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# Influence of polymer coated aggregate on the aggregate impact and crushing value

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**Abstract.** Polyethylene Terephthalate (PET) and latex belong to the family of the polymer. PET type of plastic bottle is the most commonly found in the household waste stream. Recycling this type of plastic into another form is the cheapest and the best way of recycling. However, this may not become a green waste management solution when energy is used to transform this plastic into another useable form. In this study, PET was used to discover the potential for improvement of asphalt mixture properties. This study examines the plastic waste used as an aggregate coating. PET plastic bottle was shredded and sieved to obtain size 0.425 to 0.075mm then was blended with hot aggregate to form a thin layer of plastic coating on the aggregate surface. The comparison between unmodified aggregate properties and modified properties was studied. 1%, 3%, 5%, 7%, 9%, 11%, 13% and 15% of plastic by weight of aggregate were used as aggregate coating. The aggregate impact value test (AIV) and aggregate crushing value test (ACV) were done on the plastic coated aggregate. The test result had shown an improvement in the properties of plastic coated aggregate. From the experiment results conducted on the PET and aggregate, we can conclude that the lowest percent of aggregate loss on the crushing value test is 16.34% when PET content is 9% while 8.00% when PET content is 13% for the impact value test. The lowest percent of aggregate loss for impact value is then compared with the percent loss of PET Latex coated aggregate. The presence of latex and PET has caused the strength of the aggregate to increase where the percentage loss value when performed impact test is very low that is can achieve 3.48%. The quality of flexible pavement can be improved when the surface of the aggregate is coated with the polymer.

**Keywords:** Aggregate Test; Polyethylene Terephthalate; Plastic Coating; Road Performance.

## 1. Introduction

The performance of a road depends on the quality of aggregate used during the paving process. Crushed rock, gravel, slag, dust and sand are the example of aggregate that was used in pavement. Hot Modified Aggregate (HMA) can be formed by mixing the selected aggregate with asphalt binder [1]. The weight of the aggregate is one of the main support of HMA pavement component. This is because almost 95% of HMA is made up of aggregate. Hence, the characteristic of the aggregate can affect the performance of HMA pavement [2]. The characteristic of aggregate can be reinforced by the presence of plastic coating. Therefore, the presence of too much plastic waste in Malaysia can be used for the road construction industry.



Nowadays, there is a worldwide study on the use of waste material as secondary material. The most produced waste is plastic bottles [3]. Since the last decade, plastic bottles were so popular in the food industry because of safe, durable and good for packaging [4]. PET is a semi-crystalline thermoplastic polymer with high strength and transparency properties [5].

The soft blend can be achieved at low temperature and a stiffer blend is obtained at high temperature when PET is added which proves that it is a good modifier [6]. Another reason PET is considered as a good modifier is because it does not emit any harmful gas when heated to temperature range of 30°C to 180°C [7]. PET has good binding properties [8], hence it can be mixed with bitumen to enhance its properties. Malaysia has tropical climate temperature which is around 22°C to 32°C [9]. At this range of temperature, PET remains stable and would not decompose or degrade [10].

This study is focused to evaluate the properties of the aggregate by comparing the coating aggregate with unmodified aggregate. The different percent of PET is used to coat the aggregate and this process also known as dry process. Aggregate Impact Value Test and Crushing Value Test have been done to the unmodified and coated aggregate. The hypothesis for these tests are aggregate percentage loss for crushing value and impact value of aggregate should decrease as the amount of PET coated increases. Presence of Latex can enhance the strength of aggregate by decreasing the aggregate percentage loss.

## 2. Materials

PET, latex and aggregate is the main material for this study. Mineral water bottles were collected and shredded into small sizes. PET is defined as a polymer that happens by polymerization reaction between acid (terephthalic acid) and alcohol (ethylene glycol) [5]. PET is one of the polyester which is easy to handle and chemically stable [11]. For this research, PET plastic bottles were collected and shredded. These shredded PET are sieved to get the size of 0.425 to 0.075mm. PET has an average molecular weight between 30000 - 80000 g mol<sup>-1</sup> and can be melt at temperatures 255°C to 265°C. The density of PET is 1.41 g cm<sup>-3</sup> and has a glass transition temperature between 69°C to 155°C [12].

