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# Using of Plastic Material on Stabilization of Soil

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**ABSTRACT:** Soil stabilization is any process which improves the physical properties of soil, such as increasing shear strength, bearing capacity etc. which can be done by use of controlled compaction or addition of suitable admixtures like cement, lime and waste materials like fly ash, phosphogypsum etc. The cost of introducing these additives has also increased in recent years which opened the door widely for the development of other kinds of soil additives such as plastics, bamboo etc. This new technique of soil stabilization can be effectively used to meet the challenges of society, to reduce the quantities of waste, producing useful material from non-useful waste materials. Use of plastic products such as polythene bags, bottles etc. is increasing day by day leading to various environmental concerns. Therefore the disposal of the plastic wastes without causing any ecological hazards has become a real challenge. Thus using plastic bottles as a soil stabilizer is an economical utilization since there is scarcity of good quality soil for embankments. This project involves the detailed study on the possible use of waste plastic bottles for soil stabilization. The analysis was done by conducting plate load tests on soil reinforced with layers of plastic bottles filled with sand and bottles cut to halves placed at middle and one third positions of the tank. The comparison of test results showed that cut bottles placed at middle position were the most efficient in increasing strength of soil. The optimum percentage of plastic strips in soil was found out by California Bearing Ratio Test and using this percentage of plastic, plate load test was also performed. The size and content of strips of waste plastic bottles have a significant effect on the enhancement of strength of the soil.

**KEYWORDS:** Expansive soil , Clay soil , Soil stabilization

## I. INTRODUCTION

Soil stabilization is the process by which the engineering properties of the soil are improved and it is made more stable. It is used to decrease the soil's unqualified characteristics such as permeability and consolidation potential and increase the shear capacity [2]. The method is mainly adopted for highway and airfield construction projects. Commonly, activities such as compaction and pre-consolidation are used to improve types of soils which are already in good form. But soil stabilization goes way up to encouraging usage of weak soil and reducing the uneconomical process of weak soil replacement. Other than working on the soil mass interaction, chemically altering the soil material itself is also the focus of this process. Sometimes, soil stabilization is used for city and suburban streets to make them more noise-absorbing [3]. Different methods have been developed previously to stabilize weak and unsuitable soils. Some of these methods include mechanical (granular) stabilization, cement stabilization, lime stabilization, bituminous stabilization, chemical stabilization, thermal stabilization, electrical stabilization, as well as grouting stabilization by geotextile and fabrics. Recently, researchers have introduced another way of soil stabilization by using waste materials. Plastics are one of the leading waste materials that are found to be suitable for this purpose. They reduce the cost of stabilization at a large rate [4]. Using plastics for this purpose simultaneously solves the challenges of improper plastic waste recycling that is currently a teething problem in most developing countries. Improper plastic waste disposal is becoming a pressing environmental issue in most African countries. They are currently covering landfills and water bodies, clogging sewage systems, disrupting the ecological cycle and creating an aesthetically unpleasing environment. This in turn causes serious damage to animal, plant and human lives. Polyethylene Terephthalate (PET) bottles are conventional plastic bottles that currently are highly utilized. They are used to package water, soft drinks, liquid foods, and various other beverages. With their increasing demand, their disposal is becoming difficult. The degradation of waste PET bottles takes a very long time in nature (more than a hundred years) [5]. Recycling and using these plastic bottles to stabilize expansive clay soil are moves in the right direction making the construction industry an appropriate candidate with its high consumption ability [6]. This paper presents appropriate and easy to implement ways of recycling plastic water bottles as reinforcing material for the stabilization of expansive soil to improve and achieve the



required properties for construction works. The experimental tests that were performed with the achieved results are presented.

## II. MATERIALS

There were two materials used for this study: a representative clay type soil taken from the Bole area in Addis Ababa, Ethiopia and rectangular PET bottle strips. The strips were prepared from waste plastic bottles that were collected from the nearby surroundings. The bottles were cleaned properly after collection and cut into three different sized strips, manually using scissors (Figure 1). The strip sizes are shown in Table 1.



