



An-Najah National University  
Faculty of Engineering & Information Technology

**Graduation project 2**

**Studying the effect on mechanical properties of concrete when  
pyrolysis carbon black is added**

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## Abstract

In our project, we have made a particular number of concrete specimens, some are containing carbon black with a specified percentage, and the others are without any carbon black at all, this carbon black is taken from waste tire pyrolysis process, and we have added this carbon black to concrete that is used in buildings, the PCB we used is without any chemical purification.

After we prepared the concrete cubes specimens, we have applied several tests on these specimens, the tests were applied on both, the specimens with carbon black with specified percentage, and the specimens that are completely without any carbon black, and this was done to compare between the results from both, and to check if the results are preferable or not, the tests were applied on the specimens after 7 and 28 days since making the specimens. The tests were used in our project are compressive test and this was to check the compressive strength before and after adding the PCB, friction test, and this was to check the loss in mass with time due to a friction load, water adsorption, and this test was applied to check if water adsorption increase or not, and the last was the slump test.

Generally from results we had, the compressive strength was increased, while the water adsorption was decreased, about the slump, results gave the minimum slump, from friction test results, we have noticed that the friction was minimum, looking to those results, using PCB with specified percentage gave a preferable results.

# Chapter 1: Introduction

## 1.1 Background

Concrete is the most widely used man made construction material in the world. It is obtained by mixing cement materials, water and aggregates in required proportions. Being a versatile material, presence of pores in concrete proves to be a major problem since ever it was discovered. Pores in turn attract water that leads to various ill effects such as freezing and thawing, acid intrusion, decreased resistance to chloride ions, and reduced compressive strength, etc. By considering this problem, a study is made to minimize the pores presence by using carbon black powder as a filler, which is taken from waste rubber industry.

Since carbon black powder particles size is extremely small, they can fill the pores existing in concrete, thereby it is expected to achieve the following benefits: increase in the density of concrete, which means an increase in strength and resistance to atmospheric attack and decrease in permeability of concrete.

Carbon black is virtually pure elemental carbon in the form of colloidal particles that are produced by an incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. It has a physical appearance of a black, finely divided pellet or powder. Carbon black is a waste from rubber industry, in which the disposal of it is generally difficult and usually not environmental friendly. Normally these rubber wastes are dumped into soil creating soil pollution and contamination in water table. Therefore, by using carbon black as a filler in concrete we can reduce this problem to a great extent. Thereby reusing the waste usefully and making it eco-friendly to environment.

## 1.2 Objectives

This project aims to find a healthy way to use and dispose the PCB which results from tire processing production, in the concrete mixes in order to improve the performance of concrete, reduce the cost, and reduce the environmental impact.

The specific objectives of this project include the following:

1. Investigate the ability to add PCB to the concrete.
2. Determine the mechanical properties of concrete and characterize it when adding PCB powder at various percentage.
3. Investigate the proportion of PCB effects on the mechanical properties of the concrete.
4. Investigate which is the best ratio of PCB (various percentage) added to concrete that would lead to a better concrete performance.

## 1.3 Scope of project

The scope of our project, knowing the suitable compositions of concrete ingredients in addition to the added carbon black may change concrete mechanical properties to a better-enhanced performance. It is also essential to know those ingredients costs, availability in market, and their effect on concrete itself, so this project will be based on studying the effect of carbon black with other compositions in concrete on concrete mechanical properties, and if it could give the good wanted results, this would kill two birds by one stone, in which two benefits can be achieved, which they are firstly, concrete with enhanced mechanical properties and secondly, a better disposal of waste tires with the minimum environmental pollution.

### 1.3.1 Pyrolysis carbon black

The carbon black used in our project is taken from waste tires pyrolysis process. The high using rate of motor vehicles in the world, have a rate of one and a half billion vehicles according to statistics of 2019, which is expected to increase over the coming years. Due to the high using rate of motor vehicles, there will be a high percentage of waste tires around the world where they are disposed of in landfills. These waste tires are disposed of by burning them, so this will lead to a negative influence the environment and human health, they are also disposed of by burial, and this is a problem because it takes large areas as shown in the figure 1.1. Therefore, these tires should be utilized, disposed of in an environmental friendly way and more economical through recycling.

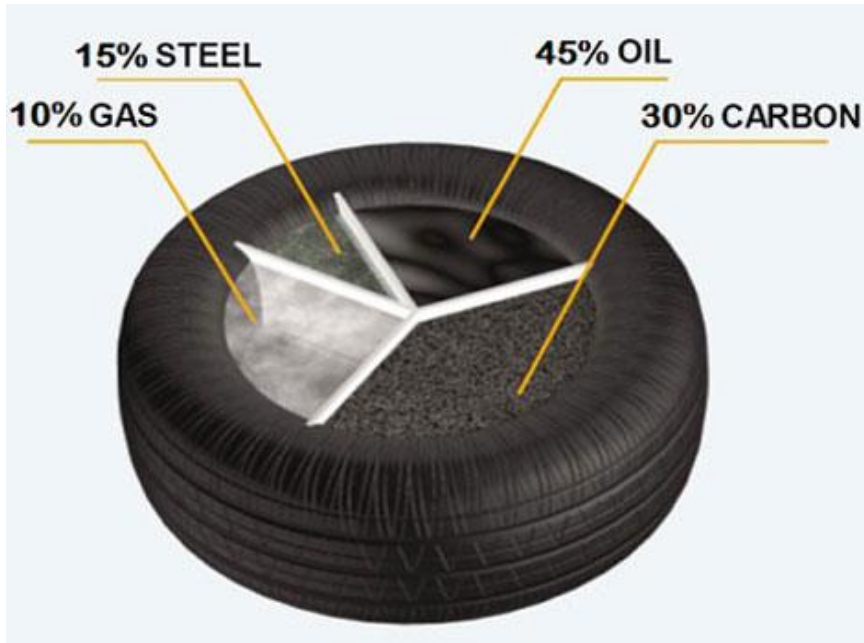


*Figure 1- 1 Waste tire disposal and burning in desert Kuwait*

There are many treatments or recycling of waste tires methods, such as, ambient mechanical grinding, cryogenic mechanical grinding and pyrolysis process. We are interested in this project in recycling waste tires by pyrolysis to get carbon black from it.

Pyrolysis process system consists of four parts, first one is the feeding system, second is the reactor system, third is the vessel for pyrolysis carbon black and the last part is the condensation system. So, by taking pyrolysis process system, first of all and before pyrolysis starts, the tires need to be shredded into smaller pieces.

The pyrolysis carbon black is one of the most essential products of the pyrolysis process, since that carbon black is considered to be around 30-40% of the whole weight of the tire, while the steel is around 15%, gas is around 10% and oil is around 45% from the waste tire recycling products. Figure 1.2 shows the percentage of products from waste tire pyrolysis.



*Figure 1- 2 Percentage product from waste tire by pyrolysis.*

The resulting carbon black from the pyrolysis process is about 30 to 35% from between other products produced by pyrolysis, so here, carbon black is known as pyrolysis carbon black which is containing around 75% carbon black, a maximum of 9% ashes, 4% of sulfur, and 12% of a minimum butadiene copolymer; because carbon black contains sulfur and other heavy materials, this product is harmful to the environment and human health if left for a long period of time due to reactions with surrounding and the release of toxic gases. Therefore, finding a suitable application process for carbon black will not just make the process environmental friendly, but even profitable as well. Figure 1.3 shows a pyrolysis carbon black.



