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An Experimental Study on Concrete Durability Using Bubble Wrap (LDPE) as Partial Coarse Aggregate of Concrete

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Abstract

In this research, bubble wrap is used to improve performance of concrete in terms of durability. It is essential to define optimum percentage properly and optimally during the laboratory process to improve durability of the concrete samples. Since bubble wrap has been used globally for packaging, based on previous study there are several problems that occur in recycling centre and environment are frequently caused by plastic waste. The main objective of this study is to determine concrete performance with bubble wrap that contain light-density polyethylene (LDPE) as partial replacement coarse aggregate. Besides, this research investigates the physical properties of coarse aggregate of LDPE by conducting slump at each type of replacement samples involve in this project. Next, to study the water absorption of concrete with coarse aggregate of LDPE and to determine carbonation depth of concrete surface that partially mix with LDPE. In addition, it can increase durability with quality when replacing gravel with LDPE replacement aggregates. Water absorption and carbonation depth test has been conducted for the comparison of conventional concrete and replacement concrete. From there, it can be shown that LDPE aggregates helps decrease water absorption and carbonation depth of the samples and it is experimentally proved better than control samples. Other than that, slump test is the variables that were valuated which is three different type of slump such as true slump, shear slump and zero slump to define the best percentage of replacement aggregates on concrete. As a result, the 5% LDPE aggregates has a greater impact on concrete durability. Based on the outcomes of the experiment, by increasing the LDPE aggregates replacement on concrete can affect the water absorption and carbonation depth, the workability of the samples is the most significant element impacting the integrity of a concrete.

1. Introduction

For the last 6 decades, plastic has become a beneficial and multipurpose material with a wide range of applications. Besides, supplier or consumer around the world normally use anything that made from plastic such as plastic bottles and food containers because it has lower price rather than other product, yet durable. Polyethylene (PET) commonly used as plastic bottles for drinks and condiments meanwhile low-density polyethylene (LDPE) widely used as bubble wrap in any courier service to wrap the costumer parcel [5]. Bubble wrap comes in handy each time consumer relocates, send or get anything from a courier. Courier service in Malaysia commonly used bubble wrap in order to protect a customer parcel from possible damage. Hence, every year a significant amount of LDPE plastic waste is found in a landfill [5]. The significant amount of plastic that not being recycled will end up in landfill, being thrown into dump sites or being sent to the developing country.

1.1 Problem Statement

Over the past three decades, the e-commerce business has experienced remarkable growth. Besides, consumers change their preference to online shopping instead buying goods from shop makes bubble wrap products are increasingly produce by supplier and used by consumer. Compared to recycling companies, plastic manufacture companies operate at significantly larger profit margins. The recycle industry will face an increase in costs and environment pollution as result of using bubble wrap film [1].

In addition, plastic films are known as harms towards recycling system. These materials are not economical for recycling organisations because of their low bulk density and tiny thickness, which can lead to technical problems during conventional recycling operations [2]. This will give a threat to both recyclers and their machine equipment.

1.2 Objective and Scope of the project

The aim of this study to determine concrete performance with bubble wrap that contain light-density polyethylene (LDPE) as partial replacement coarse aggregate. The following below are the three objectives that must be met to achieve the study's overall goals:

i. To investigate the physical properties of coarse aggregate of LDPE.

ii. To study the water absorption of concrete with coarse aggregate of LDPE.

iii. To determine carbonation depth of concrete surface that partially mix with LDPE.

This research aims to examine the durability of concrete with partial coarse aggregate of bubble wrap that contain light-density polyethylene (LDPE). This research is limited to the use of bubble wrap which is categorized under Resin Identification Code (RIC #4) that made up of low-density polyethylene (LDPE).

