ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology
No. 1/2022

doi: 10.21307/ACEE-2022-006

ASSESSMENT OF SUSTAINABLE CONCRETE USING CARBON BLACK DUST AS AN ADDITIVE ADMIXTURE

Pravar PARASHAR [a*], Prityumn NAGAR [a], Ritik NEEMA [a], Rutul KHADSE [a], Ashish NIM [b]

[a] UG Student; Civil Engineering Department (NBA Accredited), IPS Academy, Institute of Engineering and Science, Indore, INDIA. (A UGC Autonomous Institute)
*E-mail address: *22pravarparashar@gmail.com*

[b] Assistant Prof.; Civil Engineering Department (NBA Accredited), IPS Academy, Institute of Engineering and Science, Indore, INDIA. (A UGC Autonomous Institute)

Received: 14.04.2021; Revised: 18.10.2021; Accepted: 8.11.2021

Abstract

Concrete is the most essential and demanding construction material that is mainly used to develop structural and non-structural elements. Along with the better engineering properties, concrete has its drawbacks like the presence of pores and micro cracks, and this affects its properties like permeability and water absorption which tend to reduce its durability and strength. Carbon black dust (CBD) is one of the industrial byproducts that can be effectively used as an additive in concrete. It is a necessity for us to reduce environmental pollution arising due to CBD. This research paper attempted an investigation to assess the effect of CBD as an additive material into the concrete. The chemical properties of raw materials were determined by X-ray fluorescence (XRF) spectroscopy analysis and the mechanical properties of hardened concrete were carried out followed by destructive and non-destructive testing. Compressive strength of 150 mm concrete cubes was determined at 7th, 14th and 28th day of curing that contains various percentages (2.5%, 5%, 7.5% and 10%) of CBD. Concrete with 0% CBD served as the control specimen. On the basis of experimental investigations, the maximum compressive strength reported for concrete specimens containing 7.5% CBD as 17.23% was more than that of control specimen. At 10% CBD, strength got decreased but significant improvement with respect to control specimen was also noted. As per the chemical analysis, CBD contains substantial amount of fluxing and strengthening agents that improve the performance of concrete and it can be used as an additive admixture.

Keywords: **Carbon dust black; Admixture; Compressive strength; Durability; Sustainability.**

1. INTRODUCTION

Concrete is the material which is used primarily in physical development of structure all around the world. Cement concrete is widely used construction material available in its different forms like plain cement concrete (PCC), reinforced cement concrete (RCC), fiber reinforced concrete (FRC), high performance and ultra-high-performance concrete (UHPC) as well as pre-stressed concrete etc. In building construction, PCC and RCC are mainly used to develop structural components such as columns, beams, slabs, staircases, lintels etc. In road construction, paved quality concrete (PQC) is used with higher compressive and flexural strength characteristics. In important transportation structures like bridge, canal, harbor etc., mainly UHPC and pre-stressed concrete are mostly preferred. The strength and durability characteristics of concrete is dependent on its inert materials like coarse and fine aggregates that one mixed with active constituents like water and cement. The cement concrete mixture is in plastic state; when it is allowed to set it becomes hard. By adjusting the proportions of cement, coarse aggregate, fine aggregate, and water suitably it is possible to get compressive strength of concrete sufficient for different uses. Due to the advantages like high strength capability in compression, ease of construction, economy, high durability, better appearance etc., the cement concrete in relation to the other materials is considered useful. Typically used concrete in construction has density of 2400kg/m^3 [1]. To withstand tensile forces plain cement concrete must be reinforced in structures usually by steel.

Nowadays, society is showing more interest towards the use of new materials in place of traditional materials. Since past decades the search for cement replacement material has continued [2] and played an undeniable role in the construction industry from economic and ecological points of view. The most widely used material in the world after water is cement but major environment problem is also caused due to emission of CO_2 during the rapid production process of cement [3]. As there are no alternative building materials available which totally replace the cement, search for any alternative material for cement should lead to global sustainable development. A huge number of industrial byproducts generated from the wide range of industries cause serious concerns to the environment. When industrial byproducts are used as a partial replacement of cement, it can result in sustainable development. Some of the industrial byproducts presently in use are fly ash, silica fumes, ground granulated blast furnace slag, rice husk ash etc. [3].

One of the industrial byproducts that can be used as additive and eco-friendly is Carbon Black Dust (CBD). CBD is virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. Along with the various advantages, one of the major drawbacks of concrete is the presence of pores within the core structure that increases the permeability of concrete and ultimately affects strength and durability. Present research work is intended towards the use of CBD as an additive admixture into the concrete and to evaluate its effect on strength and durability characteristics. When CBD is used as an admixture in concrete, it tends to increase the self-compacting nature which promotes packing molecules to reduce the presence of pores into the core structure [4].

2. CBD AND ENVIRONMENT

With the increasing industrialization there are so many byproducts generated every day and it becomes impractical to recycle most of them. CBD is one of such byproduct generated mostly from industries using coal-based boilers. CBD also gets deposited in the chimneys of the boilers and is a non-biodegradable substance, therefore it ends up in landfills. Due to unscientific disposal of CBD, it results in degradation of soil quality and improper management of CBD also causes air pollution.