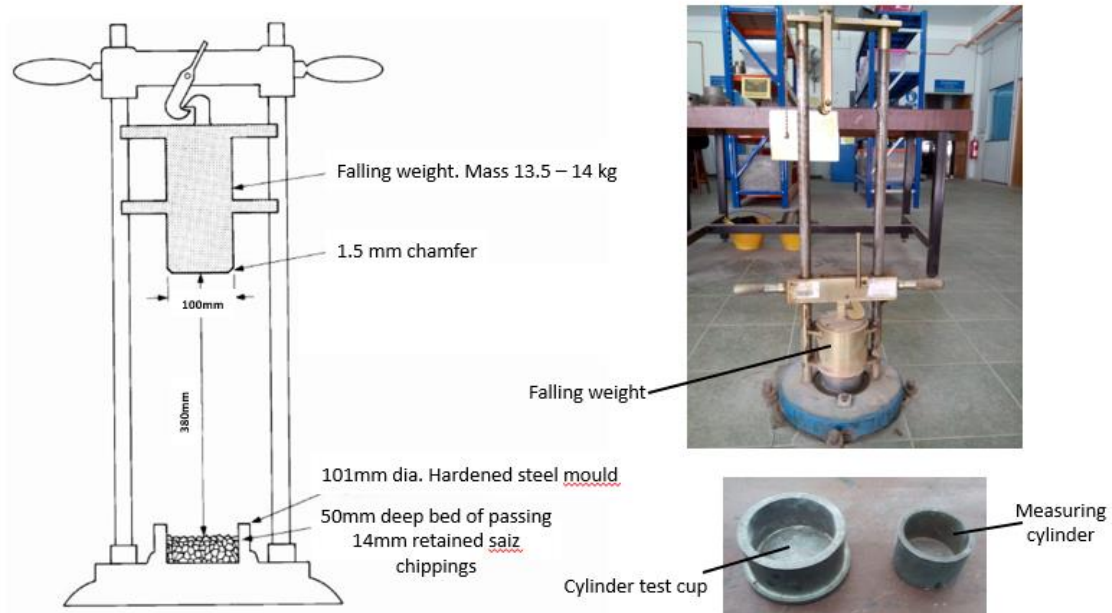
High ammonia natural rubber (HANR) latex was provided by Lembaga Getah Malaysia. Field latex contains 64% water content, 36% rubber and a small number of impurities. Field latex can only last for 3 hours in liquid form. It needs to be preserved for storage and will be used later in different applications. [13]. Therefore, ammonia is used to preserve the latex and to keep latex in liquid condition.

The aggregate used for this study is obtained from quarry in Berkelah, Pahang. HMA consists of three types of aggregate which are coarse aggregate, fine aggregate and mineral filler [14]. The size for coarse aggregate is 2.36mm or larger [15, 16] while the size for fine aggregate is between 2.36mm to 0.075mm [17]. Mineral filler is composed of dust or slag that is less than 0.075mm [16, 18]. 10mm size of aggregate was used in this research.

## 3. Methodology

Aggregate Impact Value Test and Crushing Value Test have been done to the selected aggregate. Based on British Standard where this standard is also used as a guideline in Malaysia, the limit of average aggregate percentage loss for crushing value test and impact value test is must less than 30% [19-21].

For impact value test, the experiment shows how to know the impact value of road aggregate in the laboratory and to evaluate its suitability in road construction based on impact value. This experiment complied with the SSRW in Malaysia [22] and British Standard BS 812-112:1990 [20]. The test is initiated by heating the aggregate at 160°C and then coat the aggregate with PET at the designated percentage. After cooled the aggregate at room temperature, it then undergoes impact value test which according to the method stated in the British Standard BS 812-112:1990. The experiment is repeated to obtain the average of the result. Figure 1 shows the schematic image and apparatus of the impact value test.