2. Literature Review

The literature study underlines the growing issue of plastic waste which has quadrupled between 2000 and 2019, highlighting the importance for new construction solutions to reduce environmental effect. The chapter addresses using bubble wrap composed of low-density polyethylene (LDPE) as a partial replacement for typical coarse aggregate in concrete. In order to assess bubble wrap's sustainability in building, the historical context, manufacturing process, and chemical makeup of LDPE are described. Previous studies on the mixing of plastic waste into concrete are reviewed, with encouraging findings in improving concrete characteristics while addressing plastic pollution. The invention of bubble wrap when two innovators named Alfred Fielding and Marc Chavannes experimented with plastic sheets in their garage, bubble wrap was created. They wanted to puff air between the sheets to create bubble-like pillows to make a pretty covering for wallpaper. However, the first idea did not get anyone interest. Then in 1957, the two men realized that their invention could be used to protect breakable objects [6].

LDPE has a lower density than HDPE because of its lower percentage of crystallinity, which thus partially reduces its protective properties. LDPE is also softer and more flexible than HDPE. Due to its low cost and strong resistance to chemicals and oils, LDPE is a great material for a wide range of flexible packaging applications. LDPE appears cloudy yet it is clearer than HDPE. When utilized as a heat-seal layer in a flexible packaging, its lower melting temperature relative to HDPE is generally an advantage rather than a disadvantage [7].

Table 2.1: Material properties [7]

Composition	LDPE	MFI (g/10 min)	Density (g/cm^3)
Virgin LDPE	100%	20	0.920

2.1 Previous Study on Plastic Waste as Partial Coarse Aggregate in Concrete

In comparison to conventional concrete, it aims to determine the ideal proportion replacement for natural coarse aggregate in a mixture of plastic and gravel aggregates. This mixture can produce concrete that is just as strong and as workable [3]. The spread of awareness of using sustainable development in the construction allows more sustainable resources being developed as one of the great initiatives in order to keep environment safe. Plastic waste can be one of the main sustainable resources to replace coarse aggregate as it can easily to collect and cheap in price. Therefore, polypropylene (PP) waste plastic is considered to be a solution to some of the challenges associated with eliminating polymer wastes, preventing pollution of the environment, saving energy, and decreasing the dependence on natural aggregates.

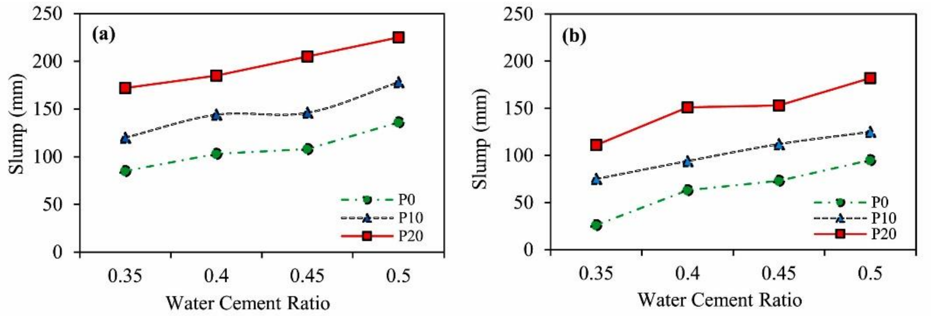

Figure 2.2: Workability of the fresh concrete with PP aggregate [4].

Table 2.2: The correlation between the workability, slump value and slump class [4].

Slump (mm)	Degree of Workability	Slump (mm)	Class
0	No slump, Zero Slump		
0-10	Very Low	10-40	S1
10-30	Low	50-90	S2
30-60/80	Medium	100-150	S3
60/80-120/150	High	160	S4

Figure 2.2 and Table 2.2 show the workability of fresh concrete containing PP aggregate that has been done measure by using slump test. A methodology has been used in this study to define the slump value and workability degree. The slump value for 0% PP replacement concrete is 85mm shortly after mixing at the lowest water-cement ratio (0.35) showing a great performance of fresh concrete's workability with a class of S2. Concrete's slump values increase as the PP percentage increases from 0% to 20%. As a result, the concrete has a very good workability and slump classes of S3 and S4, respectively, for 10% and 20% of the PP aggregate.