3. LITERATURE REVIEW

Goldman and Bentur (1993) [5, 6] indicated that carbon black was effective in modifying basic concrete matrix strength to an extent similar to silica fumes. Concrete strength was enhanced by the impact of micro fillers. The authors substituted silica fumes by carbon black as an alternate micro filler. They concluded that the compressive strength of concrete with smaller particle size carbon black is more compared to the larger particle size of 0.33 micrometer. It was found that micro filler effect had larger importance for strength enhancement. Lately, in 1994 Goldman and Bentur also concluded that improved mechanical properties are due to an increase in the density of material of the transition zone. The mechanical overall performance of concrete is tremendously lifted by carbon black as a non-reactive filler.

Ahmedzade and Geckil (2007) [7] examined that carbon black enhances both mechanical and electrical conductivity of asphalt mixture. Marshal's stability, creep stiffness, indirect tensile strength and indirect tensile modulus tests were performed to investigate the carbon black effect on the electrical and mechanical properties of an asphalt mixture.

Kharita et al. (2009) [8] studied that due to addition of carbon black in the hematite there is 6% of carbon black powder by weight to concrete that can increase its strength by about 15%. It has been observed that addition of carbon black powder causes a decrease in properties of hematite radiation shielding properties of concrete, but enhances the mechanical properties of hematite concrete.

Chitra et al. (2014) [9] examined that to reduce the porosity in traditional concrete, carbon black (rubber industry waste) is used as a filler material. They replaced cement in percentage of 0%, 2%, 5%, 8%, 12% and 15%. Total number of 18 cubes and 12 cylinders were cast with different replacement for testing. During their research work they conducted various tests like water absorption, compressive strength test, split tensile test, surface hardness etc. Later it was concluded that specimen with 2% and 5% carbon black showed good results and 8% showed excellent state of pores and water absorption.

Masadeh (2015) [10] examined the effect of carbon black (a rubber reinforcing additive) in concrete mixture when corrosion occured during steel reinforcement. Steel bars were routed in distinctive percentages of carbon black along with distinctive concretes. The carbon black/concrete ratio taken was 0.1, 0.2, 0.3, 0.4 & 0.5. For a half year, specimens were immersed in 3.5% chloride solution. After this the corrosion rate and chloride permeability were measured. The outcome was that with the expansion in content of carbon black, the rate of corrosion and penetrability of chloride dropped because of the brimming quality of carbon black's tiny particles, and it was in order not as much as 250 nm.

Padmapriya et al. (2016) [11] analyzed polyethylene terephthalate's impact on discrete strength qualities of M40 grade of concrete with 0%, 10% and 20%. In the percentage of 0%, 10%, 20% and 30% cement is partially replaced by carbon black. Carbon black powder is taken from the rubber industry. It is a by-product of incomplete combustion of heavy petroleum products and vegetable oil. We got to know that the strength decreases when there is an increase in the fine aggregate ratio of polyethylene terephthalate. Finally, it is concluded that in concrete, up to 30% replacement of cement by carbon black is effective.

Jayashree et al. (2017) [12] performed research on the carbon black in concrete. They added carbon as filler in concrete. They performed split tensile strength, uniformity, compressive strength, flexural strength tests and surface hardness on concrete block with various percentage of carbon black. They also examined the concrete cylinder containing carbon with rebar. On concrete cylinders test conducted were split tensile strength, chloride ingress determination test and OCP test. Nondestructive test using ultrasonic pulse velocity, compressive strength test using compressive testing machine and rebound hammer were conducted on concrete cubes. It was found that carbon black added between 5%to 8% as a filler material can effectively be used for enhancement of properties of concrete.

Nagavkar (2017) [3] demonstrated the effect of partially replaced calcium sulphate and a rubber industry waste carbon powder in cement on wet and hardened concrete properties. Concrete cubes and cylinders were casted. Carbon black was replaced in percentage (0%, 3%, 5%, 7%, 9% and 12%). It was noted that in concrete the use of carbon black can heighten the mechanical properties.

Danish Fayaz et al. (2018) [13] analysed the concrete with various percentage of robo sand and carbon black. Authour has replaced fine aggregate with quarry dust and cement with carbon black.

A waste form rubber industry i.e. carbon black was collected and used as filler material. They found that as the content (quarry dust and carbon) increases permeability decreases. The strengths like split tensile strength, compressive strength and flexural strength of the concrete increase and permeability decreases due to blocking of pores when quarry sand is replaced by 50% and carbon black by constant 5%. They also concluded that durability of concrete increases and property like corrosion decreases due to decrease in permeability.

Divya et al. (2019) [14] studied the effect of carbon black added in different percentage of replacement to cement in concrete mix. Cement was replaced by 5%, 10%, 15% and 20% of carbon black. They have concluded that up to 10% of carbon black replacing cement can be used with technical and environmental benefits. It is also observed that from 15% replacement there is considerable decrease in compressive strength.

Irshidat (2020) [15] experimented that in the production of cement, mortar particles of cement were slightly replaced by carbon dust which is gathered from aluminium industry as an industrial waste. The conclusion states that 10% part of carbon dust can be added to the concrete mixture without affecting the strength of mortar. In 5% replacement ratio, best enhancement in compressive strength was achieved. To justify the results in research scanning electron microscopy, X-ray diffraction, and X-ray fluorescence were used. The structural analysis by electron microscopy indicates that when carbon dust is used in a percentage of less than 10%, the concrete is formed to have an increased density and is more compact.

As per the review of previous research works, various CBD have been added in different percentage as an additive or fillers in cement concrete. Table1 shows a summary of research work done for use of CBD as a waste from industries in cement as a replacement or additive.

