UTILIZATION OF RECYCLED CARBON BLACK ASH IN RIGID PAVEMENTS

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Abstract - *Concrete is the essential construction material used for many applications in the construction industry. Though it is used worldwide, it has its ill effects like the presence of pores and micro cracks. These ill effects lead to acid intrusion and less resistance to atmospheric attack. As a result, its durability and strength get reduced. The current tendency in the world is to find new materials at lower cost which can guarantee better performances during their incorporations in the rigid pavements. Usage of waste materials for construction purpose enhances the traditional methods of construction. The effect of addition of carbon black ash, a waste from rubber industry as a cementinous material in concrete is investigated. Study on split tensile strength, flexural strength and compressive strength of concrete specimens containing various percentages of carbon black were carried out. The effect of added carbon black to concrete mix on mechanical properties was studied by utilization of super plasticizer. This was carried by replacing in different concrete mixes containing 10, 20, 30, 40, 50 and 60% Carbon black ash.*

Key Words: Carbon black, Durability, Super Plasticizer, Waste materials.

1.INTRODUCTION

India has a road network of over 5,903,293 kilometers (3,668,136 mi) as of 31 January 2019, the second largest road network in the world. At 0.66 km of roads per square kilometers of land, the quantitative density of India's road network is similar to that of the United States (0.65) and far higher than that of China (0.46) or Brazil (0.20). As of May 2017, India had completed and placed in use over 28,900 kilometers of recently built 4 or 6-lane highways connecting many of its major manufacturing centers, commercial and cultural centers. The rate of new highway construction across India accelerated after 1999. Major projects are being implemented under the National Highways Development Project, a government initiative. The Government of India is attempting to promote foreign investment in road projects. Foreign participation in Indian road network construction has attracted 45 international contractors and 40 design/engineering consultants, with Malaysia, South Korea, United Kingdom and United States being the largest players. Road transport is vital to India's economy. It enables the country's transportation sector to contribute 4.7 percent towards India's gross domestic product, in comparison to railways that contributed 1 percent. Road transport has gained in importance over the years despite significant barriers and inefficiencies in inter-state freight and passenger movement compared to railways and air. The government of India considers road network as critical to the country's development, social integration and security needs of the country. India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. Indian road network is administered by various government authorities, given India's federal form of government. The table below describes the regulating bodies.

Table-1: Regulating bodies and Distances

ROAD CLASSIFICATION	AUTHORITY RESPONSIBLE	TOTAL KILOME TERS (as of 2016)
National Highways	Ministry of Road Transport and Highways (Central Government)	1,01,011
State Highways/	State Government (State public works department)	1,76,166
Major and other District Roads	Local governments, panchayats and municipalities	5,61,940
Rural Roads	Local governments, panchayats and municipalities	27,49,80 5

1.1 Rigid Pavement

There are two major types of pavement surfaces - Portland cement concrete (PCC) and hot-mix asphalt (HMA). Underneath this wearing course are material layers that give structural support for the pavement system. Concrete pavements have been used for highways, airports, streets, local roads, parking lots, industrial facilities, and other types of infrastructure. When properly designed and built out of durable materials, concrete pavements can provide many decades of service with little or no maintenance.

Three main types of concrete pavements commonly used are Jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP), and continuously reinforced concrete pavements (CRCP). JPCP's are constructed with contraction joints which direct the natural cracking of the pavement. These pavements do not use any reinforcing steel. JRCP's are constructed with both contraction joints and reinforcing steel to control the cracking of the pavement. High temperatures and moisture stresses within the pavement creates cracking, which the reinforcing steel holds tightly together. At transverse joints, dowel bars are typically placed to assist with transferring the load of the vehicle across the cracking. CRCP's solely rely on 3 continuous reinforcing steel to hold the pavement's natural transverse cracks together. Pre stressed concrete pavements have also been used in the construction of highways; however, they are not as common as the other three. Pre-stressed pavements allow for a thinner slab thickness by partly or wholly neutralizing thermally induced stresses or loadings.

The first concrete pavement was built in Bellefontaine, Ohio, in 1891, by George Bartholomew. He had learned about cement production in Germany and Texas and found pure sources of the necessary raw materials, limestone and clay, in central Ohio. Because this was the first concrete pavement, the city council required him to post a $5,000 bond that guaranteed the pavement would last 5 years.