3. Methodology

The main elements in this study are cement, fine aggregate, bubble wrap (LDPE) as coarse aggregates and water. These elements will form the concrete with the additional element, low-density polyethylene (LDPE). LDPE is an alternative that will replace conventional coarse aggregates. The coarse aggregate in concrete plays a crucial role that help to make concrete mixes more compact.

This project's approach specifies the procedures that will be used. This chapter demonstrates how to do an experiment study of LDPE aggregates as replacement of conventional coarse aggregate. Figure 3.1 illustrates the project process flowchart. Therefore, each process flow will include the steps required to complete the project. In order to conduct laboratory testing, concrete samples with partial replacement ratios of LDPE coarse aggregate were created throughout this investigation. A suitable mix for sample is important to investigate the properties of LDPE coarse aggregate in concrete. In this research, the sample will have divided into 4 groups according to percentage of LDPE coarse aggregate replacement. The samples are namely conventional concrete (control sample) and concrete with partial LDPE coarse aggregate. The main purpose of the conventional concrete with no replacement is to act as a control sample and compare its result with other samples.

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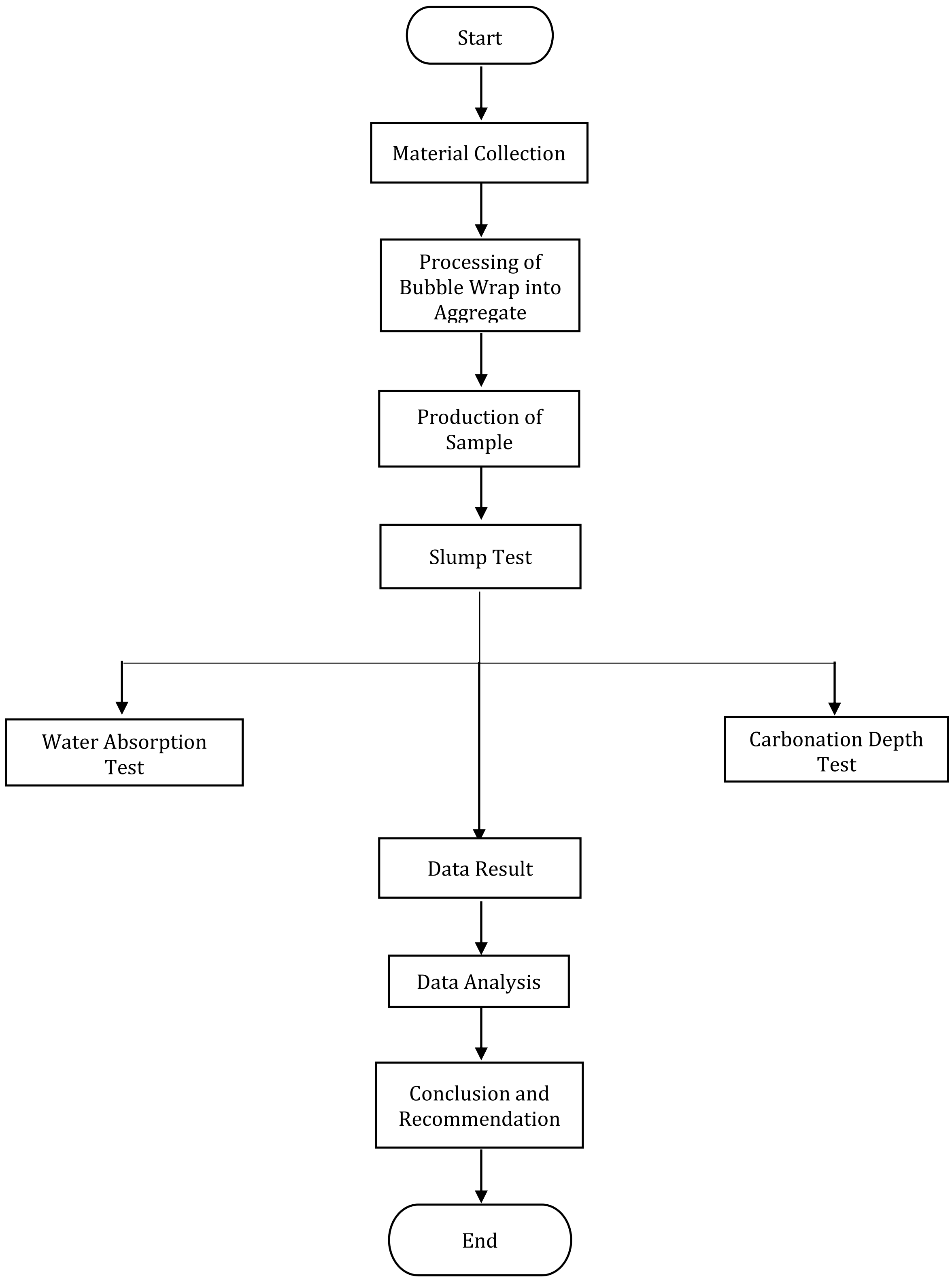
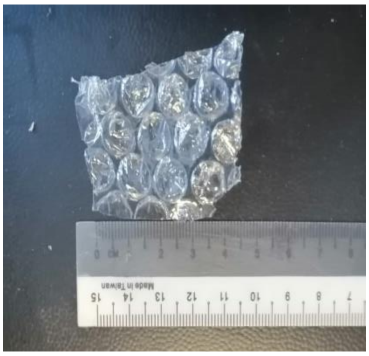