*Figure 1- 3 Black carbon powder.*

The mechanical properties of pyrolysis carbon black as the following:

1. Presence of inorganic compounds in pyrolysis carbon black makes it having lower hardness and tear strength than the original one.
2. Pyrolysis carbon black substances have a higher surface area than the conventional carbon black because they have higher surface roughness.

### 1.3.2 Concrete

Concrete is a composite material and heterogeneous mixture, it consists of aggregates, sand, cement and water with some pores and some other material (additives) can be added to obtain certain properties. The proportions of these materials are chosen in concrete mix according to the type of work required and the materials available. As these materials are mixed together, the concrete is obtained which begin with progressive solidifying with time until they become solid and strong and their strength varies according to the basic components. Figure 1.4 shows the Component of concrete mixture.



*Figure 1- 4 Component of concrete mix.*

Functions of concrete components first, cement is a soft, dark material that has a cohesive and contiguous properties in the presence of water, which makes it able to attach concrete components to each other and to bond with reinforcing steel. Second, sand and aggregate (gravel), they have a significant impact on the properties of the concrete as they form a mass of concrete, increasing its strength and stability.

Concrete has advantage as the following:

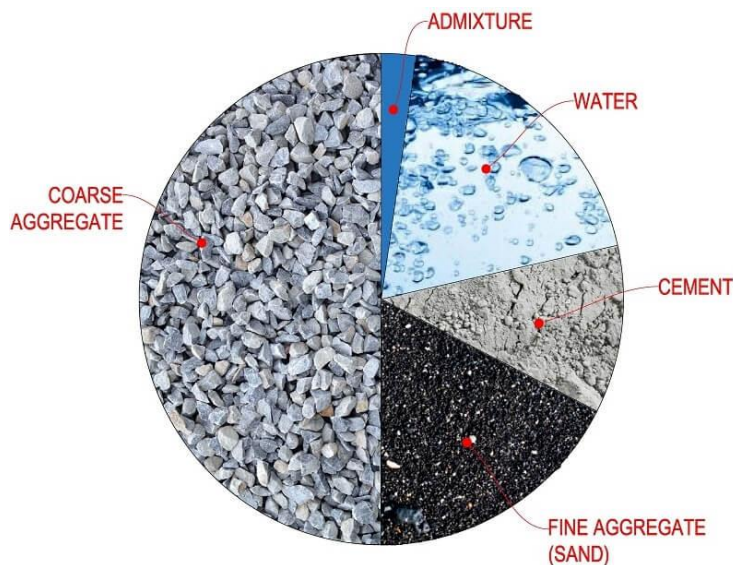
1. Concrete components are readily available.
2. Concrete is free of defects unlike natural stones.
3. Concrete strength can be controlled with economy.
4. The durability of concrete is very high.
5. Easy to form concrete for the desired shape.
6. The cost of concrete maintenance is very low.
7. The default lifetime for concrete is long.
8. Fire-resistant concrete.
9. Concrete can withstand high and low temperatures.
10. Concrete is resistant to wind and water, so is high strength.
11. Concrete is characterized by sound insulation material.

Disadvantage of the concrete as the following:

1. The tensile strength of the concrete is low.
2. Concrete is high brittle.
3. Its weight is high compared to its strength.
4. Concrete contains soluble salts which affect their properties.
5. Concrete contains pores.

### 1.3.3 Concrete Additives.

Additives are used in concrete for several purposes are (plasticizers, super plasticizers, retarders, accelerators and air entraining agents) plasticizers and super plasticizers helps to improve workability by maintaining the fluidity in concrete by releasing the water (from flock) which is entrapped during initial mixing. Retarders slows down the setting of concrete for example hydration process will take place slowly. Accelerators helps to set the concrete at faster rate (cold regions very helpful). Air entraining agents, even though these will affect the strength but in cold regions air entraining agents helps to prevent freezing and thawing cycles. Figure 1.5 shows the concrete mix with admixture. In our project add PCB to the concrete for air entraining agents to enhance properties of concrete.



*Figure 1- 5 Concrete mix with additives.*

## 1.4 Mechanical testing

Several mechanical testing methods are designed to measure different mechanical properties of various materials such as, compressive strength, ductility, hardness, tensile, impact resistance, friction, porosity, slump, water adsorption, etc. There are several types of test to determine various mechanical and physical properties of material. The precision results of these tests is used to determine suitability of materials for the field application.

In our project, we are interested in some mechanical properties such as compressive strength test, friction test, water adsorption and slump test. A compressive strength is the maximum compressive stress that under a gradually applied load a given solid material will sustain without fracture. A friction is a force that opposes motion between two surfaces that are in contact caused corrosion of the body. Water adsorption for concrete, the test procedure involves drying a specimen to a constant weight, weighing it, immersing it in water for specified amount of time, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its adsorption (in percent). The average adsorption of the test samples shall not be greater than 5% with no individual unit greater than 7%. Slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

## Chapter 2: Literature review

**M. Jeyashree, G. Chitra (2017)**<sup>13</sup> conducted a study on uniformity, surface hardness, split tensile strength, flexural strength and compressive strength of concrete specimens containing various percentages of carbon black. From the experimental result, it was seen that optimum percentage of 5% to 8% carbon black can be effectively used for the enhancement of concrete properties. Influence of adding carbon black as filler material in concrete was studied by casting and testing the specimens. Flexural behavior of PCC beam was studied by conducting flexural strength test. In addition to that, the tests conducted on concrete cubes were non-destructive testing using Ultrasonic Pulse Velocity (UPV), compressive strength using Rebound hammer and the compressive strength test using compression testing machine. The tests conducted on concrete cylinders were split tensile strength test, OCP Test and chloride ingress determination test.

**Gaurav Navnit Nagavkar (2017)**,<sup>14</sup> an attempt was made using carbon black powder, which is taken from waste tire pyrolysis as filler and calcium sulfate in the form of hydrate which is used as desiccant to investigate the effect of carbon black calcium sulfate powder on wet properties and hardened concrete properties. Both of these additives are partially replaced by cement with different percentage. Concrete cubes and cylinders are cast depending on the percentage ratio and its effect is studied. After mixing carbon black and calcium sulfate as an additive in concrete, its properties like workability, setting time, bleeding, reactivity, hardness, shrinkage, etc. and other physical and chemical properties gets integrated. If they were added in an accurate and right percentage ratio, their bonding matrix would act more effectively. Also changes of carbon and sulfate attack can be manipulated.

**M.H.Kharita et al. (2009)**,<sup>15</sup> we concluded from this paper, when using carbon black in a hematite concrete 15% of weight of the cement, there was an improvement on the mechanical properties of the hematite concrete. Where the ratio of 6% additives of black carbon to concrete enhanced the workability of the concrete mixture, and the compressive

strength of the concrete. In this study, carbon black was added at high temperature, because they are easily affected by heat.