The rigid pavements being constructed in India are mostly Plain Cement Concrete Pavements with dowel bars at contraction and construction joints. The expansion joints are provided only at the junction of the pavement with a bridge deck slab or approach slab. The pavement normally comprises of a tied shoulder 1.50 m wide along the outer slow lane, 2 x 3.5 m wide traffic lanes plus 0.25 m extra width beside a barrier type kerbs next to the central median. The sub- base comprises of a layer of roller compacted Dry Lean Concrete (DLC) having 10 Mpa 7-day compressive strength. It is separated from the pavement by a 125-micron thick polythene sheet. The thickness of concrete pavements varies from 300 to 340 mm. Contraction joints are provided at 4.5 m Centre to Centre. There are two longitudinal joints, one in the Centre of the traffic lane sand the other along the inner edge of the tied shoulder.

1.2 Stabilizing Additive used in the Study

The cost of concrete is reduced by replacing cement with pozzolanas. From the middle of the 20th century, there has been an increase in the consumption of mineral admixtures by the cement and concrete industries. The increasing demand for cement and concrete is met by partial cement replacement. Substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intense Portland cement. The use of by-products is an environmentally friendly method of disposal of large quantities of materials that would otherwise pollute land, water, and air. Most of the increase in cement demand will be met by the use of supplementary cementing materials.

Use of industrial by-products in concrete will lead to green environment and such concrete can be called as "Green Concrete". There are various types of industrial wastes which can be considered for usage in concrete. The most commonly used industrial waste to replace sand and cement in concrete are Fly Ash, Rice Husk Ash, Blast Furnace Slag, Pond ash, Red Mud and Phosphor, Gypsum, Silica Fume, Fumed silica, Crushed glass, Eggshells. India depends primarily on coal for the requirement of power and its power generation and it is likely to go up with each passing day.

1.3 Carbon Black Ash

The disposal of carbon black ash shown in figure 1 is derived from crumb rubber is a big challenge to all as concerning their quantity which is increasing day by day. Hence worldwide investigation was performed to find alternative use of this waste material and its use in concrete as a partial replacement of cement is one of the effective methods of utilization. The carbon black ash as a replacement to cement in concrete is taken into consideration.

Fig-1: Carbon Black Ash

Table-2: Physical properties of Carbon Black Ash

S. No	Parameter	Values
1.	Physical state	Solid-powder form
2.	Odour	Odourless
3.	Specific Gravity	1.13
4.	Colour	Black

2. RESEARCH ON CONCRETE

Concrete is the most common used material for construction and design. The use of large quantities of cement produces CO2 emissions and as a consequence the greenhouse effect.

Concrete research looks for materials and processes to:
1. Reduce material costs and energy costs
2. Obtain high initial and final resistance
3. Improve the density and compressive strength
4. Improve workability, pump ability and finishing
5. Improve durability and reduce permeability
6. Reduce shrinkage cracks, dusting problems
7. Chemical resistance, e.g. sulphate resistance

2.1 Chemical Admixtures

Chemical admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that are added to the mix immediately before or during mixing. Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

The construction industry uses concrete to a large extent. Concrete is used in infrastructure and in buildings. It is composed of granular materials of different sizes and the size range of the composed of granular materials of different sizes and the size range of the composed solid mix covers wide intervals. The overall grading of the mix, containing particles 300 mm to 32 mm determines the mix properties of the concrete. The properties in the fresh state (flow properties and workability) are for instance governed by the particle size distribution (PSD), but also the properties of concrete in the hardened state, such as strength and durability, are affected by the mix grading and resulting particle packing.

Successful use of admixtures depends on the use of appropriate methods of batching and concreting. Most admixtures are supplied in ready-to-use liquid form and are added to the concrete at the plant or at the jobsite. Certain admixtures, such as pigments, expansive agents, 6 and pumping aids are used only in extremely small amounts and are usually batched by hand from premeasured containers. The effectiveness of an admixture depends on several factors including type and amount of cement, water content, mixing time, slump, and temperatures of the concrete and air. Sometimes, effects similar to those achieved through the addition of admixtures can be achieved by altering the concrete mixture-reducing the water-cement ratio, adding additional cement, using a different type of cement, or changing the aggregate and aggregate gradation.