Figure 3.1: Project Flow Chart

3.1 Bubble Wrap (LDPE) into aggregate

The size of coarse aggregate in concrete is a crucial factor that influences the workability, strength, durability and overall performance of the concrete mix. The characteristic of the bubble wrap aggregate must be similar to traditional coarse aggregate. Plastic were collected from waste and were shredded into pieces according to the range size of coarse aggregate which is 9.5 mm to 37.5 mm. Bubble wrap were shredded using a craft knife and scissors then the bubble wrap cutting is done carefully according to the specified size. Next, all LDPE aggregates are weighed and kept in the container.


(a)


(b)

Figure 3.5: Bubble wrap into aggregates (a) 4.5 cm (b) 3 cm

In order to create a reference sample, a standard concrete sample containing 0 % use of partial LDPE coarse aggregate was created. The weight and volume of all materials in concrete mix were measure to prevent any waste of materials. Concrete mixes mix in bulk to ensure the uniformity of the concrete can be achieved. The following dimensions were produced by three 100-milimiter-sided concrete cubes for each replacement ratio.

The mixing of the concrete was performed by using a shovel in a mixing tray. Cube moulds are measured 100 mm x 100 mm x 100 mm. The moulds need to be lightly coated with a mould release agent before the sample concrete is scooped into them. This helps remove the cube and guarantees that the concrete will not stick to the mould.

3.2 Concrete Mix Design

Concrete mix design is a process that determines the appropriate proportions of concrete ingredients to achieve the desired performance in both the fresh and hardened states. The unique characteristics of LDPE aggregates and how they impact the behavior of the concrete must be taken into account during the design phase when using plastic waste in place of conventional aggregates. In order to produce a mixture that meets specific strength and durability requirements, concrete mix design requires determining the ratios of cement, water, aggregates (sand and gravel) and any admixtures. The purpose of adding LDPE aggregates to concrete is to improve certain of the material's capabilities while reducing environmental pollution.