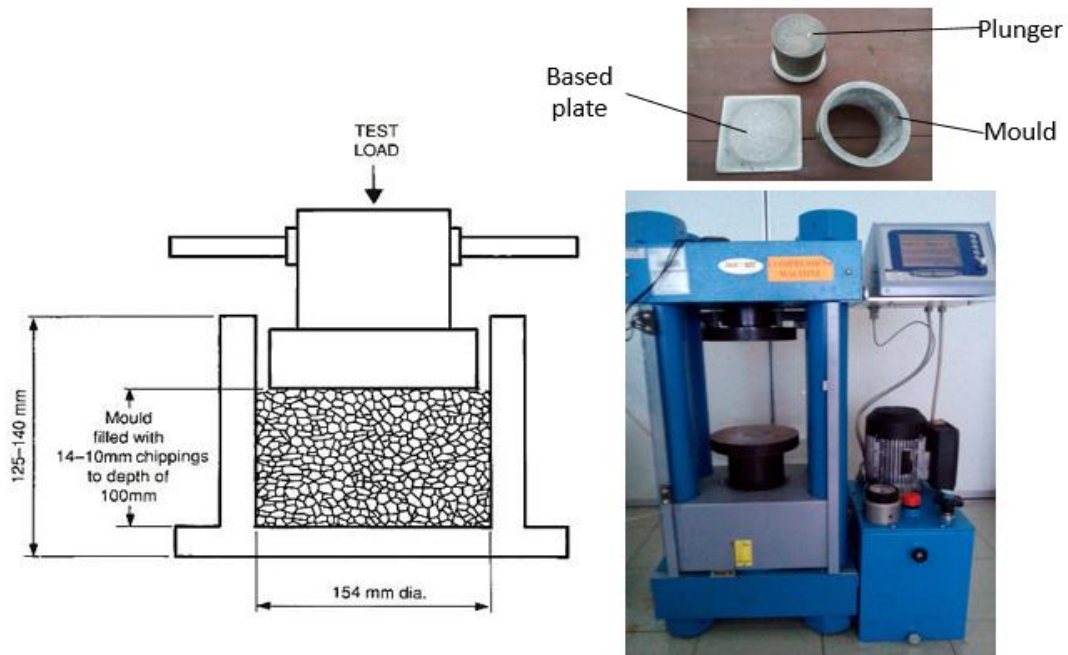
**Figure 1.** Schematic image and apparatus of the impact value test.

Aggregate crushing value is a percentage of the weight of the crushed aggregate obtained from the test where the specific load is applied to the aggregate tested. The best aggregate quality to be used in the surface course should not more than 30% aggregate lost. This experiment was based on British Standard BS 812-110 : 1990 [21] which on par with Standard Specification of Road Work (SSRW) in Malaysia [22].

The first step of this test is the same as the aggregate impact value test which heats the aggregate at 160°C and then coat the aggregate with PET at the designated percentage. Figure 2 shows the shredded PET plastic used for this research. After the aggregate was cold at room temperature, it then undergoes a crushing value test. The experiment is repeated to obtain the average of the result. Figure 3 shows the schematic image and apparatus of the crushing value test.



**Figure 2.** Plastic size 0.425 to 0.075mm used to coat the aggregate.



**Figure 3.** schematic image and apparatus of the crushing value test.

**4. Results and discussions**

From this experiment, the aggregate test result shows the aggregate quality value. The aggregate quality value can be used as the guideline to classify the stones according to their toughness property. The toughness property can be evaluated by looking at the aggregate loss after done the impact and crushing test. Percent of aggregate loss can be calculated by dividing the weight of coated aggregate on pan after test with the weight of coated aggregate before test. The answer is then multiple with one hundred to get the percentage of aggregate loss [21]. The result of aggregate impact value tests is shown in Table 1 while the result of aggregate crushing value test is shown in Table 2. This table shows the comparison between PET coated aggregate and unmodified aggregate (no PET).