Admixtures are classed according to function. There are five distinct classes of chemical admixtures: air-entraining, water-reducing, retarding, accelerating, and plasticizers (super plasticizers). All other varieties of admixtures fall into the specialty category whose functions include corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, workability enhancement, bonding, damp proofing, and coloring. Air-entraining admixtures, which are used to purposely place microscopic air bubbles into the concrete, are discussed more fully in Air�Entrained Concrete.

2.2 Water-reducing admixtures:

Water-reducing admixtures usually reduce the required water content for a concrete mixture by about 5 to 10 percent. Consequently, concrete containing a water-reducing admixture needs less water to reach a required slump than untreated concrete. The treated concrete can have a lower water-cement ratio. This usually indicates that a higher strength concrete can be produced without increasing the amount of cement. Recent advancements in admixture technology have led to the development of mid-range water reducers. These admixtures reduce water content by at least 8 percent and tend to be more stable over a wider range of temperatures. Mid-range water reducers provide more consistent setting times than standard water reducers.

2.3 Retarding admixtures:

Retarding admixtures which slow the setting rate of concrete, are used to counteract the accelerating effect of hot weather on the concrete setting. High temperatures often cause an increased rate of hardening which makes placing and finishing difficult. Retarders keep 7 concretely workable during placement and delay the initial set of concrete. Most retarders also function as water reducers and may entrain some air in concrete.

2.4 Acceleration Admixtures:

Accelerating admixtures increase the rate of early strength development, reduce the time required for proper curing and protection, and speed up the start of finishing operations. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather.

2.5 Super Plasticizers:

Super plasticizers, also known as plasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water�cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction. The effect of super plasticizers lasts only 30 to

60 minutes, depending on the brand and dosage rate, and is followed by a rapid loss in workability. As a result of the slump loss, super plasticizers are usually added to the concrete at the job site.

2.6 Corrosion-Inhibiting Admixtures:

Corrosion-inhibiting admixtures fall into the specialty admixture category and are used to slow corrosion of reinforcing steel in concrete. Corrosion inhibitors can be used as a defensive strategy for concrete structures, such as marine facilities, highway bridges, and parking garages, that will be exposed to high concentrations of chloride. Other specialty admixtures include shrinkage-reducing admixtures and alkali-silica reactivity inhibitors. The shrinkage reducers are used to control drying shrinkage and minimize cracking, while ASR inhibitors control durability problems associated with alkali-silica reactivity.

3. METHODOLOGY AND EXPERIMENTAL PROGRAM

This study is focused on finding the effects on the performance of M40 grade Concrete mix with partial replacement of carbon black ash in cement. For this study mechanical properties like compressive strength, split tensile strength and flexural strength tests are conducted on different mixes. This chapter is discussed about methodology and experimental program.

3.1 Concrete mixes consider for the study:

Following are the different mixes considered for the study.

(i) Conventional concrete mix – CC
(ii) Concrete mix with 10% Partial replacement of Carbon Black Ash in Cement -CBAC-10%
(iii) Concrete mix with 20% Partial replacement of Carbon Black Ash in Cement - CBAC-20%
(iv) Concrete mix with 30% Partial replacement of Carbon Black Ash in Cement - CBAC-30%
(v) Concrete mix with 40% Partial replacement of Carbon Black Ash in Cement - CBAC-40%
(vi) Concrete mix with 50% Partial replacement of Carbon Black Ash in Cement - CBAC-50%
(vii) Concrete mix with 60% Partial replacement of Carbon Black Ash in Cement -CBAC-60%