Table 3.2: Concrete Mix Design

Percentage of LDPE replacement (%)	w/c	Cement (kg)	Water (kg)	Fine aggregates (kg)	Coarse aggregates (kg)	LDPE aggregates (kg)
0	0.5	0.96	0.48	1.74	4.25	0
1	0.5	0.96	0.48	1.74	4.21	0.04
3	0.5	0.96	0.48	1.74	4.12	0.13
5	0.5	0.96	0.48	1.74	4.04	0.21

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4. Results and Discussion

Each sample of fresh concrete has been conduct a slump test before poured into cube molds. Slump test is one of the most common methods for testing the flow properties of concrete mixes in laboratory and engineering construction sites. Therefore, the workability of self-compacting concrete is the key factor affecting its working performance. This test was performed to study the effect of LDPE aggregates on concrete workability. Zero slump concrete is defined as concrete retains its shape completely. This slump shows that the mix of concrete is very dry and more suitable used for road construction. Meanwhile, shear slump means the top half of the concrete decreases dramatically and leaning to one side. It shows the mix has workability but low in cohesion because the mix may have too much water content. The degree of workability for zero slumps is very low. A collapse value of 93 mm and 87 mm indicates medium workability mixes. Control samples shows high workability with a slump value of 143 mm.

Table 4.1: The type of slump for each percentage of LDPE replacement

Replacement Percentage (%)	Slump Value (mm)	Type of Slump	Workability Classification
0	143	True Slump	High workability
1	93	Shear Slump	Medium workability
3	87	Shear Slump	Medium workability
5	25	Zero Slump	Low workability


Figure 4.1: Zero Slump for 5% replacement LDPE aggregate

4.1 Water Absorption Test

Table 4.2 shows the water absorption (WA) values of every sample block made from LDPE aggregates from 0% (control sample), 1%, 3% and 5%. All of these figures are less than the control sample WA 5.5% value. This indicates that the concrete cubes are more prone to breaking down with alternating wetting and drying than the blocks made of LDPE aggregates. The LDPE-derived concrete cubes have a reduced water absorption capacity (WA), which gives them an advantage in terms of durability and efficiency, particularly in wet environments.

Then, the samples placed in an open air to cool. Immediately upon cooling the samples are weighed. The material is then emerged in water at agreed upon conditions, in 23°C for 24 hours. Specimens are removed, patted dry with a lint free cloth, and weighed The amount of water absorbed by the samples explains the variation in cube weights in wet and dry conditions. Next, the percentage of water absorbed is used to express the moisture absorption. The less water absorbed by sample, the greater its quality. Good quality block doesn’t absorb more than 20% water of its own weight.

Table 4.2: Water absorption test of the samples

Samples (Coarse Aggregate-LDPE)	100% - 0%			99% - 1%			97% - 3%			95% - 5%		
Initial Weight (kg)	2.15	2.20	2.20	2.00	2.05	2.15	2.05	2.00	2.05	1.95	1.84	1.75
Final Weight (kg)	2.26	2.34	2.31	2.11	2.15	2.26	2.14	2.11	2.16	2.05	1.93	1.83
Average Water Absorption (%)	5.5			5.2			5.0			4.8		

The water absorption test results, as shown in Table 4.2, indicate that the inclusion of LDPE aggregates in concrete significantly reduces its water absorption capacity compared to the control sample. The water absorption values for concrete samples with 1%, 3%, and 5% LDPE aggregates are all below the control sample value of 5.5%. Specifically, the average water absorption percentages for the samples are 5.2%, 5.0%, and 4.8% for 1%, 3%, and 5% LDPE aggregate replacements, respectively. This reduction in water absorption demonstrates the enhanced durability and efficiency of the LDPE-derived concrete cubes, particularly in wet environments.

4.2 Carbonation Depth Test

Carbonation depth is a measure of the penetration of carbon dioxide into concrete, which can lower the pH and cause corrosion of steel reinforcement. Carbonation depth test is a method to assess the durability of concrete containing Low-density polyethylene aggregates (LDPE). A slice approximately at 50 mm thick was being split by using a grinder. This splitting can prevent longitudinal carbonation which unnecessary for our measurement. Then, spray with a fine mist of 1 percent phenolphthalein to avoid the formation flow channels on concrete surface. The measurements have been conducted after the color has stabilized. By using ruler, the point carbonation depth (dκ point) were determined perpendicular to the exposed surface of the concrete.