**Table 1.** Impact value tests.

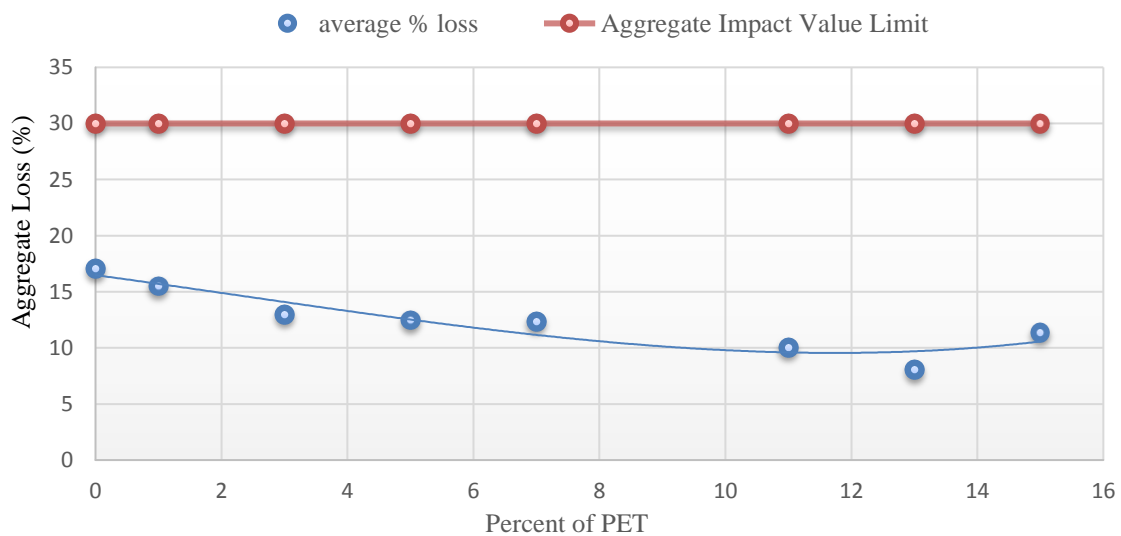
% of plastic	Weight of Crushed Agg. (g)		% Loss
	M1	M3	
0	312.94	53.32	17.04
1	300.36	46.52	15.49
3	312.50	40.61	13.00
5	323.94	40.38	12.47
7	327.65	40.52	12.37
9	334.11	40.01	11.98
11	342.67	34.43	10.05
13	343.36	37.56	8.03
15	346.15	39.32	11.36



**Table 2.** Aggregate crushing value.

% of plastic	Weight of Crushed Agg. (g)		% Loss
	M1	M3	
0	2660.62	677.72	25.47
1	2743.99	511.35	18.64
3	2491.21	430.06	17.26
5	2591.47	439.65	16.97
7	2604.79	436.67	16.76
9	3646.39	432.15	16.33
11	2780.10	469.69	16.89

Unmodified aggregate shows a higher percent of aggregate loss compared to PET coated aggregate. The trend was proven by whenever the amount of PET is decreased, the aggregate percent loss was an increase. Figure 4 shows that the percent loss of aggregate was influenced by the amount of PET coated. Based on Standard Specification of Road Work (SSRW) in Malaysia [22], the road is in the category weak on surface when the impact value is more than 35% and it will consider being exceptionally strong when the value below 10%. However, when the impact value is between 20% to 30%, the road is consider in category satisfactorily for road surfacing while the value is between 10% to 20% the road are in strong category. From the graph in figure 4, the lowest aggregate loss was 8 % when 13% of PET is used to coat the aggregate. The aggregate loss starts to increase when 15% of PET is used to coat the aggregate. Without any plastic coating, the aggregate is still in in good condition for road surfacing to comply with the SSRW which the aggregate loss is 25.47%. However, coating the aggregate with PET was increase the category of aggregate from satisfactorily for road surfacing to strong and exceptionally strong. Based on the result, 13% of PET coated aggregate was achieved the lowest aggregate lost which is 8%. From that indicator, the combination of latex and PET was used to coat the aggregate. The total amount combination of latex and PET is 13%. Table 3 shows the result of the impact value test for latex and PET coated aggregate. From that results, combination of 7% PET and 6% Latex seems most suitable wish it achive 3.48% of aggreagte lost. Figure 5 shows the PET+Latex coated aggregate. Figure 6 shows that the percent loss of aggregate was influenced by the amount of 13% PET coated and PET+Latex coated.