3.2 Flow chart:

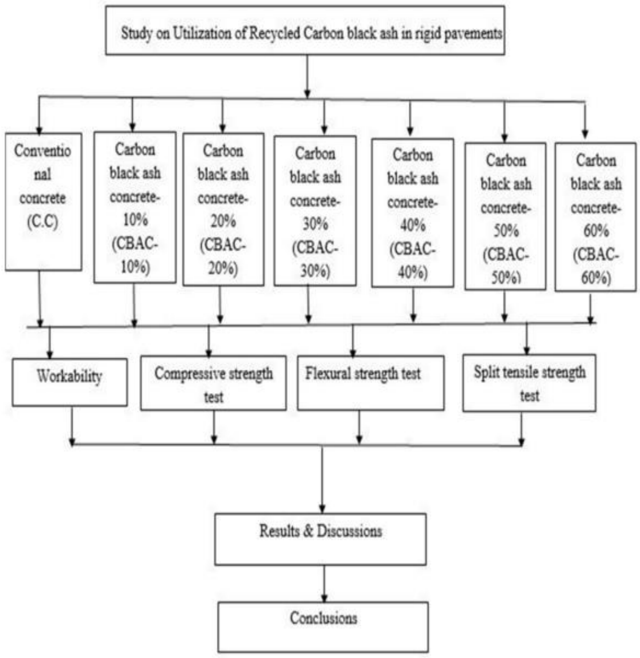

Fig -1: Flow chart showing methodology of the present study

4. MIX DESIGN

All the concrete mixes in the project are prepared as per IS:10262-2009.This standard was first prepared in the year 1982 and later revised in the year 2009. This Indian standard was adopted by the Bureau of Indian standards after the draft finalized by the cement and the concrete sectional committee has been approved by the civil engineering division council.

The following pre requisites are to be taken into consideration before designing a concrete mix:

a) Characteristic compressive strength of concrete at 28 days(f_{ck}).
b) Degree of workability desired.
c) Limitations on the water-cement ratio and the minimum cement content to ensure adequate durability.
d) Type and maximum size of aggregate to be used.
e) Standard deviation(s) of compressive strength of concrete.

4.1 Testing Data:

Specific gravity of cement	= 3.14
Specific gravity of sand	= 2.6
Specific gravity of aggregate	= 2.86
Zone of sand	= IV (From Table 4 – IS:383-1970)

4.2 Mix Design Based on Compressive Strength:

Grade designation - M40
Type of cement - OPC 43 grade conforming to (IS:8112-1989)
Max. Nominal size of aggregate - 20 mm
Minimum cement content - 450 kg/m³ (IS:456-2000)
Maximum water-cement ratio - 0.4 (IRC:44-2017)
Exposure condition – Mild

Target strength for mix proportioning:
$F^{1}_{ck} = F_{ck} + 1.65 \times S$ (S=5 for M40 grade concrete)
(Clause: 9.2.4.2 and table 11 of IS:456-2007)
=48.25 N/mm²

Selection of water cement ratio:
From table 5 of IS:456-2000, Max. water cement ratio = 0.4
Based on trails adopt water-cement ratio as = 0.38

Calculation of water content:
Super plasticizer reduces water content up to 10%
Maximum water content for 20mm aggregate size
= 186 lit (25 to 50 mm slump)
Water content =186×0.9 = 167.4 lit = 168 lit.
w/c = 0.38
Cement content=168/0.38 = 442 kg
From table 3 of IS:10262-2009, vol. of Coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone-IV)
For water cement ratio of 0.5 = 0.66
Corrected proportion of Vol. of Coarse aggregate for water cement ratio of 0.38 = 0.68

Table-3: Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate (Clauses 4.4, A-7 and B-7)

S. No	Nominal Size of Aggregate	The volume of Coarse Aggregate per unit volume of total aggregate for different zones of Fine Aggregates			
		ZONE IV	ZONE III	ZONE II	ZONE I
1	10	0.5	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.6
3	40	0.75	0.73	0.71	0.69

4.3 Mix Calculations:

a) Vol. of concrete = 1m³
b) Vol. of cement = (mass of cement/specific gravity of cement) × (1/1000)
= (442/3.14) x (1/1000)
= 0.1407m³
c) Vol. of water = (mass of water/specific gravity of water) × (1/1000)
= (168/1) x (1/1000)
= 0.1674 m³
d) Vol. of chemical admixture (super plasticizer) @ 0.5% by Wt. of cement = (mass of admixture/specific gravity of admixture) × (1/1000)
= (8.84/1.4) x (1/1000) = 0.019m³
e) Vol. of all in aggregate (e)
= [a-(b+c+d)]
= [1-(0.1407 + 0.1674 +0.019)]
= 0.672m³
f) Mass of coarse aggregate
= e × vol. of coarse aggregate× specific gravity of coarse aggregate x 1000
= 0.672 x 0.68 x 2.86 x1000
= 1306 kg/m³
g) Mass of fine aggregate
= e × vol. of fine aggregate × specific gravity of fine aggregate x 1000
= 0.672 x (1-0.68) x 2.6 x 1000
= 559.12 kg/m³

4.4 FOR M40 GRADE CONCRETE: (IS:456-2000):

Table-4: Mix design based on compressive strength

Mix	Cement	F. A	C.A	Water
Ratio	1	1.52	2.67	0.4
Quantity	442Kg/m³	560Kg/m³	1306Kg/m³	168Lit.