**Dr. G. Ghitra. P. Vetri and Dr. Vijayala kshmi, (2014),<sup>6</sup>** in this paper, author took the carbon black as an additive into a conventional concrete, to suggest the optimum percentage of carbon black to be added to the concrete, totally 18 number of concrete cubes, 12 number of concrete cylinders with carbon black of different percentage (0%, 2%, 5%, 8%, 12%, 15%) were cast. Morphology, surface hardness, uniformity, compressive strength, tensile strength were carried out on the specimens of concrete with carbon black, and it was shown in the results that when taking carbon black of 8% it was not effective and this was noticeable from the reduction of the performance of 12% and 15% samples, it was maintained that the addition of carbon black up to 5% of a filler would be so effective in conventional concrete. The addition of 8% carbon black into concrete showed and excellent closure of pores and for water absorption.

**Danish fayaz, Ashfaq Malik, Tufail Ahmad Malik (2018),<sup>18</sup>** in this paper authors took pores in concrete as a problem that should be solved, they mentioned that the presence of so much pores in concrete would attract more amount of water that leads to a several bad effects such as acid intrusions, freezing and thawing, decrease in resistance to chloride ions and reduced the compressive strength, they studied the permeability/porosity property effect on mechanical properties of concrete, by adding carbon black and robo sand, it was found that the replacement of cement in concrete by 5% carbon black made the concrete denser with lower porosity, and it was shown that less permeability gives more strength, less corrosion and more tensile strength. In our project, pyrolysis carbon black will be added alone to concrete to study the porosity, friction and impact resistance properties.

**B. Padma Priya, Mrs, k. Pandeeswari.M.E (2016),<sup>10</sup>** in this paper strength properties of concrete were investigated by the addition of carbon black and PET to concrete, the

strength properties of M40 grade concrete were studied with 0%, 10%, 20%, of PET. It was conducted that the strength decreases when rising the ratio of used PET percentage, so they used a constant amount of PET, then they added carbon black powder(10%,20%,30%, 40%,) mixed with fly ash to concrete, they conducted a compressive strength test and a tensile strength test, it was shown here that the addition of carbon black increased the strength of concrete, and it was shown that 30% carbon black gave the best results, same percentage of carbon black is found to be with high tensile strength.

**Sami Masadeh (2015),<sup>7</sup>** in this paper authors studied the effect of adding carbon black to concrete to reduce the pores and as a result of this a decrease in corrosion rate should occur, so this was achieved when they inserted steel bars in different concrete mixes containing (0.1,0.2,0.3,0.4,and 0.5) of carbon black/cement, samples were cured, and immersed in a 3.5% chloride solutions for 6 months nearly, after applying tests, results showed that the corrosion rate and chloride ion penetration properties were decreased after adding carbon black to concrete mix, this was explained by that the addition of fine carbon black particles could fill pores are found in concrete, the used particles had a size of 250nm, which even makes the concrete denser.

**Perviz Ahmed Zade (2017),<sup>17</sup>** here authors has studied the effect of carbon black addition on mechanical properties of asphalt mixtures. Creep stiffness, tensile modulus, tensile strength and stability were studied. It was shown from this paper study that mechanical properties were improved with mixing the suitable percentage of carbon black with asphalt mixture.

**Dae- Geun lee, Kyung Hoon Kim, Hyeong Gi Kim and young seak lee (2016),<sup>16</sup>** in this paper, authors studied the effect of carbon additives on mechanical properties of highly strength cement mortar, it was mentioned that high early strength cement mortar usually have a short working time of under 40 min and a compressive strength of 24 MPa, they

suggested to add carbon materials in which carbon black is one of them to enhance the mechanical properties and even heat transfer properties, the bulk density and the surface area of the carbon black was added were 0.12 g/c and 800 /g respectively. It was resulted that the compressive strength, flexural strength and tensile strength of the prepared cement mortar was observed in day 1 were increased, this result shows that the addition of carbon black with carbon fibers could improve the mechanical properties of the cement mortars , and this is was due to the effect of bridging between the carbon fibers and the carbon black.it was resulted that at the age of 28 day the strength increased because carbon black was added adsorbs a good amount of water during mixing and this is due to the large surface area of the carbon black was used here.

So, in our project, carbon black will be added to concrete to study its effect on other mechanical properties in addition to strength property, such as; friction and porosity. And so, carbon black powder will be taken from waste tire pyrolysis and added alone without applying a high temperature as they did in last papers.

## Chapter 3: Experimental Work

### 3.1 Material

The type of concrete that is used in this study is B300 (1 : 2.3 : 4.03)Kg, the main reason for selecting this type of concrete is that it is the most commonly used in the West Bank-Palestine, it consists of three main components: cement, sand and aggregate. These components are used for preparing the concrete sample for testing.

#### 3.1.1 Cement

Cement acts mostly as a binding agent between coarse aggregate (gravel), fine aggregate (sand) and provides strength to concrete on setting and hardening. Figure 3.1 shows a picture of cement (42.5 N) obtained from Majed Abu-Khadeja Company in Qalqilia-Palestine.



*Figure 3- 1 Cement.*

#### 3.1.2 Aggregate

Gravel or coarse aggregates increases the crushing strength of concrete, makes concrete solid hard mass, reduce cost of concrete by occupying major volume in concrete. Also it should be noted that coarse aggregate plays major role in transition zone. In our project we are used three type of coarse aggregates: large (18-25) mm, medium (7-17) mm and small

(1-6) mm. Figure 3.2 shows a picture of aggregate obtained from Majed Abu-Khadeja Company in Qalqilia-Palestine.



*Figure 3- 2 Aggregate.*

### 3.1.3 Sand

Sand or fine aggregate reduces shrinkage and cracking, fills voids present in coarse aggregates and helps in hardening of cement. Figure 3.3 shows a picture of sand obtained from Majed Abu-Khadeja Company in Qalqilia-Palestine.



*Figure 3- 3 Sand*

### 3.1.4 Water

Water acts as one of the component in concrete mix for reaction with cement which result in hard cement after drying but increase water to cement ratio due to the reduction in concrete strength.

### 3.1.5 Pyrolysis carbon black (PCB)

Figure 4.1a shows a photograph of PCB, a by-product that result from the pyrolysis process of waste tires, which was provided by Al-Khaldi Factory in Jenin-Palestine. The sample considered as an improving and binding agent in our project between cement and aggregate.

The PCB sample was used without further purification. However, before any use, the sample was screened by sieves. Figure 4.1b shows particle size distribution of the considered sample.

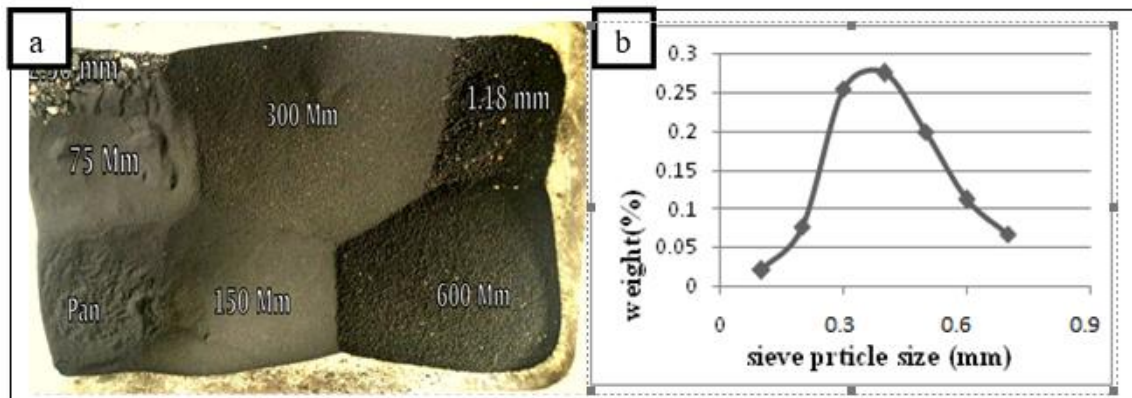


Figure 3- 4 Pyrolysis carbon black at diffrenet particl size

### 3.1.6 Water to cement ratio

The water–cement ratio is the ratio (w\c) of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability. And in our project, it's taken 50% because it's more typically used.