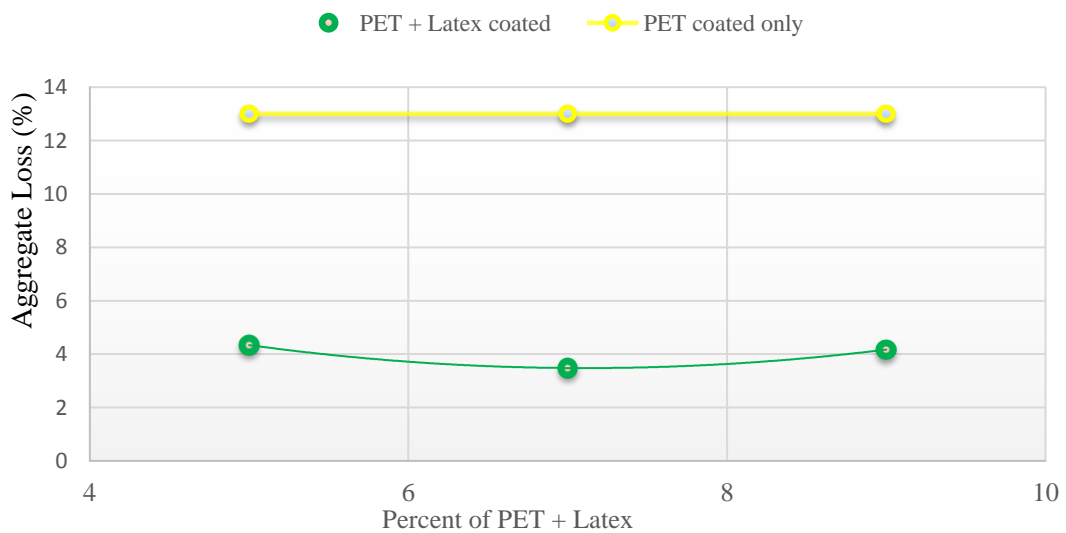
**Figure 4.** Impact value test.

**Table 3.** Result of aggregate impact value test for PET+Latex coated aggregate.

Amount of binder (PET+Latex)		% Loss
PET (%)	Latex (%)	
5	8	4.34
7	6	3.48
9	4	4.17



**Figure 5.** PET+Latex coated aggregate.

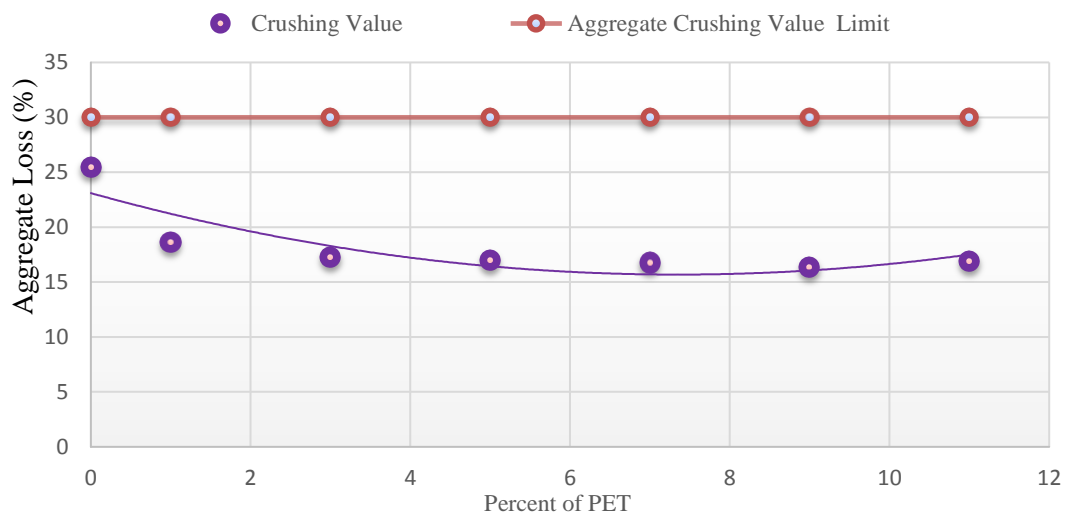


**Figure 6.** Percent loss of aggregate was influenced by the amount of 13% PET coated and PET+Latex coated.

Figure 6, it shows that the combination of PET and Latex can increase the strength of aggregate. The same result also achieves by Wayal and Wagal which state that coating of plastics and rubber over the