Table 1.
Use of carbon black in concrete by various researchers

S.No.	Type of carbon waste used	Outcomes	Reference
1	Carbon black from local petro-chemical plant and Cabot	Authors concluded that the micro filler effect is of larger significance to strength enhancement and carbon black was effective in modifying the basic concrete mixture strength to an extent similar to that obtained by silica fume.	[5]
2	Carbon black powder from rubber industry	The Total number of 18 cubes and 12 cylinders were cast with replacement of cement in percentage of 0%, 2%, 5%, 8%, 12%, and 15%. And it is concluded that specimen with 2% and 5% carbon black show good results and 8% shows excellent stanch of pores for water absorption.	[9]
3	Carbon black powder from rubber industry	Polyethylene terephthalate's impact on different strength properties of concrete grade M40 was conducted. In the percentage of 0%,10%,20% and 30% cement is partially replaced by carbon black. We came to know that the strength is reduced when PET ratio to fine aggregate is raised. It was found that cement till 30% substitution of carbon black in concrete is effective.	[11]
4	Carbon black from rubber industry, petrochemical plant and oil plant	Authors studied that as a filler material when carbon black powder is added in concrete mix to improve concrete properties, we can successfully add carbon black between 5% to 8% as a filler additive.	[12]
5	carbon black powder from rubber industry	Authors studied that when Carbon black was replaced in percentage of 0%, 3%, 5%, 7%, 9% and 12%, it was noted that in concrete the use of carbon black can enhance the mechanical properties.	[3]
6	Carbon dust from aluminum industry	Authors partially replaced cement particles in cement mortar production. The conclusion states that without having an effect on the mortar strength carbon dust can be added by mass of cement till 10% in concrete. Overall strength has been achieved in 5% substitution ratio improvement.	[15]

Table 2.
Physical properties of raw materials

Material	**Physical property**				**Procedure**
Sand	Specific gravity	Unit weight (kg/m^3)	Silt content		As per IS 383:2016 [16] and IS 2386- Part- I and III:1963 [17, 18]
	2.45	1640.0	Negligible		
Coarse Aggregate	Specific gravity	Moisture content	Abrasion value		As per IS 383:2016 [17] and IS 2386- Part- III and IV:1963 [18,19]
	2.78	2.35%	7.5%		
OPC Cement	Standard consistency	Unit weight (kg/m^3)	Initial and final setting time	Fineness through 90micron sieve	As per IS 12269:2013 [20]
	32%	1440	38 minutes and 590 minutes	98% Passing	
CBD	Fineness through 90micron sieve				-
	100% Passing				

From the above discussion, a very detailed literature review was carried out and it was revealed that carbon black can successfully contribute to an improvement in the properties of conventional concrete mix. Thus, the main aim of the current work was to use CBD, a waste collected from pharmaceutical industry as an additive admixture by weight of OPC 53 grade cement in concrete mixtures of various percentages. CBD was added in various replacement levels (0%, 2.5%, 5%, 7.5% and 10%). According to the results obtained, the optimum percentage of carbon black was also determined.