### 3.1.7 Super G7






Super G7 is a substance which can be added to concrete to increase the workability of concrete when mixing concrete ingredients together, the most favorable advantage for this substance that it can make the mixture less harder without the need for using more amount of water, even this super does not affect the strength of concrete by increasing it or decreasing it.





## 3.2 Instruments and characterizations

Our project involves the preparation of concrete specimens that having a specified amount of aggregate, cement, sand and PCB content. The specimens were prepared and tested by using many instruments which must be always ready in advance to carry out the specimen mixing, compacting operation, and preparing PCB as quickly and efficiently as possible. So, in this section, the instruments are presented in sequence starting from the beginning to the end of test, as follows:

*Table 3- 1 Instruments used for preparing and testing concrete specimens*

No	Instrument	Name and Uses
1		<b>Scoop handle.</b> For holding the aggregate to be mixed with the concrete samples.

2		<p><b>Digital Balance.</b></p> <p>For measuring out the mass of materials, which are aggregate, cement, sand and PCB.</p>
3		<p><b>Steel Trays.</b></p> <p>Uses to mix the elements to make concrete.</p>
4		<p><b>Concrete Mixture Machine</b></p> <p>Uses to mix the elements to make concrete by revolving drum.</p>
5		<p><b>Water path.</b></p> <p>For putting the concrete cubes for 28 days to obtain the maximum strength of concrete.</p>
6		<p><b>Concrete cubes.</b></p> <p>For putting concrete samples on it. The volume equal is <math>10\text{ cm} * 10\text{ cm} * 10\text{ cm} = 1000\text{ cm}^3</math></p>

7		<p><b>Compression testing machine.</b></p> <p>For check the samples strength.</p>
8		<p><b>Drying oven</b></p> <p>For drying concrete cubes at 110°C.</p>
9		<p><b>Grinding Machine</b></p> <p>For check the samples friction</p>
10		<p><b>Cone tool</b></p> <p>For check the slump test</p>

### 3.3 Methodology

To design concrete, we have to identify the type, proportions, and properties of the materials involved in the preparation of the concrete. Our reference here is the local market in Palestine. The types and proportions of materials used to make the concrete that typically used in buildings.

In this project there are four test preparation that were followed:

#### ❖ **Compression strength**

Step 1: Preparing concrete specimens.

A typical concrete contains cement (1 kilogram) ( $w/c = 0.50$ ), sand (2.3 kilograms) and aggregate (4.03 kilograms) with previous materials and proportions, we are used three types of aggregate type one has a diameter around 18-25 mm (1.66 kilogram), type two has a diameter around 7-17 mm (0.9 kilogram) and type three has a diameter around 1-6 mm (1.46 kilogram) and we added super G7 20g (Super cement ration 2%). The following samples are prepared:

We want to study the effect of different concentration of PCB at first (0%, 4%, 7 % and 10%) on the traditional concrete at constant PCB particles, then adding (3% and 5%), then adding (3.5% and 4.5%).The aforementioned samples were prepared as follows:

1. First of all, PCB powders were already prepared from the factory.
2. Digital balance using for weighting the samples according to the percentage of their size and masses.
3. Adding PCB particles to concrete by different percentage as mentioned previously.
4. Putting the components in the machine mixer for 4 minutes.
5. Putting concrete that includes PCB specimens in cubes.
6. Removing concrete samples from concrete cubes after 24 hours.

Step 2: Testing the samples.

After preparing the concrete samples compressive test was conducted. The following steps were added during the tests.

By using water path, the concrete specimens were submerged for 7 days, and then it was taken out of the water path.

Waiting for 7 days to take the first specimens' results that have (60-70) % of the total strength, waiting for 14 days to take second specimens' results that have (80-85) % of the total strength and waiting 28 days to take the final specimens' results that have 100% strength.

Placed the concrete specimens in compression testing machine to check the compressive strength of concrete after 7 and 28 days.

**Procedure:**

1. Check all the things you need are ready. Check concrete compression machine is in working order.
2. Safety: Wear hand gloves and safety goggles.
3. Taking measurement: Take the measurement of concrete specimens (which are sent to laboratory for testing). Calculate the cross-sectional area (unit should be on mm<sup>2</sup>) and put down on paper. Do the same for each specimen.
4. Start machine: Turn on the machine. Place one concrete specimen in the center of loading area.
5. Lowering piston: Lower the piston against the top of concrete specimen by pushing the lever. Don't apply load just now. Just place the piston on top of concrete specimen so that it's touching that.
6. Applying load: Now the piston is on top of specimen. It is the time to apply load. Pull the lever into holding position. Start the compression test by pressing the zero button on the display board.

7. Increasing pressure: By turning pressure increasing valve clockwise, adjust the pressure on piston so that it matches concrete compression strength value. Apply the load gradually without shock.
8. Test is complete: Observe the concrete specimen. When it begins to break, stop applying load. Recording: Record the ultimate load on paper displaying on machine's display screen.
9. Calculate compressive strength of concrete.

$$\text{Compressive strength} = \frac{\text{Ultimate load (N)}}{\text{mm}^2} = \text{MPa}$$

*Equation 3-1 Compressive strength*

### ❖ Friction

Step 1: Preparing concrete specimens.

A typical concrete contains cement (1 kilogram) ( $w/c = 0.50$ ), sand (2.3 kilograms) and aggregate (4.03 kilograms) with previous materials and proportions, we are used three types of aggregate type one has a diameter around 18-25 mm (1.66 kilogram), type two has a diameter around 7-17 mm (0.9 kilogram) and type three has a diameter around 1-6 mm (1.46 kilogram) and we added super G7 20g (Super cement ration 2%). The following samples are prepared:

We want to study the effect of different concentration of PCB at first (0%, 2%, 4%, 6%, 8%, and 10%) on the traditional concrete at constant PCB particles.

1. Digital balance using for weighting the samples according to the percentage of their size and masses.
2. Putting the components in the machine mixer for 4 minutes.
3. Putting concrete that includes PCB specimens in cubes.
4. Removing concrete samples from concrete cubes after 24 hours.
5. Putting concrete cubes in water bath for 7 days.

Step 2: Testing the samples.

After preparing the concrete samples friction test and was conducted. We have carried some steps within applying the test.

We placed the concrete specimens in the grinding machine for nearly three minutes, and this was to measure the friction percentage with time. And then to check the friction in the specimens after 28 days.

The data were taken from the grinding machine using the revolution per minute (RPM). 2800 rpm.

**Procedure:**

1. Check all the things you need are ready. Check concrete fiber machine and microscope are in working order.
2. Safety: Wear hand gloves and safety goggles.
3. Place the samples on the fiber machine and turn on the device for a 5 minute.
4. Taking measurement: Take the measurement of concrete specimens (which are sent to laboratory for testing). Calculate the mass before friction and after friction or measure the thickness of the specimens. Do the same for each specimen.
5. Calculate the friction of the concrete:

$$F_{\text{friction}} = \frac{m_i - m_f}{m_i} * 100\%$$

*Equation 3- 2 Friction equation*

Where  $m_i$  is mass before friction and  $m_f$  is mass after friction.