stone aggregate improves the quality of the aggregate [23]. This is because the presence of latex can make the aggregate elastic and able to protect aggregate from strong impact [24]. The indicator of this experiment result could be accepted when the percent loss of aggregate impact lies in the range of strong for road surfacing. Based on SSRW in Malaysia, the percentage of aggregate loss for impact value for wearing course should be below 30% [19, 22, 25]. This test is important to adjudge the suitability of aggregate whether it strong enough to be used in road construction. The ability of the road stone to resist the impact and pounding action due to traffic load can be determined by this test. In order to produce high quality pavement, this test also helps to determine the durability of stone that has the ability to break into smaller pieces if repeated impact is applied.

The PET coated aggregate has lower percent of aggregate loss than the unmodified aggregate. 16.34% of aggregates loss was found in 9% of PET plastic coating. Figure 7 shows that when the amount of PET increase, the percent of aggregate loss decrease.



**Figure 7.** Crushing value test.

The ability of an aggregate to resist crushing can be measured through the aggregate crushing value. Based on the test results, it showed that all results are adhering to the SSRW in Malaysia which the aggregate loss recorded is 25.47%, 18.64%, 17.26%, 16.97%, 16.76%, 16.33% and 16.89%. Low aggregate crushing value is more preferred to increase the quality of the pavement. The best quality of aggregate for surface layer pavement should have lower than 30% of aggregate loss. Based on all results, this kind of aggregate was strong enough for this study as it will be applied to the surface course layer. It was proved that coating of aggregate with PET can improve the strength of properties of aggregate. This is because the PET coated aggregate can help to fill the pores at the surface. The brittleness of the aggregate is measured as an impact value. Void sand air cavity in the aggregate can be reduced by coating the aggregate with polymer. Cracking can be prevented when the polymer layer formed. Coating aggregate with PET can increase the strength of the aggregate. This can be proved by comparing the percentage of aggregate loss on a plain aggregate and modified aggregate. To compare with the study by Kumar and Vikranth on 2017 [26], they used Polypropylene (PP) as their modifier. Their result shows that as the amount of PP is increase, the percent of aggregate loss was decreased. Gurpreet Singh and Rajiv Chauhan [27] studied about coating the aggregate by using the PET. The trend of their results is also the same with this study. The results comparison of aggregate impact value is presented in figure 8 and the comparison of aggregate crushing value is presented in figure 9. The impact value test of Kumar and Vikranth study shows lower percent of aggregate loss compared to this research. This might be due



to the use of a different type of plastic. PP has a melting point of 164°C while PET is 252°C [28]. Therefore, PP can coat the aggregate better because it melt easily compared to the PET.