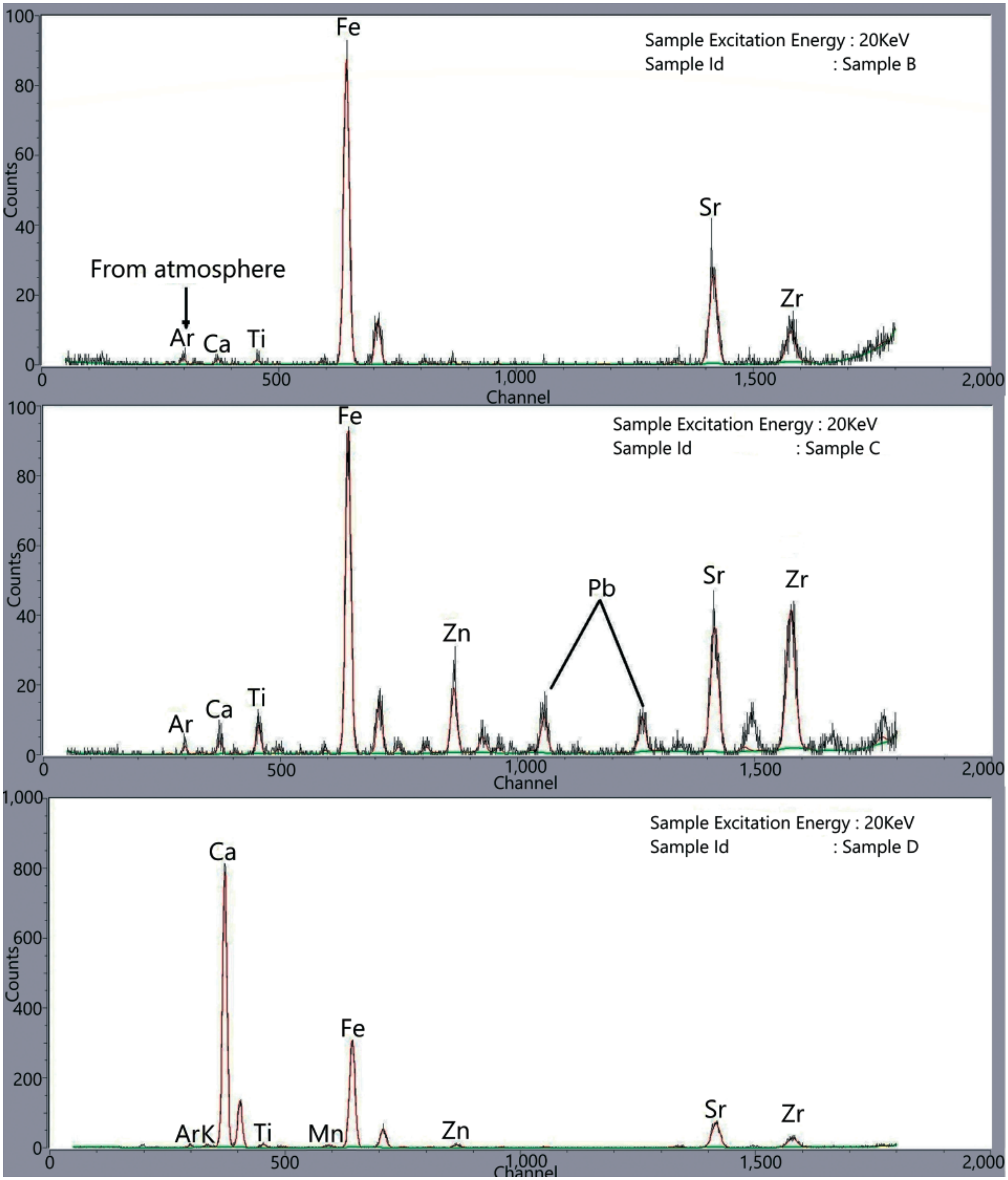


Figure 1.
XRF spectrum of sand, cement and CBD

Table 3.
Chemical analysis of raw materials

Chemical constituent and their oxides	Material with sample identity			
	Sand (B)	OPC Cement (C)	CBD (D)	Oxide proportion
Silica (SiO_2)	√	√	√	Major
Alumina (Al_2O_3)	√	√	√	
Iron oxide (Fe_2O_3)	√	√	√	
Calcium oxide (CaO)	√	√	√	
Titanium oxide (TiO_2)	√	-	√	Minor
Potassium oxide (K_2O)	-	-	√	
Zinc oxide (ZnO)	-	√	√	
Manganese (Mn)	-	-	√	In (ppm)
Strontium (Sr)	√	√	√	
Zirconium (Zr)	√	√	√	
Lead (Pb)	-		-	
Chromium (Cr)	-	-	-	

Table 4.
Majorly available components and their application in concrete

Components	Applications in concrete	References
Iron component	Strengthening agent	[21]
Calcium, magnesium, iron and manganese components	Fluxing agents	
Calcium and magnesium components	CO_2 Absorbing agent	
Iron, calcium and silica components	Stabilizing agent	
Titanium, and manganese compound	Corrosion resisting agent	

4. CHARACTERISTIC OF RAW MATERIAL

The characteristic of raw materials used in this research work was examined on the basis of their physical and chemical properties.

4.1. Raw material and their physical properties

CBD was collected from the TA Pharmaceutical industry located in Indore, M.P, India. Characteristics of raw materials have been carried out considering procedure and requirements as described in IS Codes. In order to determine specific gravity, water absorption and unit weight of river sand, 1.18mm passing particles were selected. Sand used in this research work was Narmada River sand. Similarly, to determine properties of OPC cement the particle size chosen was finer than 90 microns. The properties of raw materials are shown in Table 2.

In a certain volume, particle has filled efficiently and is called as packing density. In this research work a mix proportion of 10 mm and 20 mm coarse aggregate was used through which possibility of voids in concrete is reduced.

4.2. Chemical properties

In order to determine chemical properties of raw material used, X-Ray fluorescence (XRF) analysis was carried out form Centre for Advanced Technology, RRCAT, Indore, M.P., India. The XRF spectrums for raw material samples are shown in Figure 1. Table 3 demonstrates various chemical components present in sand, cement and CBD samples. The application of majorly available oxide components into the concrete are shown in Table 4.

XRF results depicting chemical properties of raw materials adduce that CBD contain substantial proportion of strengthening, fluxing and stabilizing agents like cement and sand, and may be suitably used as an admixture into concrete. The presence of titanium and manganese components may also improve corrosion resisting property of concrete.

5. SPECIMEN PREPARATION

Waste CBD was used to add as an admixture from 2.5% to 10% by weight of the cement in concrete. The control concrete specimens were also prepared

Table 5.
Proportioning of raw materials in one cube

Raw materials	Quantity				
OPC 53 grade cement	1.297 kg	1.297 kg	1.297 kg	1.297 kg	1.297 kg
Sand	1.945 kg	1.945 kg	1.945 kg	1.945 kg	1.945 kg
Coarse aggregate in equal combination (50% 10 mm and 50% 20 mm)	3.891 kg	3.891 kg	3.891 kg	3.891 kg	3.891 kg
Percentage of CBD	0%	2.5%	5%	7.5%	10%
Weight of CBD	0	34.133 gm	68 gm	102 gm	136 gm
Water quantity	518 ml	529 ml	538 ml	547 ml	555 ml
Water cement ratio	0.400	0.408	0.415	0.422	0.428