6. Take the ideal sample (least friction).

❖ **Water adsorption**

Step 1: Preparing concrete specimens.

A typical concrete contains cement (1 kilogram) ( $w/c = 0.50$ ), sand (2.3 kilograms) and aggregate (4.03 kilograms) with previous materials and proportions, we are used three types of aggregate type one has a diameter around 18-25 mm (1.66 kilogram), type two has a diameter around 7-17 mm (0.9 kilogram) and type three has a diameter around 1-6 mm

(1.46 kilogram) and we added super G7 20g (Super cement ration 2%). The following samples are prepared:

We want to study the effect of different concentration of PCB at first (0%, 4%, 7 % and 10%) on the traditional concrete at constant PCB particles, then adding (3% and 5%), then adding (3%, 3.5% and 4.5%).The aforementioned samples were prepared as follows:

1. First of all, PCB powders were already prepared from the factory.
2. Digital balance using for weighting the samples according to the percentage of their size and masses.
3. Adding PCB particles to concrete by different percentage as mentioned previously.
4. Putting the components in the machine mixer for 4 minutes.
5. Putting concrete that includes PCB specimens in cubes.
6. Removing concrete samples from concrete cubes after 24 hours.

Step 2: Testing the samples.

After preparing the concrete samples water absorption test was conducted. The following steps were employed during the tests.

By using water path, the concrete specimens were submerged for 7 days, and then it was taken out of the water path to dry at standard.

Placed the concrete specimens in dry oven at 110°C to totally drying of concrete after 28 days and we used the digital balance to weight concrete after constant drying this process called is concrete dry.

After complete drying, the concrete cubes are submerged in water for 48 hours and then removed and the surface is dried, after that they are weighed and wet this process called is concrete wet.

And can we are calculate adsorption by:

$$\text{Adsorption test} = \frac{\text{Wet} - \text{Dry}}{\text{Dry}} * 100\%$$

*Equation 3- 3 Adsorption equation*

### ❖ Slump test

Step 1: Preparing concrete specimens.

A typical concrete contains cement (1 kilogram) ( $w/c = 0.50$ ), sand (2.3 kilograms) and aggregate (4.03 kilograms) with previous materials and proportions, we are used three types of aggregate type one has a diameter around 18-25 mm (1.66 kilogram), type two has a diameter around 7-17 mm (0.9 kilogram) and type three has a diameter around 1-6 mm (1.46 kilogram) and we added super G7 20g (Super cement ration 2%). The following samples are prepared:

We want to study the effect of different concentration of PCB at first (0%, 4%, 7 % and 10%) on the traditional concrete at constant PCB particles, then adding (3.5%, 4.5% and 5%), then adding 5.5% and 6%). The aforementioned samples were prepared as follows:

1. First of all, PCB powders were already prepared from the factory.
2. Digital balance using for weighting the samples according to the percentage of their size and masses.
3. Adding PCB particles to concrete by different percentage as mentioned previously.
4. Putting the components in the machine mixer for 4 minutes.
5. Putting concrete that includes PCB specimens in the steel trays.

Step 2: Testing the samples.

Measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

### **Procedure**

1. The mold for the slump test is a frustum of a cone, 300 mm of height, the base is 200 mm in diameter and it has a smaller opening at the top of 100 mm.
2. The base is placed on a smooth surface and the container is filled with concrete in three layers.
3. Each layer is tamped 25 times with a standard 16 mm diameter steel rod.
4. When the mold is completely filled with concrete, the top surface is struck off (leveled with mold top opening) by means of screening.
5. Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump.
6. The decrease in the height of the center of the slumped concrete is called slump.
7. The slump is measured by placing the cone just besides the slump concrete and the tamping rod is placed over the cone so that it should also come over the area of slumped concrete.
8. The measurement is done by the ruler (cm).

*Note: The test must be repeated again if a horizontal slump happened for the concert when rising the mold, and if the horizontal slump kept happening, then the nature of the made concrete is not typical with the preferred specifications.*

## Chapter 4: Results and Discussion

**The first result compression test as the following:**

About compression test specimens weight was measured before the compression test is applied, then after taking specimens weight, we applied the test on specimens, and the results were taken exactly when the specimen is fractured.

*Table 4- 1 Result of Compression test at all percent PCB*

Ratio PCB%	Age (Days)	Weight (gm)	Density (gm/cm <sup>3</sup> )	Compression test (MPa)	Compression test (Kg/cm <sup>2</sup> )
0%	7	2379.8	2.3798	22.5	229.4
		2364.2	2.3642	21.9	223.3
		2391.7	2.3917	22.3	227.3
	28	2153.2	2.1532	30.3	308.9
		2204	2.2040	30.1	306.9
		2132.3	2.1323	31	316.1
3%	7	2297.1	2.2971	28.2	287.5
		2264.8	2.2648	27.3	278.3
		2201.4	2.2014	27.9	284.5
	28	2198	2.1980	35.6	364.01
		2203	2.2030	36.3	370.1
		2245	2.2450	35.7	364.03
3.5%	7	2431.8	2.4318	28.6	291.6
		2350.4	2.3504	28.1	286.5
		2387.2	2.3872	27.8	283.4
	28	2234	2.2340	36.7	374.2
		2265.3	2.2653	37.2	379.3

		2301.2	2.3012	35.9	366.07
4%	7	2294.1	2.2941	29.5	300.8
		2243.5	2.2435	29.8	303.8
		2322.3	2.3223	28.8	293.6
	28	2134.3	2.1343	38.9	396.6
		2198.2	2.1982	38.7	394.6
		2204.9	2.2049	37.6	383.4
4.5%	7	2345.1	2.3451	27.9	284.5
		2346.8	2.3468	27.3	278.3
		2537.6	2.5376	26.8	273.2
	28	2145.8	2.1458	36.2	369.1
		2213.4	2.2134	35.4	360.9
		2156.9	2.1569	35.1	357.9
5%	7	2375.2	2.3752	26.8	273.2
		2403.9	2.4039	27.1	276.3
		2418.1	2.4181	26.2	267.1
	28	2237.4	2.2374	34.2	348.9
		2352.1	2.3521	34.9	355.8
		2146.8	2.1468	35	356.9
7%	7	2342.8	2.3428	24.1	245.7
		2431.3	2.4313	23.8	242.6
		2452.6	2.4526	24.5	249.8
		2453.2	2.4532	31.4	320.1

	28	2231.1	2.2311	32.8	334.4
		2230.3	2.2303	33.1	337.5
10%	7	2315.3	2.3153	21.3	217.1
		2456.1	2.4561	21.9	223.3
		2234.2	2.2342	20.8	212.1
	28	2312.3	2.3123	29.8	303.8
		2201.1	2.2011	30.3	308.9
		2356.2	2.3562	29.9	304.8

We have noticed that in table (4-1) the strength started to increase from 3% and continued to rise up until it has reached 7% from the original specimen which is without additions, then at 10% we have noticed that the strength started to go down compared to the original specimen without additions, and this means that the addition of PCB to concrete increase the strength until a particular percentage, and the reason behind all of this that the PCB is a brittle substance, and increasing the amount of it in the concrete would increase the carbon content too, which makes the concrete can't resist the pressure when applying the test, because more PCB more pressure is spreader on the PCB which means less pressure on the concrete which can lead to less strength and then the specimen would fracture.