4.5 Mix proportion:

Table-5: Mix Proportions along with Additives

Mix proportions	Cement (Kg/m³)	F.A (Kg/m³)	C.A (Kg/m³)	Water (lit.)	w/c ratio	Extra Water	Carbon black ash (Kg/m³)	Super plasticizer (0.5% of Cement)
CC	442	560	1306	168	0.4	12	-	-
CBAC -10%	398	560	1306	168	0.4	12	44	1.99
CBAC -20%	354	560	1306	168	0.4	12	88	1.77
CBAC -30%	309	560	1306	168	0.4	12	133	1.55
CBAC	264	560	130	168	0.4	12	178	1.32

-40%			6					
CBAC -50%	221	560	130 6	168	0.4	12	221	1.1
CBAC -60%	177	560	130 6	168	0.4	12	265	0.9

4.6 Mix Design Based on Flexural Strength:

Based on flexure strength (IRC:44-2017)
Target strength $f_{cr}^1 = f_{cr} + 1.65S_r$
Sr - assumed standard deviation = 0.392
(IRC:44-2017)
= 4.427+1.65(0.392)
= 5.0738 N/mm2 (or) $f_{cr}^1 = f_{cr} + 0.55$
= 4.427+0.55
= 4.977 N/mm^2
Target strength is whichever is higher.
(IRC: 44-2017)
Therefore, target strength is 5.0738 N/mm^2
For 28days flexural strength of 4.411 N/mm^2 (OPC 43 grade) the approximate w/c ratio is 0.4.
(IRC: 44-2017)
Adopting w/c = 0.4
For maximum nominal size of aggregate = 20mm
Water content =184.32 kg/m^3 (As per table 10 of IRC: 44-2017)
Medium slump of 75 mm Water content will increase by 3% for every 25 mm increase of slump over 50 mm
(IRC: 44-2017)
Water content = 184.32+184.32(3/100) = 189.82 kg/m^3
Cement content = 189.82/0.4 = 474.54 kg/m^3
For maximum nominal size of aggregate 20mm and zone II of fine aggregate, proportion of coarse aggregate = 0.646
(IRC: 44-2017)
Proportion of FA = 1- 0.646 = 0.353
For 1m^3 of concrete Volume of cement = (mass of cement/specific gravity) x (1/1000)
= (474.5.822/3.14) x (1/1000) = 0.1511 m^3
Volume of water = (mass of water/specific gravity) x (1/1000)
= (189.82/1) x (1/1000) = 0.190 m^3
Volume of aggregate = 1- (0.15+0.190) = 0.6589 m^3
Mass of CA = 0.6589 x Proportion of CA x Specific gravity x 1000
= 0.6589 x 0.646 x 2.86 x 1000
= 1114.69428 kg
Mass of FA = 0.679 x Proportion of FA x specific gravity x 1000
= 0.6589 x 0.354 x 2.6 x 1000 = 606.6313 kg
Therefore, requirement of ingredients are:
Mass of cement = 474.51 kg/m^3
Mass of CA =1217.357 kg/m^3
Mass of FA = 606.45 kg/m^3
Mass of water = 189.82 kg/m^3
Therefore, Cement: FA: CA = 1:1.28:2.56

Table-6: Mix design based on flexural strength

Mix	Cement	F. A	C.A	Water
Ratio	1	1.28	2.56	0.4
Quantity	475Kg/m^3	608Kg/m^3	1216Kg/m^3	190Lit.