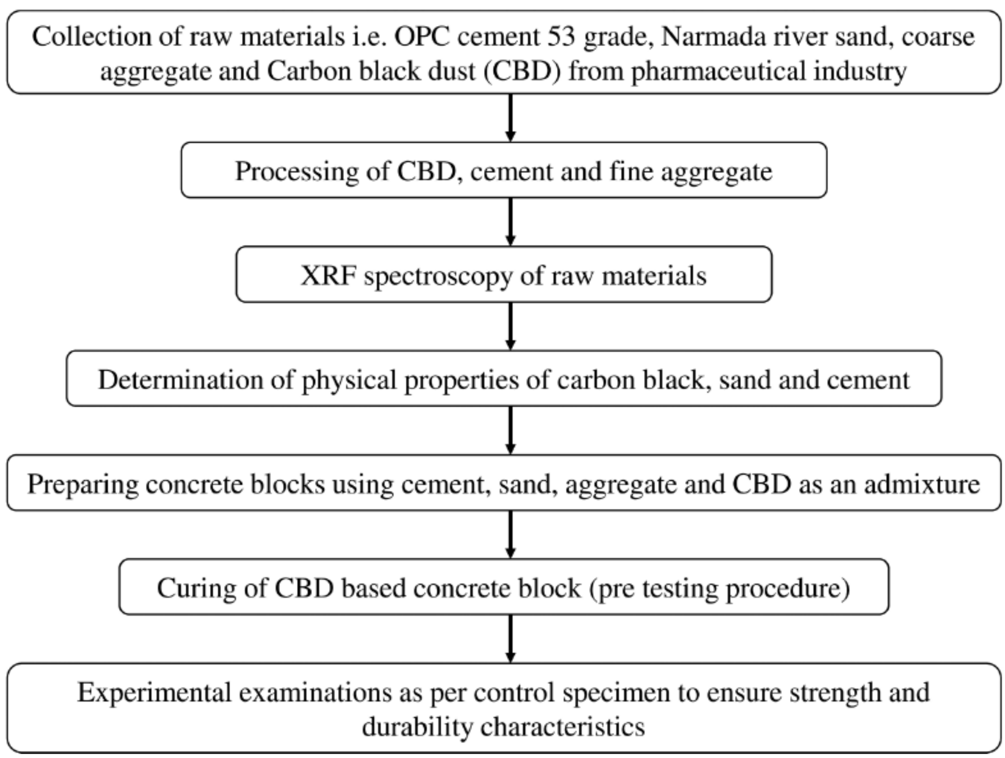


Figure 2.
Methodology for this research work

of 0% CBD to set the benchmark for results. The grade used for making cement concrete was M20 with 1:1.5:3 standard mix. Concrete specimens were casted in the form of cubes (150 × 150 × 150 mm). For conducting destructive and non-destructive tests, the moulds were casted with 0%, 2.5%, 5%, 7.5% and 10% of CBD by weight of cement. Initially dry mixing of raw materials was done; then a small quantity of water by 40% of weight of cement [3] that is water-cement ratio equals to 0.40 was also computed by performing slump cone test as per IS 1199-1959 [22] and IS 456-2000 [23]. Table 5 shows the proportion of raw materials used for making different CBD based concrete specimens.

As the percentage of CBD increases in the concrete mix, slightly increase in the water cement ratio also required due to the presence of fluxing agents in CBD.

6. METHODOLOGY

The main scope of this research is to create concrete using CBD as an admixture and to conduct destructive and nondestructive experiments to determine efficacy of concrete.

Methodology to conduct this research work is mentioned in Figure 2.

Table 6.
Water absorption percentage of CBD based concrete specimen

Percentage of carbon	0%	2.5%	5%	7.5%	10%
Water absorption percentage	3.913%	4.442%	3.929%	2.861%	3.444%

7. EXPERIMENTAL PROCEDURE

To check the influence of CBD into the concrete the specimens were tested for water absorption, compression using digital CTM and non-destructive testing using ultrasonic pulse velocity meter (UPV) and digital rebound hammer.

7.1. Water absorption test

Water absorption test was carried out after 28 days curing of concrete cubes. Initially concrete cubes were dried using ventilated oven by maintaining temperature to 110°C. After drying, the weight is taken (W1) then they were immersed in clean water at a room temperature of 27±2°C for a period of 24 hours. After 24 hours immersion the concrete cubes were removed and wiped out using damp cloth. Again, weight is taken as (W2) [24].

The percentage of water absorption is calculated form:

$$(W2\text{-}W1)/W1 \times 100 \qquad (1)$$

7.2. Compressive strength test

Compressive strength measurements were made on 150 mm x 150 mm x 150 mm cube concrete specimens. The specimens were cast in three layers, each layer being tampered with 25 strokes of the tamping rod spread uniformly over the cross section of the mold. The molds and their contents were kept in the curing room temperature and relative humidity not less than 90% for 24 hours. All specimens were demolded after 24 hours and cured in water after stripping. The compressive strength of prepared concrete cubes was determined as per the procedure described in IS 516:1959 [25] at different curing ages 7, 14 and 28 days using digital compression testing machine of 2000 kN capacity. The average readings of three cubes were reported as results.

7.3. Ultrasonic Pulse Velocity Test

The UPV test was performed for strength prediction of concrete, in accordance with IS 13311 Part 1 (1992) [26]. It involves measuring the velocity of sound travelling through the concrete. Ultrasonic

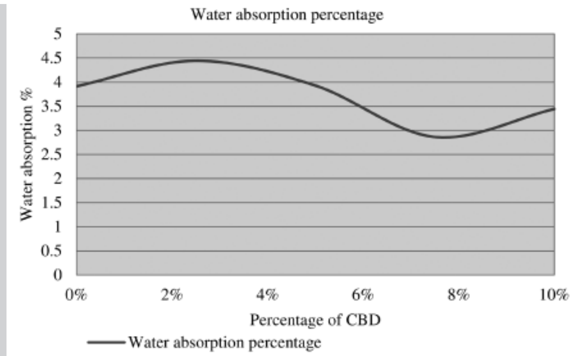


Figure 3.
Graph of Water absorption Test

concrete tester machine was arranged first; both the transducer and amplifier were placed on the faces of concrete cubes from both the sides and then the reading was noted down. The transducers were continued to be on hold onto the surface of the material until a consistent reading appeared on the screen, which is the time in microsecond for the ultrasonic pulse to travel the distance "L". Finally, the pulse velocity corresponding to path length and travel time was obtained using below equation.