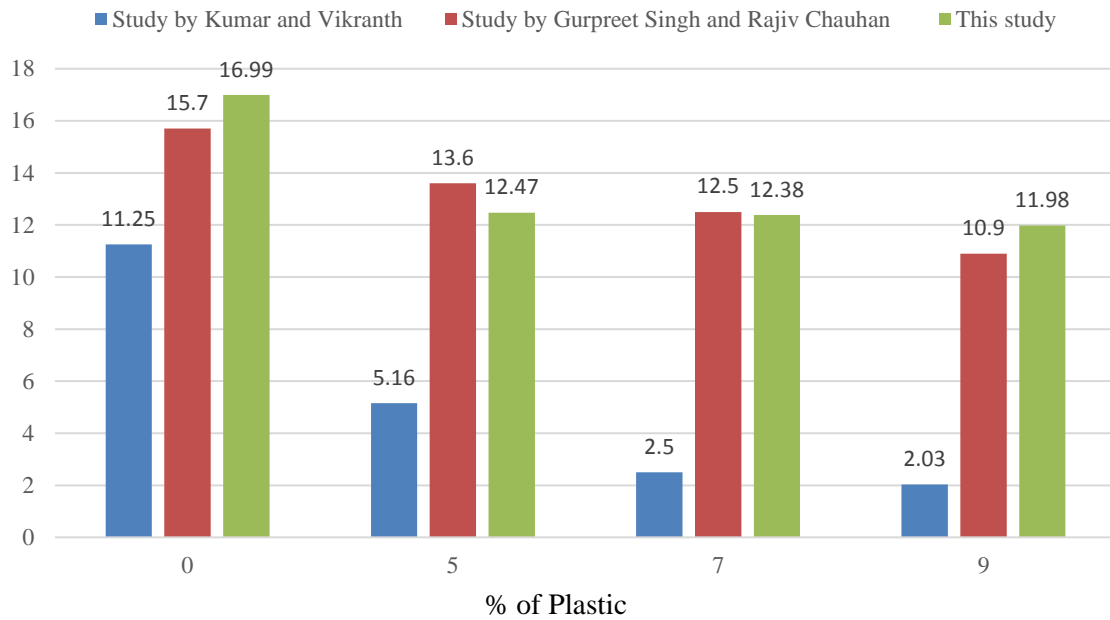


Figure 8. Comparison of Aggregate Impact Value between researchers.

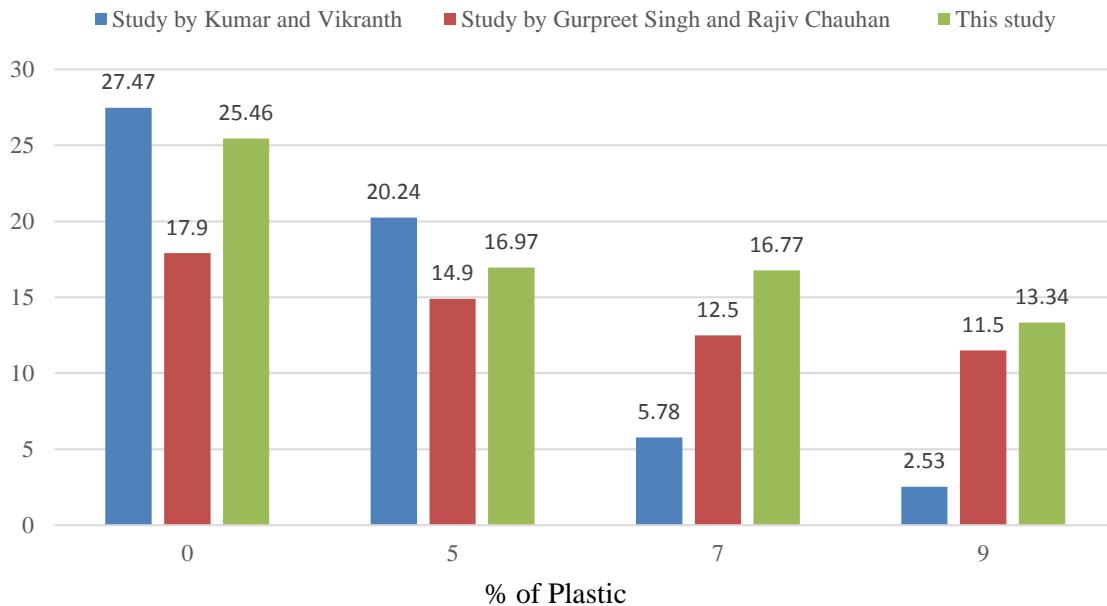


Figure 9. Comparison of Aggregate Crushing Value between researchers.

5. Conclusions

Coating aggregate with polymer (PET and latex) can produce new raw material for flexible pavement which this also known as dry process. The results allows the following conclusion to be drawn:

- i. The lowest percent of aggregate loss on the crushing value test is 16.34% when PET content is 9% while 8% when PET content is 13% for the impact value test.

- ii. The presence of latex has caused the strength of the aggregate to increase where the percentage loss value when performed impact test is very low that is can achieve 3.48%.
- iii. The quality of aggregate can be improved when the surface of the aggregate is coated with a polymer.
- iv. The quality of the pavement can be improved as the aggregate strength increases.
- v. Using waste plastic in road construction is able to help the waste polymer disposal process in an eco-friendly method. With this eco-friendly method, the waste that disposes of through incineration and land filling can be avoided. It also able to help to create jobs as rag pickers.

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