4.5 Preparation of Samples:

In order to determine the mechanical characteristics such as compressive and flexural strengths, different samples are prepared. Later they were tested on compressive testing machine and UTM. Samples are prepared with an optimum dosage of carbon black Ash.
The compressive strength of concrete has been evaluated by testing cubes of size 150 x 150 x 150 mm. The flexural strength of concrete has been evaluated by testing prisms of dimension 500 x 100 x 100 mm. After casting of these specimens these are kept in moulds for 24 hours at a temperature of 27 ± 2 degree Celsius. After 24 hours these are removed from the moulds and are put into curing tank and tested for 7, 28 days respectively.

4.5 Testing of Samples:

The prepared samples as mentioned in the previous section and the testing methodology for compression and flexural strengths are followed according to the IS: 516:1959 and they are explained below.

4.5.1 Compressive Strength:

The compressive strength of a material is that the value of uni-axial compressive stress reached when the material fails completely. The cubes are then tested between the loading surfaces of the compressive testing machine of capacity 2000KN in such a way that the smooth surface directly receives the load and it is applied until the failure of the load. The compressive strength is determined by the ratio of failure load to the cross-sectional area of the specimen.

$$f_c = \frac{\text{failure load}}{\text{cross sectional area}}$$

The flexural strength may be expressed as the modulus of rupture fb, which, if a "equals the distance between the line of fracture and the nearer support, measured on the Centre line of the tensile side of the specimen, shall be calculated to the nearest 0.5kg/sq.cm as follows:

$$f_b = \frac{pl}{bd^2}$$

When a is greater than 20.0 cm for 15 cm specimen or greater than 13.3 cm for a 10.0 cm specimen

$$f_b = \frac{3p \times a}{bd^2}$$

When a is less than 20.0 cm but greater than 17.0 cm for a 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm
Where:
b = measured width in cm of the specimen
d = measured depth in cm of the specimen.
l = length in cm of the span in which the specimen was supported and
p = maximum load in kg applied to the specimen.

5. RESULTS AND DISCUSSIONS

An experimental study in conducted a utilization of recycled carbon black ash in Rigid Pavements. Mechanical properties like Compressive Strength, Flexural Strength and Split Tensile Strength are performed and based on obtained test results graphs are plotted and results are discussed.

Workability of Conventional and Carbon Black Ash Mix:

Table 7 shows the results obtained from slump cone test. Based on the slump values and graphs are conventional concrete and carbon black ash concrete mixes plotted as shown in chart 1.

Table-7: Slump values for different mixes.

Mix Type	Slump (mm)
Conventional concrete (CC)	65
Carbon Black Ash concrete (CBAC)	39

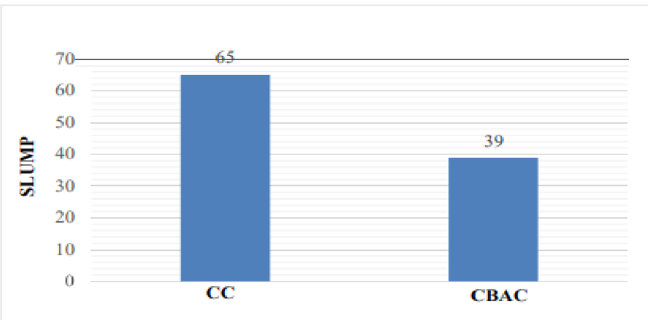

Chart -1: Workability of concrete mixes.

From the chart 1, it is observed that workability is reduced for carbon black ash concrete compared to conventional concrete by 40%.

5.1 Mechanical Properties:

5.1.1 Compressive Strength:

Comparison of Compressive Strength of CC, CBAC- 10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

Table 8 shows the compressive strength of CC, CBAC-10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28 days. Comparative graph for the same is provided in chart 2 for compressive strength of CC, CBAC-10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 and 28 days.

Table-8 Comparison of Compressive Strength of CC and CBAC - 10, 20, 30, 40, 50 and 60% of CBA Concrete Mix at the 7 days, 14 days and 28 days curing period.