$$\textit{Pulse velocity} = (\textit{Path length}/\textit{Travel time}) \qquad (2)$$

7.4. Rebound hammer test

Rebound hammer test was conducted as per IS 13311 Part2 (1992) [27]. The method is applied to investigate strength characteristics of concrete. The rebound hammer is a spring control hammer that slides on a plunger within a tubular housing. When the plunger is pressed against the surface of the concrete the mass rebound from the plunger, it retracts against the force of the spring the hammer impacts against the concrete and the spring control mass rebounds taking the rider with it along the guide scale, the writer indicates the distance travelled by the mass which is called the rebound number.

The relationship between rebound number and compressive strength with hammer horizontal and vertical on a dry or wet surface of the concrete is mentioned by an equation below:

Rebound Number = Sum of readings recorded / no. of readings (3)

8. RESULTS AND DISCUSSION

Results followed by the discussion for CBD based concrete is mentioned in this section.

8.1. Water Absorption

Water absorption test results after 28 days of curing are mentioned in Table 6. From the results it is observed that specimen containing 7.5% CBD shows least water absorption of 2.816%. It concludes that 7.5% CBD containing specimen is more densely packed than other specimen due to the particle size of CBD is finer than cement and presence of calcium in it which results in more effective bonding between the particles. Figure 3 shows graphical representation for water absorption of CBD based concrete.

8.2. Compressive strength

The observations were obtained from compressive strength test on the specimens having various percentage of CBD, tested after 28 days of curing and the results are as follows:

a. 7.5% specimen showed 17.23% increase in compressive strength than the control specimen,
b. 5% specimen showed 12.26% increase in compressive strength than the control specimen,
c. 2.5% specimen showed 7.36% increase in compressive strength than the control specimen,
d. 10% specimen showed 5.936% increase in compressive strength than the control specimen.

Hence using CBD as admixture of 7.5% will result in 17.23% increase in strength but using any amount of admixture above 7.5% will result in decreased compressive strength when compared to specimen using CBD as 7.5% admixture, although it might be more than the control specimen. Table 7 shows the observation for compression test whereas Figure 4 shows the graphical representation of compressive strength of CBD based concrete.

8.3. Non-Destructive test result

8.3.1. Ultrasonic pulse velocity test

The ultrasonic test gives an idea of the internal density and the presence of cracks. The presence of any crack and voids will result in increase in transit time.

From the results shown in Table 8, it is deduced that the most appropriate version of concrete was formed using 7.5% of CBD as admixture to concrete. Other than 7.5%, 2.5% and 5% also showed better pulse

Table 7.
Compressive strength of CBD based concrete specimen

Percentage of carbon	Compressive strength (MPa)		
	7 day curing	14 day curing	28 day curing
0 %	12.889	19.262	20.230
2.5%	13.089	20.022	21.720
5.0%	13.080	17.107	22.711
7.5%	12.889	18.804	23.716
10.0%	11.898	17.778	21.431

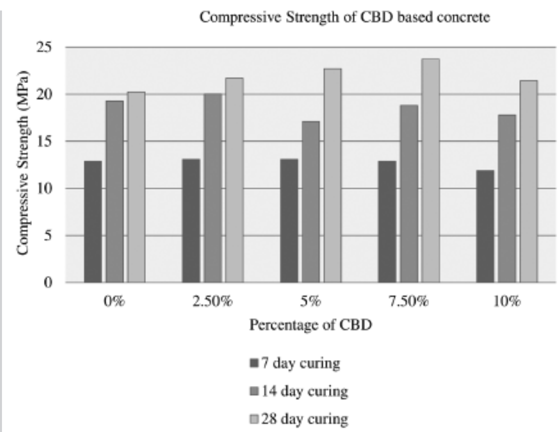


Figure 4.
Graph of Water absorption Test

Table 8.
Ultrasonic pulse velocity of CBD based concrete specimen

Percentage of carbon	Pulse velocity (km/sec)			Concrete quality as per IS 13311-1 [18]
	7 day curing	14 day curing	28 day curing	
0 %	3.807	3.989	4.098	**Good**
2.5%	3.546	4.011	4.360	**Good**
5.0%	3.704	4.098	4.225	**Good**
7.5%	**3.505**	**4.12**	**4.505**	**Excellent**
10.0%	3.823	4.011	4.043	**Good**

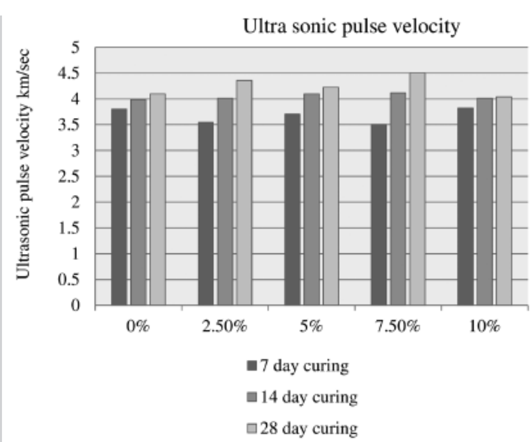


Figure 5.
Ultra sonic pulse velocity of CBD based concrete

velocity than the control specimen.

