Mean	7.5	47.125
Variance	41.66667	4.675833
Observations	4	4
df	3	3
F	8.911068	
P(F<=f) one-tail	0.052731	
F Critical	9.276628	

Test statistics Result:

In this F- Test F ≅Fcritical, hence Null hypothesis reject, and the alternate hypothesis is accepted**.**

Interpretation and Discussion:

There is significant possibility of some kind of performance increase or decrease when rubber powder and waste plastic in modified road construction process is being used.

V. CONCLUSION AND FUTURE SCOPE

CONCLUSION

Plastics will increase the melting point of the bitumen. The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source on income. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50oC and torrential rains create havoc, leaving most of the roads with big potholes. It is hoped that in near future we will have strong durable and eco-friendly roads which will relieve the earth from all types of plastic-waste.
Rubber waste which is the major challenge for the environmental can be reduce by re using it to the bitumen road construction. All the above authors have concluded that the use of waste tires in road can be improve it near about all the parameter of the bitumen road.

The combination of wet and dry process can be used, part of the plastic waste is coated on aggregate for improvement of impact and crushing strength of aggregate by applying dry process and remaining part of plastic waste is mixed in bitumen by applying wet process therefore the total loading of plastic waste can be increased as well as the improvement in mechanical properties will occurred.

Following results showing maximum loading of waste into bitumen for road construction, which is obtained for each blend. For olefin waste, optimum results were obtained as 6% loading by weight addition of plastic waste in bitumen. As the plastic content increases there is reduction in ductility, because the plasticity of bitumen increases at services temperature. Minimum value of ductility (in cm) is required for proper application of bitumen in road is 62; otherwise. It will tend to from cracks and crazes at heavy load,

1. For Crumb rubber, it is found that 4% of waste can be successfully added in bitumen but there is non-uniform mixture observed as increase in the % addition of crumb rubber which affects the surface of road.
2. The mixture of crumb rubber-HDPE loading obtained optimum results. This kind of mix polymer waste was added upto 8% i.e. 4% crumb rubber and 4% HDPE.
3. The HDPE & PP Plastics waste were added separately but the only limitation was that doesn't disperse uniformly in the bitumen. Maximum amount of loading observed was upto 4% because further addition of HDPE and PP Plastics waste reduces ductility of bitumen.
4. The addition of LDPE waste plastic optimum results were obtained at 6% percent loading with respect to weight of bitumen.
5. The addition of crumb rubber and HDPE waste optimum result were obtained upto 8% loading with respective weight of bitumen. The maximum amount of polymer waste that can be added in bitumen was 8%. Above which the properties of bitumen considerably falls.
6. Discussion for flash and fire point result – At high temperatures depending upon the grades of bitumen materials leaves out volatiles. These volatiles are susceptible for to catch fire which is cause (explosion) or hazardous. Hence, it is essential to qualify this temperature for each bitumen grade.

VI. FUTURE SCOPE

Flash and fire point of bitumen used in this experimentation significantly increased with increased in polymer (%) concentration thus the possibility of hazardous situation becomes less.

The increasing in traffic volume and higher traffic load brings challenges to the construction of roads; this is compounded by insufficient repair and maintenance work which have resulted in failure and reduced service life of roads. The properties and behavior of bitumen are related to loading period and temperature. In tropical countries, bitumen tends to be soft and more liquid as temperature increases, and this results in poor viscoelastic and rheological properties of the bitumen, thereby causing distress, such as permanent deformation (rutting), on road surface. In cold regions, on the other hand, bitumen turns hard and stiff, and this results in higher brittleness, thereby causing fatigue distress. A number of previous studies have shown that conventional bitumen experiences high pavement distress, especially rutting, fatigue failure and moisture damage. These problems have motivated researchers in the field of the highway and pavement engineering to find methods to solve the problems related with pavement distresses. Natural rubber is a sustainable alternative for petroleum-based modifiers since it is locally produced, environmentally friendly and low price fluctuation compared to petroleum-based modifiers. Therefore, the researchers hope to develop a cost effective and long-lasting natural rubber modified flexible road pavements which would also be fatigue and rut resistant. This will reduce the amount of work and expenditure required for the annual maintenance of asphalt mixtures around the world.

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