Mix Designation	Compressive Strength (N/mm^2)		
	7days	14days	28days
Convention Concrete (M40)	32.12	40.04	48.26
CBA replacement (10%)	25.13	32.80	42.85
CBA replacement (20%)	28.12	36.04	43.97
CBA replacement (30%)	30.13	38.92	45.73
CBA replacement (40%)	32.27	40.16	48.35
CBA replacement (50%)	26.10	34.29	41.34
CBA replacement (60%)	28.30	32.56	36.83

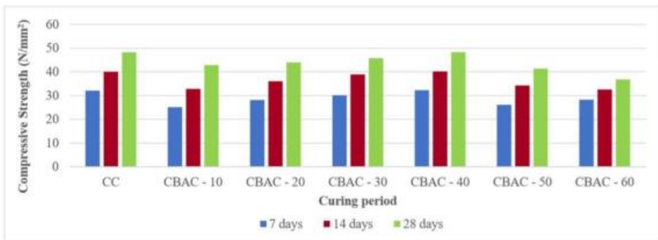

Chart-2 Comparison of Compressive strength of CC, CBAC-10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

From the chart 2, it is observed that, among all the considered mixes CBAC – 40% meets the requirement of CC mix. It is observed from the results that there is the strength variation at 7 days compressive strength ie.,25.13, 28.12, 30.13, 26.10 and 28.30 N/mm^2 for CBAC- 10%, CBAC-20%, CBAC-30%, CBAC-50% and CBAC-60% respectively, when compared to conventional concrete mix (CC). The strength variation at 14 days compressive strength ie.,32.80, 36.04, 38.92, 34.29 and 32.56 N/mm² for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50% and CBAC-60% respectively, when compared to the conventional concrete mix (CC). The strength variation at 28 days i.e., 42.85, 43.97, 45.73, 41.34 and 36.83 N/mm² for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50%, CBAC-60% respectively, when compared to conventional concrete mix (CC).

5.1.2 Flexural Strength:

Comparison of Flexural Strength of CC, CBAC- 10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

Table 9 shows the flexural strength of CC, CBAC-10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 and 28 days. Comparative graph for the same is provided in chart 3 for flexural strength of CC, CBAC-10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 and 28 days.

Table-9 Comparison of Flexural Strength of CC, CBAC- 10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

Mix Designation	Flexural Strength (N/mm²)		
	7days	14days	28days
Convention Concrete (M40)	3.64	4.04	4.56
CBA replacement (10%)	3.76	4.22	4.84
CBA replacement (20%)	3.56	4.34	4.92
CBA replacement (30%)	3.78	4.48	4.76
CBA replacement (40%)	3.66	4.08	4.58
CBA replacement (50%)	3.60	4.18	4.62
CBA replacement (60%)	3.71	4.28	4.54

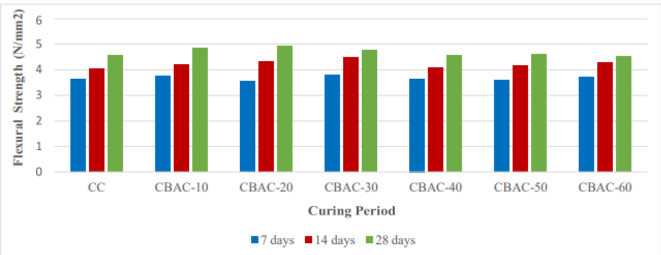

Chart-3 Comparison of Flexural strength of CC, CBAC - 10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 days and 28 days curing period.

From the chart 3, it is observed that, among all the considered mixes CBAC – 40% meets the requirement of CC mix. It is observed from the results that there is the strength variation at 7 days flexural strength ie.,3.76, 3.56, 3.78, 3.60 and 3.71 N/mm2 for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50%, CBAC-60% respectively, when compared to conventional concrete mix (CC).The strength variation at 14 days flexural strength ie.,4.22, 4.34, 4.48, 4.18 and 4.28 N/mm² for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50%, CBAC-60% respectively, when compared to conventional concrete mix (CC).The strength variation at 28 days ie.,4.84, 4.92, 4.76, 4.62 and 4.54 N/mm² for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50%, CBAC-60% respectively when compared to conventional concrete mix (CC).

5.1.3 Split Tensile Strength:

Comparison of Split Tensile Strength of CC, CBAC- 10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

Table 10 shows the split tensile strength of CC, CBAC-10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 and 28 days. Comparative graph for the same is provided in chart 4 for split tensile strength of CC, CBAC-10, 20, 30, 40, 50 and 60% mix at the age of 7, 14 and 28 days.