The concrete cube prepared using 10% CBD also formed good quality of concrete, but it was slightly less than the control specimen. The graphical representation for ultrasonic pulse velocity of CBD based concrete is shown in Figure 5.

8.3.2. Rebound Hammer

Rebound hammer test was conducted to determine the surface hardness of concrete. The results are shown in Table 9. The conclusions from results of 28 Days rebound hammer are shown as follows:

a) 7.5% specimen showed 35.60% increase in surface hardness when compared with control specimen.

b) 5% specimen showed 24.08% increase in surface hardness when compared with control specimen.

c) 10% specimen showed 13.61% increase in surface hardness when compared with control specimen.

d) 2.5% specimen showed 6.28% increase in surface hardness when compared with control specimen.

The results conclude that using CBD as admixture in concrete shows an increase in surface hardness, specimen containing 2.5%, 5%, 7.5% CBD shows gradual increase in surface hardness. 10% shows increase in surface hardness compared to control specimen, but it was slightly less than 7.5%. Figure 6 shows the graphical representation for rebound number of CBD based concrete.

Table 9.
Rebound number of CBD based concrete specimen

Percentage of carbon	Rebound number		
	7 day curing	14 day curing	28 day curing
0 %	15.85	17.90	19.10
2.5%	16.10	21.30	20.30
5.0%	17.95	22.00	23.70
7.5%	**19.80**	**20.00**	**25.90**
10.0%	18.40	19.55	21.70

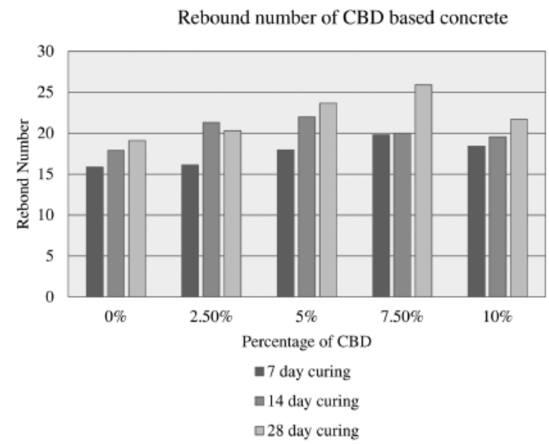


Figure 6.
Rebound number of CBD based concrete

8.4. Failure pattern analysis

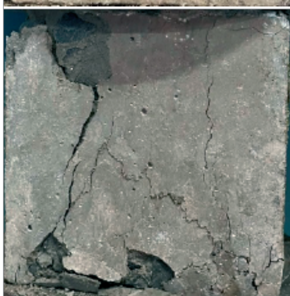
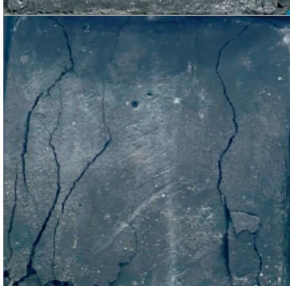
Failure pattern of tested concrete specimens were also observed to assess the failure nature of concrete under loading [1, 28]. Table 10 shows different failure patter corresponding to variation in CBD percentage.

9. CONCLUSION

From the present study the following conclusions could be drawn on the basis of experimental study and results.

1. XRF result reveals that CBD also contains oxides of iron, calcium, silica, and manganese such as presented in cement which ultimately promotes the strength and durability properties of concrete.
2. From the compressive strength test it is noticed that adding CBD as an admixture to concrete increases the compressive strength when compared to control specimen, the compressive strength increased in 2.5%, 5%, 7.5% and 10%. 7.5% gives the maximum increased compressive strength of 17.23% with respect to control specimen.
3. Use of CBD above 7.5% shows increase in compressive strength when compared to control specimen, but there is a decrease with respect to 7.5% specimen.
4. The water cement ratio increased as the percentage of CBD increases in the specimen. This is due to cementitious property in CBD.
5. Water absorption test results show that the specimen created using 7.5% CBD as an admixture gives the least water absorption percentage of 2.861%.
6. Concrete prepared using 7.5% CBD as an admixture result in excellent concrete quality when tested through ultrasonic test.
7. From the rebound hammer test it is noticed that adding CBD as an admixture to concrete increase in surface hardness when compared to control specimen, the surface hardness increased in 2.5%, 5%, 7.5% and 10%. 7.5% gives the maximum increased surface hardness of 35.60% with respect to control specimen.

Table 10.
Crack pattern in concrete specimen

Failure pattern	Specimen identity	Failure type	Remark
	0% CBD	Satisfactory failure with more brittle manner	Specimen splitting out in brittle failure mode
	2.5% CBD	Satisfactory failure with brittle manner	Brittle failure without splitting
	5.0% CBD	Satisfactory failure with ductile manner	Brittle failure without splitting due to ductile nature
	7.5% CBD	Satisfactory failure with more ductile manner	Ductile nature increases
	10.0% CBD	Satisfactory failure with more ductile manner	Ductile nature increases

ACKNOWLEDGEMENT

The authors would like to express gratitude for technical support provided by Centre for Advanced Technology, RR CAT, Indore, M.P. and IPS Academy, Institute of Engineering & science (A UGC Autonomous Institute), Indore, M.P., INDIA.

REFERENCES

[1] Rahman A. F., Goh W. I., and Jhalial A. A. (2019). Flexural study of reinforced foamed concrete beam containing palm oil fuel Ast (POFA) and eggshell powder (ESP) as partial cement replacement. *International journal of sustainable construction Engineering and Technology 10*(1), 93–100.

