Solving Ecological Problem of Pyrolysis Carbon Black (PCB)

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***Abstract*— Tire waste is one of the most important problems of environmental solid waste in the world. Since, the waste tire cannot be treated in a landfill nor burned, because it releases serious toxic gases. So, several methods have been proposed for waste tire treatment. Among these methods waste, tire pyrolysis is considered the most favorable. Pyrolysis is a process of converting waste tires into gases, fuel oil, steel, and a by-product, which is pyrolyzed carbon black (PCB). However, gas and oil can be sold out in the local market as well as steel, while PCB that contains 30-35 wt% of the waste tire product becomes another solid waste problem. In this experimental investigation, an attempt was made to employing PCB in concrete that is used in building. Accordingly, a PCB sample will obtain from a local pyrolyzed waste tire plant; this will use as received without any chemical purification. The compression strength will be tested to find the effect of adding PCB to concrete.**

Keywords— Concrete, tire, ecology, pyrolyzed carbon black (PCB), Properties of Concrete, Pyrolysis.

I. Introduction

Concrete is a mixture of cement, aggregate, sand, and water. Cement is one of the most used materials in the world [1]. The big production of cement creates serious problems for the environment due to the emission of CO_2 during the production process of the cement. The CO_2 emission is very harmful and creates serious changes in the environment. Approximately, 1kg of carbon dioxide is released into the atmosphere when1 kg of ordinary cement is manufactured [2]. Since there is no alternative construction material for the cement. The search for an alternative or supplementary material for cement should lead to less environmental impact. It has been possible to achieve substantial energy and low cost when using industrial by-products in a mixture of concrete. The presence of pores in concrete is considered a major problem since ever concrete was discovered. These pores attract water that leads to serious undesirable effects such as reduced compressive strength, acid intrusion, freezing and thawing, and decreased resistance to chloride ion, etc [3].

Pyrolysis is thermochemical decomposition, turns waste into energy-rich fuels by heating the waste, like waste tires under controlled conditions at elevated temperatures in the absence of oxygen. It occurs at around 500 ºC and atmospheric pressure. It is an environment-friendly operation and has nearly no emissions or waste, pyrolyzed carbon black is the only by-product. The main products of the tire pyrolysis process include [4, 5]:

- Gases (about 10 wt. %): The composition of the produced gases is carbon dioxide, carbon monoxide, hydrogen, methane, ethane, and other hydrocarbons. The gases can be used in the heating application.
- Fuel oil (40-45 wt. %): this oil is highly aromatic, relatively low sulfur content, and is considered good industrial fuel for heating applications.
- Steel wire (10-15 wt. %): which is very easy to sell in the local market for steel production.
- Carbon black powder (30-35 wt. %): which is considered the by-product of this process.

By pyrolysis process, which is mentioned previously, a high pyrolyzed carbon black content component was produced as a by-product with approximately 30-35 wt% yields of the tire, which is known as coke or pyrolyzed carbon black. This contains 95 wt% carbon black, and more than 3 wt% sulfur [5]. Therefore, the produced carbon black could render the tire pyrolysis environmentally unfriendly as this product contains sulfur and other heavy metal that could leach after some time after uncontrolled dumping [6]. Hence, finding a suitable application process for carbon black will not just make the process environmentally friendly but profitable as well.

Several researchers used many materials as fillers in concrete. Goldman and Bentur [7, 8] investigate the effect of adding micro fillers for enhancing the properties of concrete. Chitra et al. [9] tested the best carbon black ratio that could be added to the concrete mixture for optimal properties. Siddique, R. and Naik, T.R. [10] showed that scrap-tire rubber can be used to make workable rubberized concrete mixtures. Torgal et al. [11] presented a detailed review of the performance of concrete using polyethylene terephthalate bottles (PET) and tire rubber wastes. They investigated that concrete using tire waste is especially recommended for severe earthquake risk and dynamic actions. Mohammed, B.S. et al. [12] Reviewed in detailed the previous researches that investigating the hardened and fresh properties of rubbercrete. They concluded that Rubbercrete has improved workability and using Nano silica as cementitious addition can be offset economically the reduction in the strengths of rubbercrete. Senin et al. [13] reviewed in detailed inclusion of waste rubber for replacing part of aggregate with waste rubber. They showed that as the rubber ratio increases the strength and workability of concrete decrease. in general concrete with rubber content has better water adsorption ability. They summarized that the optimum percentage for the rubber to replace aggregate is 3%.