Table 4- 2 Compression test average at seven days

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

In table (4-2), the midpoint for each percentage from the three specimens for the 7 days test was measured, three specimens were taken to take an accurate results.

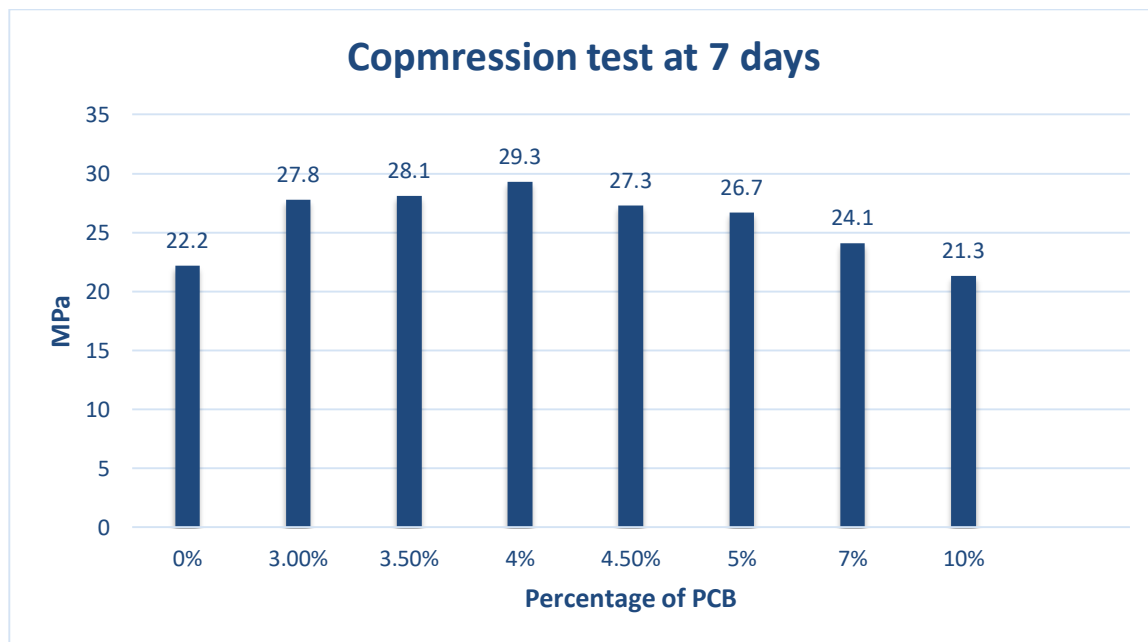


Figure 4- 1 Compression test at 7 days in all percentage PCB

Table 4- 3 Compression test average at twenty-eighth

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

In table (4-3), the midpoint for each percentage from the three specimens for the 28 days test was measured.

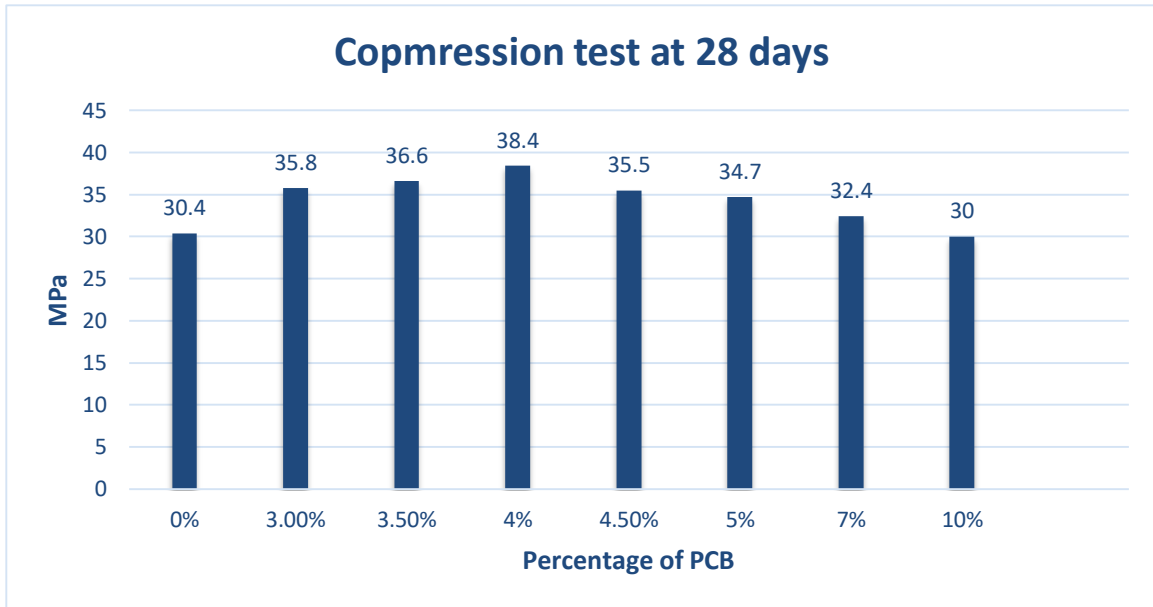


Figure 4- 2 Compression test at 28 days in all percentage PCB

**The second result water adsorption test as the following:**

Table 4- 4 Result of Water adsorption test at all percent PCB

Ratio PCB%	Weight concrete dry (gm)	Weight concrete wet (gm)	Adsorption test (%)
0%	2257.8	2368.3	4.89
	2127.7	2241.6	5.35
	2427.5	2536.2	4.47
3%	2158.8	2248.2	4.14
	2269.9	2356	3.79
	2307.1	2398.7	3.97
3.5%	2365.6	2453.3	3.70
	2485.1	2571.7	3.48
	2057.4	2145.6	4.28

4%	2393.5	2481.6	3.68
	2510.2	2593.1	3.30
	2347.3	2432.8	3.64
4.5%	2474.8	2538.4	2.56
	2430.3	2498.7	2.81
	2533.7	2597.3	2.51
5%	2358.9	2438.1	3.35
	2314.3	2394.7	3.47
	2167.5	2243.6	3.51
7%	2217.4	2314.3	4.36
	2313.5	2406.1	4.00
	2263.1	2358.2	4.20
10%	2427.4	2534.3	4.41
	2515.9	2617.8	4.05
	2578.1	2684.5	4.12

In table (4-4) after taking results from the water absorption test, the difference between them was measured, and then we could calculate the percentage of water absorption, we have noticed that at 4.5% the absorption of water was reduced to 50%, then above 4.5% the water absorption started to increase, and this is actually good, because at high percentage of carbon in concrete, the strength is lower, because even the concrete contents are weakly connected to each other's, even that the PCB close the pores in the concrete, but higher carbon amount means less concrete strength.

Table 4- 5 Water adsorption average test

Ratio PCB%	Weight concrete dry (gm)	Weight concrete wet (gm)	Adsorption test (%)
0%	2271	2382.03	4.90
3%	2245.2	2334.3	3.96
3.5%	2302.7	2390.2	3.82
4%	2417	2502.5	3.54
4.5%	2479.6	2544.8	2.62
5%	2280.2	2358.8	3.44
7%	2264.6	2359.5	4.18
10%	2507.1	2612.2	4.19

In table (4-5), the midpoint for the three specimens for each percentage, three specimens are taken to get more accurate results.