[2] Raheem A.A., and OlatundeIbiwoye E. (2018). A Study of Neem Seed Husk Ash as Partial Replacement for Cement in Concrete. *International Journal of Sustainable Construction Engineering &Technology* (ISSN: 2180-3242) *9*(2).

[3] Nagavkar G.N. (2017). Effect On Properties Of Concrete With Partial Replacement Of Additives With Cement. *International Journal Of Engineering Sciences & Research Technology.*

[4] Alyhya W.S.S., Alameer S.A.A., and Ridha L.A. (2018). Experimental Investigation on Self-Compacting Concrete with Waste Carbon Black. *International Journal of Engineering &Technology, 7*(4.20) 414–419.

[5] Goldman A., and Bentur A. (1993). The influence of micro fillers on enhancement of concrete strength. *Cement and Concrete Research*, 23962–72.

[6] Goldman A., and Bentur A. (1992). Effects of pozzolanic and non-reactive micro fillers on the transition zone in high strength concretes, Interfaces in Cementitious Composites. *Proceedings of the International Conference held by RILEM, Edited by J.C. Maso*, 58–67.

[7] Ahmedzade P., and Geckil T. (2007). Influence of Carbon Black on the mechanical and electrical properties of Asphalt Mixtur. *Indian J Eng Mater Sci*; 14, 358–64.

[8] Kharita M.H., Yousef S., and Alnassar M. (2009). The effect of carbon powder addition on the properties of hematite radiation shielding concrete. *ProgNucl Energy*; 51, 388–92.

[9] Chitra G., VetriSelvi P., and Vijayalakshmi D. (2014). Carbon Black as an Additive in Conventional Concrete. *International Journal of Emerging Technology and Advanced Engineering*.

[10] Masadeh, S. (2015). The Effect of Added Carbon Black to Concrete Mix on Corrosion of Steel in Concrete. *Journal of Minerals and Materials Characterization and Engineering*, 3, 271–276.

[11] Padmapriya B., and Pandeeswari M.E. (2016). Experimental Investigation on the Properties of Concrete with Carbon Black and PET. *International Journal of Advanced Research, 4*(4), 1082–1088.

[12] Jeyashree T.M. and Chitra G. (2017). Experimental Studies On Concrete Elements Using Waste Carbon Black As Filler. *Material Asian Journal of Civil Engineering (Bhrc)*, l8.

[13] Fayas Danish, Malik Ashfaq, Zakir Mohd, Malik Ahmad Tufail. (June-2018). Effects on the properties of Concrete by Particle Replacenment of Cement with Carbon Black and Natural Fine Aggregate with Robo Sand. *IJTIMES – International Journal of Technical Innovation in Morden Engineering & Science, 4*(06).

[14] Divya G., Ismail M.D. (2019). Experimental Study on Behavior of Carbon Black on Partial Replacement with Cement. *IJSRD – International Journal for Scientific Research & Development, 7*(05).

[15] Mohammad R., Irshidat., and Nuaimi N.A. (2020). Industrial Waste Utilization of Carbon Dust in Sustainable Cementitious Composites Production. *MDPI, Journal of materials*.

[16] BIS:383, 2016. Course and Fine Aggregate for Concrete – Specification (3nd Revision), in: (BIS) BoIS, (Ed.), New Delhi, India.

[17] BIS:2386, 1963. Method of Test for Aggregate for Concrete, Part 1: Particle Size and Shape, in: (BIS) BoIS, (Ed.), and New Delhi, India.

[18] BIS:2386, 2016. Method of Test for Aggregate for Concrete, Part 3: Specific gravity, Density, Voids, Absorption and Bulking, in: (BIS) BoIS, (Ed.), New Delhi, India.

[19] BIS:2386, 1963. Method of Test for Aggregate for Concrete, Part 4: Mechanical Properties in: (BIS) BoIS, (Ed.), New Delhi, India.

[20] BIS: 12269, 2013. Specification for 53 grade ordinary Portland cement, in: (BIS) BoIS, (Ed.), and New Delhi, India.

[21] Kumar, V., Kumar, S., Prasad, J., Keshari, K., Ghosh, S., and Bhakat, K. (2017). Feasibility Study of Dephosphorization of Slag Generated from Basic Oxygen Furnace of an Integrated Steel Plant. *International Journal of Metallurgical Engineering, 6*(2), 31–35. DOI: https://doi.org/10.5923/j.ijmee.20170602.01.

[22] BIS: 1199-1959. Methods of sampling and analysis of concrete, in: (BIS) BoIS, (Ed.), and New Delhi, India.

[23] BIS: 456-2000, Plain and reinforced concrete – code of practice (Fourth Revision)

[24] BIS 2185-1 (2005): Concrete masonry units, Part 1: Hollow and solid concrete blocks

[25] BIS: 516 (1959). Method of Tests for Strength of Concrete in: (BIS) BoIS, (Ed.), and New Delhi, India.

[26] BIS: 13311, 1992. Non-Destructive Testing of

Concrete-Method of Test, Part 1: Ultrasonic Pulse Velocity, in: (BIS) BoIS, (Ed.), and New Delhi, India.

[27] BIS: 13311, 1992. Non-Destructive Testing of Concrete-Method of Test, Part 2: Rebound Hammer, in: (BIS) BoIS, (Ed.), and New Delhi, India.

[28] Hamiruddin N.A., Razak R.A., and Muhammad K. (2018). Effect of Steel Fiber Contents with High Strength Fiber Reinforced Concrete, *International Journal of Advances in Scientific Research and Engineering, 4*(3).