The present study would be the first study to investigate the use of Pyrolyzed carbon black (PCB), a by-product that results from a local pyrolyzed waste tire plant in Jenin-Palestine, as filler in enhancing compression strength, workability, and adsorptivity of concrete.

II. METHODOLOGY

The basic material in this experiment is the PCB, so the considered tests are related to this material, where the concentration of adding PCB. The comparison is based on the Compression strength test.

PCB, a by-product that results from the pyrolysis process of waste tires, was provided by a local Pyrolysis plant in Jenin-Palestine. The PCB sample was used without further purification. The proximate, elemental, and heating value analysis for the PCB is shown in Table 1 [5].

To conclude the optimum percentage of the addition of Pyrolyzed black carbon (PCB) in the concrete number of cubes with different percentages of PCB were cast. The compression strength after adding PCB was studied and the results are compared to the blank specimen (Without PCB). Each percent of three cubes was prepared with two ages (7 and 28) days, then the average has been taken of the specimens for each age.

In this study the following components were used: cement (1 kilogram) (water-cement ratio (w/c) = 0.50), and (2.3 kilograms) and aggregate (4.0 kilograms). Aggregate is mainly composed of aggregate type one with a diameter around 18-25 mm (1.66 kilograms), aggregate type two with a diameter around 7-17 mm (0.9 kilograms), and aggregate type three with a diameter around 1-6 mm (1.46 kilogram). Concrete cubes were cast with previous materials and proportions by adding the pyrolyzed carbon black (PCB) of (0%, 3%, 3.5%, 4%, 4.5%, 5%, 7% & 10%) by weight in the amount of cement.

The type of concrete used in this study is B300. Sand, aggregate, and water were prepared on a weight basis and mixed by hand very well. Then, water was added until all the materials formed a uniform mixture. After 5 minutes additional water and cement were added and mixing for approximately 3 minutes. Finally, carbon black was added and mixed for another 3 minutes.

After preparing the concrete samples the compression test (after mixing materials) was conducted. The following steps were employed during the tests by using a water bath; the concrete cubes were submerged in water for 7 and 28 days. Wait for 7 days to take the first specimens' results that have (60-70) % of the total strength, and 28 days to take the final specimens' results that have 100% strength.

The concrete specimens were placed in a compression testing machine to check the compression strength

III. ANALYSIS RESULTS

To determine the compression strength of concrete specimens, the cubes were put in the compression testing machine as shown in Figure 1. Then the load was gradually applied until the specimen failed. This load at which the specimen failed was recorded. Figure 1 shows the compression strength testing machine.

After designing and performing the laboratory tests, the test data were analyzed to evaluate the effectiveness of the PCB on the concrete. A comparison was made between blank concrete (without PCB 0%) and concrete with different PCB ratios.

At first, for each percent three cubes were prepared with different ages (7 and 28) days, then the average has been taken of the specimens for each age, and a percentage of PCB was suggested as (0%, 3%, 3.5%, 4%, 4.5%, 5%, 7%, & 10%) to obtain the optimum strength of concrete with PCB.

The results for the average compression strength test for 7 and 28 days are tabulated in Tables 2 and 3 respectively.

TABLE 1: PROXIMATE, ELEMENTAL, AND HEATING VALUE ANALYSIS FOR THE PCB [5]

	PCB(% wt)
C[1] (%)	95.42 ± 0.16
H[1] (%)	0.77 ± 0.20
N[1] (%)	0.22 ± 0.07
S[1] (%)	3.29 ± 0.09
Cl[1] (%)	0.19 ± 0.01
O[1] (%)	0.12 ± 0.07
Ash	16.5 5± 0.34
Moisture	1.16 ± 0.14
Volatile matter (%)	2.50 ± 0.74
HHV (MJ/kg)	28.70 ± 0.18

[1] Results on a dry basis with ash-free.

Figure 1. Compression testing machine.