Table-10 Comparison of Split Tensile Strength of CC, CBAC- 10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

Mix Designation	Split Tensile Strength (N/mm²)		
	7days	14days	28days
Convention Concrete (M40)	3.22	3.62	4.26
CBA replacement (10%)	3.42	4.18	4.85
CBA replacement (20%)	3.18	4.08	4.97
CBA replacement (30%)	3.48	3.82	4.73
CBA replacement (40%)	3.28	3.68	4.28
CBA replacement (50%)	3.10	3.98	4.32
CBA replacement (60%)	3.32	3.72	4.22

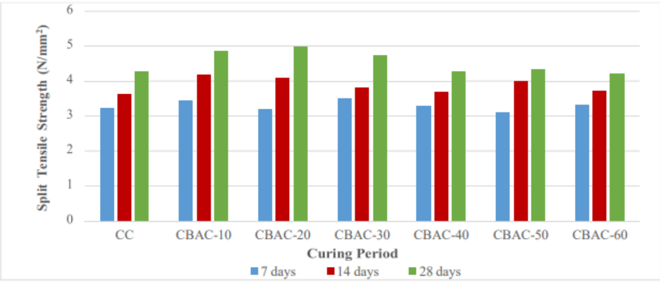

Chart-4 Comparison of Split Tensile Strength of CC, CBAC-10, 20, 30, 40, 50 and 60% Mix at the age of 7, 14 and 28days curing period.

From the chart 4, it is observed that, among all the considered mixes CBAC – 40% meets the requirement of CC mix. It is observed from the results that there is the strength variation at 7 days split tensile strength ie.,3.42, 3.18, 3.48, 3.10 and 3.32 N/mm^2 for CBAC-10%, CBAC- 20%, CBAC-30%, CBAC-50%, CBAC-60% respectively, when compared to conventional concrete mix (CC). The strength variation at 14 days split tensile strength ie.,4.18, 4.08, 3.82, 3.68, 3.98, and 3.72 N/mm^2 for CBAC-10%, CBAC-20%, CBAC-30%, CBAC-50%, CBAC-60% respectively, when compared to conventional concrete mix (CC). The strength variation at 28 days split tensile strength ie.,4.85, 4.97, 4.73, 4.32, 4.22 N/mm^2 for \CBAC-10%, CBAC- 20%, CBAC-30%, CBAC-50%, CBAC-60% respectively when compared to conventional concrete mix (CC).

6. CONCLUSIONS

Based on the investigations carried out on the usage of Carbon Black Ash in rigid pavements the following conclusions were drawn:

1. Carbon black proves as an excellent additive with which higher compressive strength can be obtained from the concrete mix.
2. Carbon black proves as good filler and fills the pores thereby making the concrete dense.
3. A maximum compressive strength of 32.27 N/mm^2 was obtained at CBAC – 40% for 7 days curing period in comparisons to CC and a maximum compressive strength of 40.16 N/mm^2 was obtained at CBAC – 40% for 14 days curing period in comparisons to CC and a maximum compressive strength of 48.35 N/mm^2 was obtained at CBAC – 40% for 28 days curing period in comparison to CC.
4. A maximum flexural strength of 3.66 N/mm^2 was obtained at CBAC – 40% for 7 days curing period in compared to CC and a maximum flexural strength of 4.08 N/mm^2 was obtained at CBAC – 40% for 14 days curing period in compared to CC and a maximum flexural strength of 4.58 N/mm^2 was obtained at CBAC – 40% for 28 days curing period in compared to CC.
5. A maximum split tensile strength of 3.22 N/mm^2 was obtained at CBAC – 40% for 7 days curing period in compared to CC and a maximum split tensile strength of 3.78 N/mm^2 was obtained at CBAC – 40% for 14days curing period in compared to CC and a maximum split tensile strength of 4.58 N/mm^2 was obtained at CBAC – 40% for 28 days curing period in compared to CC.
6. From the test results 40% partial replacement of cement with carbon black ash, hence it is the optimum percentage for replacement in cement. 67
7. It is evident that from the results flexural strength of carbon black ash concrete increases by 17% at the age of 28 days in comparison with conventional concrete.
8. The construction cost of the pavement was reduced up to 5% on usage of carbon black ash as a replacement.
9. As a whole the specimens prepared with carbon black ash concrete can be utilized for non-structural components like kerbs, footpath, shoulders, dividers.

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