Table 4.3: Carbonation Depth of Samples

Samples (Coarse Aggregate – LDPE)	0%			1%			3%			5%		
Sample	1	2	3	1	2	3	1	2	3	1	2	3
Average Point Carbonation Depth (d*κ point*)	1.71mm	1.80 mm	1.70 mm	1.4 mm	1.4 mm	1.4 mm	0.38 mm	0.42 mm	0.6 mm	0.33 mm	0.41 mm	0.36 mm

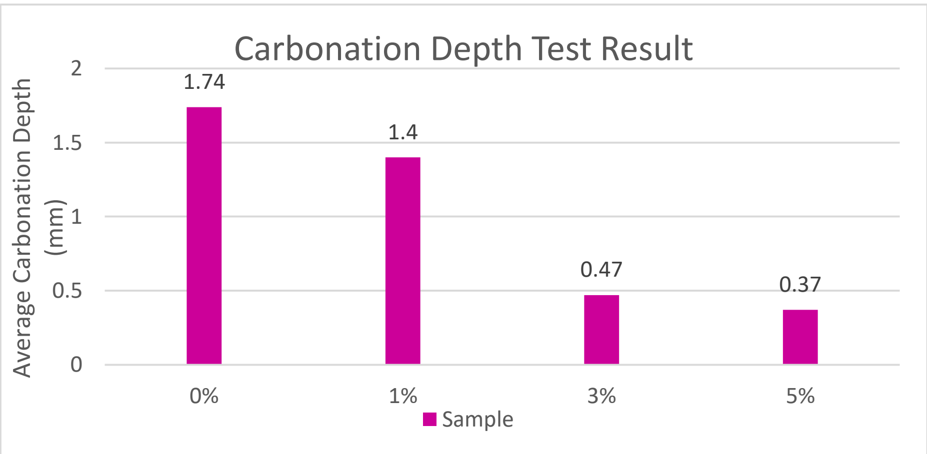

Figure 4.2: The depth of carbonation for each samples

(a)

(b)

Figure 4.3: Point carbonation depth (dκ point) measurement (a) spray with a fine mist of 1 percent phenolphthalein (b) Each points on each exposed concrete were measured

The carbonation depth test evaluates the penetration of carbon dioxide into concrete, which can lower pH and cause steel reinforcement corrosion. In this study, concrete samples containing low-density polyethylene (LDPE) aggregates were subjected to carbonation depth tests after 14 days of exposure. The carbonation depth was measured by splitting the concrete samples, cleaning the cross-section surface, and applying a phenolphthalein solution. The results showed that samples with 5% LDPE had the lowest carbonation depth, averaging 0.37 mm, compared to higher depths in samples with lower LDPE content. These findings indicate that incorporating LDPE aggregates into concrete improves its resistance to carbonation, enhancing its durability.

5. Conclusion and Recommendation

In terms of workability, 5% replacement sample showed 25 mm in slump value resulted in zero slumps. This type of slump is more suitable for pavement. Next, water absorption test showed 5% of replacement sample had low water absorption percentage than 0%, 1% and 3% replacement samples. In addition, 5% replacement coarse aggregate (LDPE) indicates low carbonation depth specifically measured at average of 0.37 mm. Based on data analysis, replacement samples have better performance than control samples. It shows that bubble wrap helps as replacement aggregates not only to reduce plastic waste from environment but also to improve the concrete performance on durability.

However, if the percentage of LDPE aggregates increase, the workability of fresh concrete will decrease and there may be zero slumps or shear slump. This happens when LDPE aggregates did not absorb the amount of water-cement ratio of 0.5. Suggested improvements using a mould that follows the size and shape of conventional aggregates ranges in 9.5 mm to 37.5 mm to improve laboratory result, add LDPE aggregates to the concrete mixture gradually during the mixing process, using other types of advanced testing such as water permeability test and rapid chloride penetration test, increase LDPE aggregates percentage below 50% as a partial substitute for coarse aggregate and adding superplasticizer into concrete mixture that can reduce yield stress at concrete.

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