TABLE 2. AVERAGE COMPRESSION STRENGTH TEST RESULTS AFTER 7 DAYS

PCB Ratio %	Weight (gm)	Density (gm/cm^3)	Compression test (MPa)	Compression test (kg/cm^2)

0%	2378.5	2.3785	22.2	226.3
3%	2254.4	2.2544	27.8	283.4
3.5%	2389.8	2.3898	28.1	286.5
4%	2286.6	2.2866	29.3	298.7
4.5%	2409.9	2.4099	27.3	278.3
5%	2399.06	2.3990	26.7	272.2
7%	2408.9	2.4089	24.1	245.7
10%	2335.2	2.3352	21.3	217.1

TABLE 3. AVERAGE COMPRESSION STRENGTH TEST RESULTS AFTER 28 DAYS

PCB Ratio %	Weight (gm)	Density (gm/cm^3)	Compression test (MPa)	Compression test (kg/cm^2)
0%	2163.1	2.1631	30.4	309.9
3%	2215.3	2.2153	35.8	365.05
3.5%	2266.8	2.2668	36.6	373.2
4%	2179.1	2.1791	38.4	391.5
4.5%	2172.03	2.1720	35.5	361.9
5%	2245.3	2.2453	34.7	353.8
7%	2304.8	2.3048	32.4	330.3
10%	2289.8	2.2898	30	305.9

The results of the effects of adding PCB to the concrete mixture is shown in Figure 2 and 3.

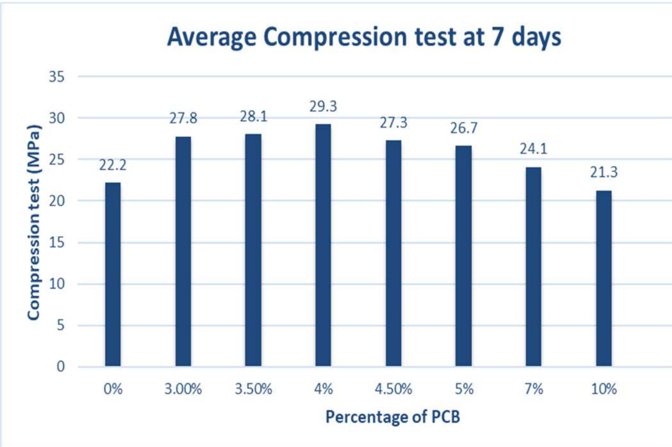

Figure 2. Average compression strength test results after 7 days.

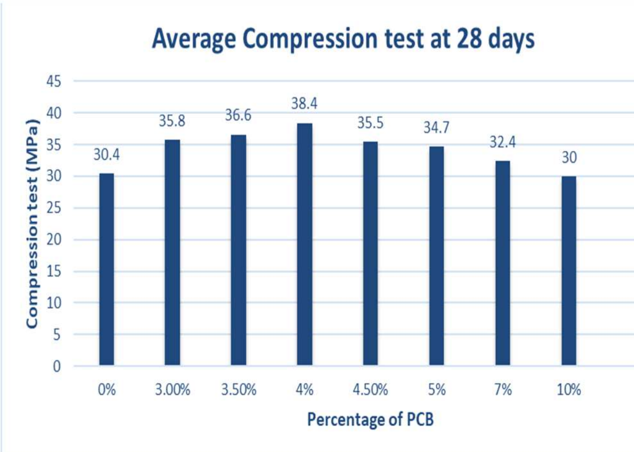

Figure 3. Average compression strength test results after 28 days.

From Table 2, Table 3, Figure 1, and Figure 2, it is concluded that the compression strength for the concrete specimen with 3%, 3.5%, 4%, 4.5%, 5%, and 7% is more than that for the blank concrete specimen. This proves that PCB increases the compression strength of the concrete mixture. Also, It is concluded that adding 4% PCB by weight in the amount of cement gives the best compression strength.

It is clear that the 10% PCB specimen has given very close compression strength to the blank specimen.

IV. CONCLUSIONS

This study investigated the effect of adding PCB obtained from a local pyrolyzed waste tire plant to concrete on the compression strength. Since there is no alternative construction material for the cement. Utilizing PCB as an alternative or supplementary material for cement would lead to less environmental impact. It has been possible to achieve Substantial energy and low cost when using PCB in a mixture of concrete.

Based on the previous results it can be concluded that using pyrolyzed carbon black (PCB) in a concrete mixture leads to a higher concrete compression strength. The best compression strength can be obtained by adding a PCB of 4 wt% in the amount of cement. From 10 wt% onwards the compressive strength value reduces. Moreover, compression strength result close to blank concrete specimen's strength can be obtained by adding PCB of 10 wt% in the amount of cement.

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