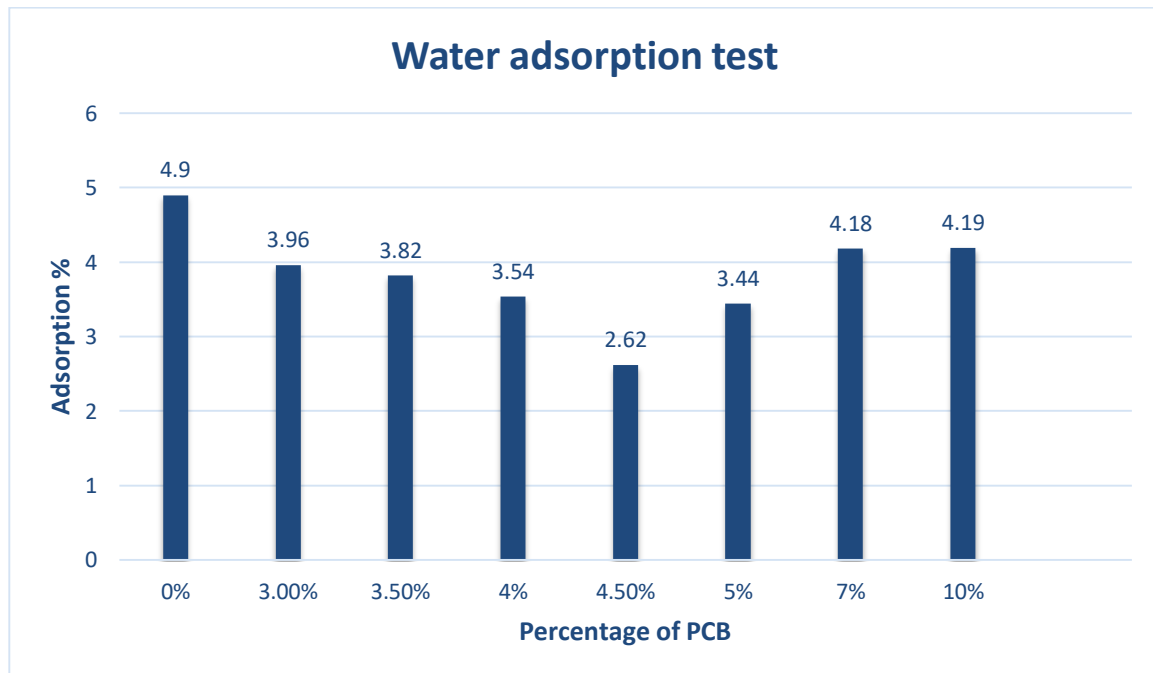


Figure 4- 3 Water adsorption test at all percentage PCB

**The third result slump test as the following:**

*Table 4- 6 Result of Slump test at all percent PCB*

Ratio PCB%	Slump (cm)
0%	10.8
3.5%	8.9
4%	8.6
4.5%	7.9
5%	7.3
5.5%	7.1
6%	9.8
7%	13.6
10%	11.1

In the table (4-6) slump test, we have noticed that at 5.5% we got less workability, but this test is applied depending on the purpose of it, we can't say is good or no because it depends on where the concrete will be used, sometimes is good to have less workability, but sometimes no, depending on the purpose from the wanted application.

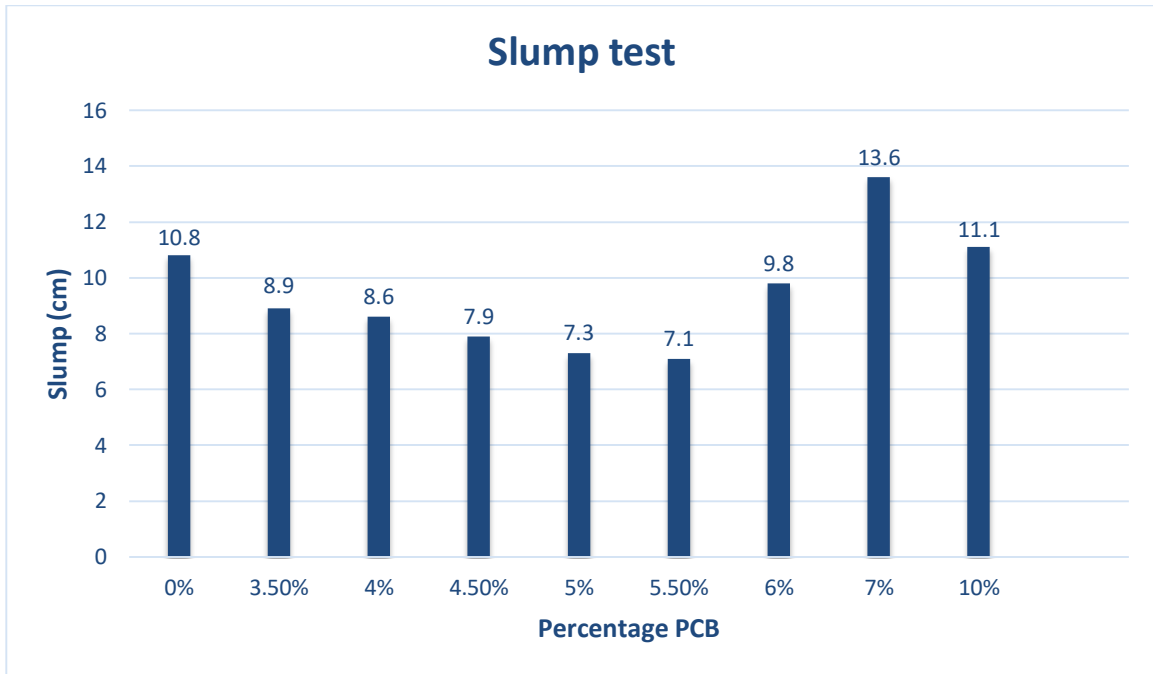


Figure 4- 4 Slump test at all percentage PCB

Finally is the result of friction loss test as the following:

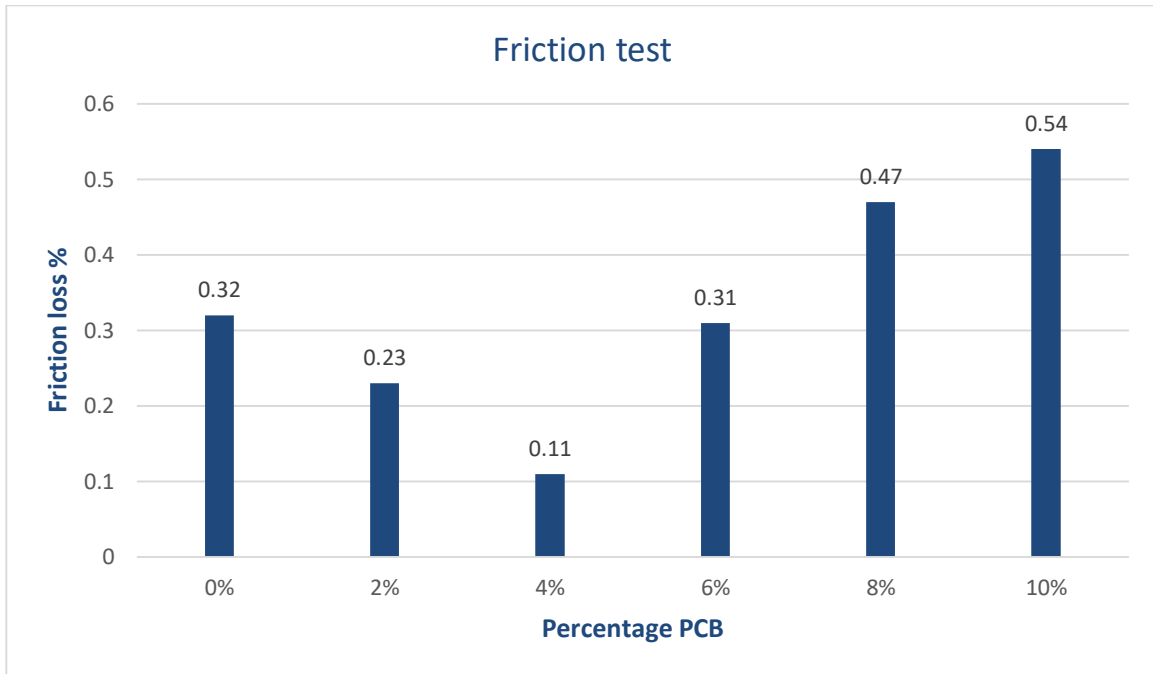
Table 4- 7 Result of friction loss test at percents of PCB

PCB Ratio %	Weight before friction (gm)	Weight after friction (gm)	Friction loss test (%)
0%	2231	2224	0.31
	2212	2206	0.27
	2221	2213	0.36
2%	2062	2058	0.19
	2120	2115	0.23
	2094	2088	0.28
4%	2086	2083	0.14
	2142	2140	0.09
	2162	2160	0.09

6%	2094	2088	0.28
	2150	2143	0.32
	2055	2048	0.34
8%	2032	2023	0.44
	2043	2034	0.44
	2078	2070	0.38
10%	2120	2109	0.51
	2006	1994	0.59
	2129	2118	0.51

*Table 4- 8 Friction loss average at percents PCB*

PCB Ratio %	Weight before friction (g)	Weight after friction (g)	Friction loss test (%)
0%	2221.3	2214.3	0.32
2%	2092	2087	0.23
4%	2130	2127.6	0.11
6%	2099.6	2093	0.31
8%	2051	2041.3	0.47
10%	2085	2073.6	0.54



*Figure 4- 5 Friction loss at all percentage PCB*

When we applied the friction test, we have noticed that results were the minimum at 4% of PCB, and then the friction (more loss in the specimen) started to increase when the carbon black percentage was above 4%, and actually this is because that carbon is a brittle material and when increasing it above the limited amount in the concrete specimens, this would make the concrete specimens more brittle, which can affect the surface of the specimens and makes the specimen even weaker and with less resistance for the friction load.

# Chapter 5: Conclusion

The idea of adding pyrolysis carbon black which is taken from waste tires by a pyrolysis process is a such great idea and this is explained by the good results that the PCB at specified amount could give to the concrete is even a great commercial idea for both the developer and the customer this is because even PCB is cheap and would enhance several properties in concrete to perform in a better way.

At the end, after having results when we applied the needed tests, and compared them by the results from the specimens without carbon black, it was clear that are the compressive strength increased at 4% percentage of carbon black, while the water absorption was decreased at 4.5% of PCB, slump gave the minimum results at 5.5% of PCB, and the friction was the minimum at 4% percentage of carbon black, so this lead us to consider that adding PCB with accurate percentage to the concrete could improve the mechanical properties of the concrete, and this was noticeable when the specimens with carbon black had better mechanical properties than the specimens that without carbon black, and this enhancement can make a an obvious difference in the manufacturing side, and gives better functionality in many applications.

## Chapter 6: Recommendations

In our project while applying the experiment to get the preferred results we had to be a bit careful in dealing with the experiment tools and substances that they were used. So here are some of the recommendations in which they were taken into account:

First of all adding water to concrete must be with a big careful so water amount that should be added must be studied and weighed carefully because any increase or decrease in the specified wanted amount of water would affect the strength in a dramatically way it was shown that when increasing water amount above the preferred amount by mistake the strength went down to unwanted result this was a mistake we had to deal with it and solve it.

Another recommendation which is dealing with pyrolysis carbon black should go in a carefully way too and this is due to the weight loss in the PCB amount during adding it because the PCB was used here is in the powder form and so the powder particles are having a low weight and this allows them to fly easily to air.

About dealing with cement it is not preferable to use cement from an opened left pocket because it would break and become useless to be used; because of cement is being exposed to the surrounded weather the humidity percentage will increase and this is an enough reason to cause damage to cement.

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## Appendices

Standard specimen of mixture concrete as the following:

<i>Component of concrete</i>	<i>Amount (gm)</i>
Cement	1000
Sand	2300
Aggregate (18-25)	1660
Aggregate (7-17)	900
Aggregate (1-6)	1450
Total Aggregate	4020
Water Cement ratio (w/c)	500
Super G7	20

Mechanical testing of standard specimens concrete as the following:

<i>Testing</i>	<i>Results</i>
Compression at 7 days	22.2 (MPa)
Compression at 28 days	30.4 (MPa)
Water adsorption	4.90%
Slump	10.8 (cm)
Friction	0.32%

## Palestine Standards Institution (PSI)

<i>Name test</i>	<i>Specification</i>
Compression at 7 days concrete B300	<i>Minimum 20(MPa)</i>
Compression at 28 days concrete B300	<i>Minimum 30(MPa)</i>
Water adsorption	<i>Maximum 7%</i>
Slump	<i>Depending on the demand</i>
Friction	<i>Not found</i>

## Effect PCB in the compression strength of the concrete

<i>Percentage of PCB</i>	<i>Compression (%) Increasing or decreasing</i>
0%	0%
3%	+17.7%
3.5%	+20.3%
4%	+26.3%
4.5%	+16.7%
5%	+14.1%
7%	+6.5%
10%	-1.3%

### Effect PCB in the water adsorption of the concrete

<i>Percentage of PCB</i>	<i>Adsorption test (%) Increasing or decreasing</i>
0%	0%
3%	-19.1%
3.5%	-22.04%
4%	-27.7%
4.5%	-46.5%
5%	-29.7%
7%	-14.6%
10%	-14.4%

### Effect PCB in the slump test of the concrete

<i>Percentage of PCB</i>	<i>Slump test (%) Increasing or decreasing</i>
0%	0%
3.5%	-17.5%
4%	-20.3%
4.5%	-26.8%
5%	-32.4%
5.5%	-34.2%
6%	-9.2%
7%	+25.9%
10%	+2.7%

### Effect PCB in the friction test of the concrete

<i>Percentage of PCB</i>	<i>Friction test (%) Increasing or decreasing</i>
0%	0%
2%	-28.1%
4%	-65.6%
6%	-3.1%
8%	+46.8%
10%	+68.7%

### Data in the device grinding machine

<i>Properties</i>	<i>Data</i>
Volt	380 <i>V</i>
Power	500 <i>W</i>
Ampere	1.5 <i>A</i>
Code	8.14.37.32
Frequency	50 <i>Hz</i>
Revolution per minute (RPM)	2800 <i>rpm</i>
Type	Femi S.P.A