**Figure 1.** Strip preparation.

**Table 1.** Strip sizes.

Strip	Width (mm)	Length (mm)
1	5	7.5
2	10	15
3	15	20

## III. METHODS

### Material Characterization :

The characterization of the soil sample taken for this study included particle size distribution, Atterberg limit and specific gravity of soil tests. The sample soil taken was sieved in order to take out any other impurities and unnecessary particles. It was then prepared for testing accordingly. Once sample preparation was done, sieve analysis and hydrometer analysis were conducted to study the particle size distribution of the soil. The tests were done as per [7] and [8] respectively. Plastic limit, liquid limit and plasticity index of the soil were determined by performing the Atterberg limit test. The test was carried out as per [9] using Casagrande's apparatus. Specific gravity of the soil on the other hand was determined from the specific gravity test in the geotechnical laboratory. A specific gravity beaker and vacuum pump were used to carry out the test as per [10]. The specific gravity was taken as the ratio of the density of soil to the density of water at the same temperature. The PET fibers on the other hand were characterized as per size (length, width and thickness), surface texture, shape and color.

### Plastic Waste Material :

In this study, polyethylene terephthalate (PE) (water bottles) and polypropylene (PP) (woven polypropylene bags) wastes were used as fibre stabilisers as shown in Fig. 1. Plastic fibres were prepared by cutting waste bottles and bags

into two sizes in lengths of 1.0 and 2.0 cm and in widths of 2.5 to 3.0 mm each as shown in Fig. 2. The fibre contents were applied at 1%, 2%, 3%, and 4% of dry weight of the clayey soil.



Fig. 1 Plastic waste materials used in the study



Fig. 2 Sample of the fibres used in this study

### Laboratory Tests :

In this study, to examine the strength and mechanical properties of both native and stabilised soils, different laboratory tests were conducted including the determination of index properties of unstabilised soil and standard proctor compaction, UCS, CBR (soaked), for stabilised and unstabilised soils. All tests were conducted according to ASTM. For all tests, the adopted content of fibres was first manually mixed into the air-dried soil in small increments. Considerable care was taken to achieve homogeneous mixture during the mixing process. Then, the required water was added as shown in Fig. 3.



Fig. 3 Mixing the fibres with soil

### Compaction Test :

The laboratory compaction tests were performed in accordance with the ASTM D698 procedure. The purpose of this test is to determine the effect of plastic fibre on optimum moisture content (OMC) and maximum dry density (MDD) of stabilised soils and to use OMC that was obtained in this test for preparing samples for UCS, CBR, dry density, and optimum moisture content.

### Unconfined Compressive Strength Test :

This test was conducted to investigate the effect of inclusion of plastic waste pieces on the unconfined compressive strength of soils. The test was performed in accordance with ASTM D2166. All the UCS test specimens were prepared at their respective MDD and OMC. All prepared specimens were air-dried in the open laboratory environment and were cured for 7 days.

### California Bearing Ratio Test :

For the CBR test, cylindrical specimens were prepared using their MDD at OMC in a rigid metallic cylinder mould with an inside diameter of 150 mm and a height of 175 mm. A mechanical loading machine equipped with a movable base that moves at a uniform rate of 1 mm/min and the calibrated proving ring is used to record the load. For this, static compaction is carried out through keeping the mould assembly in the compression machine and compacting the soil by pressing the displacer disc till the level of the disc reaches the top of the mould. This test was carried out in accordance with ASTM D1883. In this study, the soaked specimens were made at OMC as determined from the standard compaction test.

## IV. RESULTS AND DISCUSSION

### Compaction Test :

The results of the compaction tests for the native soils and soils stabilised with PE and PP stabilisers of 1.0 cm and 2.0 cm in length at different stabiliser content ratios are shown in figures 4, 5, 6, 7, 8, 9, 10, and 11. For the native soil, the OMC was 21% and the MDD was 1645 kg/m<sup>3</sup>. He stabilised soils compared to the native soils. The decrease in both of these two properties can be noticed as the fibre content increases. These can be seen clearly in Figs. 6 and 7. This consistent trend of effect of fibre content increase cannot be seen for the stabilisation with PP fibres (see Figs. 8, 9, 10, and 11). For the soils stabilised with PE at various fibre contents of 1.0 cm and 2.0 cm in length, the results demonstrated a similar trend in terms of reduction in OMC. The results revealed that by increasing the PE percent, OMC was decreased. The reduction value for 1.0-cm and 2.0-cm-length PE is from 20% for 1% PE content to 17% for 4% PE content. Similarly, the MDD for both lengths at all fibre contents showed reduction in a value with the increase in the PE percent. The highest decrease was obtained at 4% fibre content for both lengths by 55 kg/m<sup>3</sup>. These data clearly state that by adding more PE percent, both OMC and MDD values decrease; also, if the length of PE increases from 1.0 to 2.0 cm, the OMC decreases more as shown in Figs. 6 and 7, except for MDD at 3% showing an odd trend.

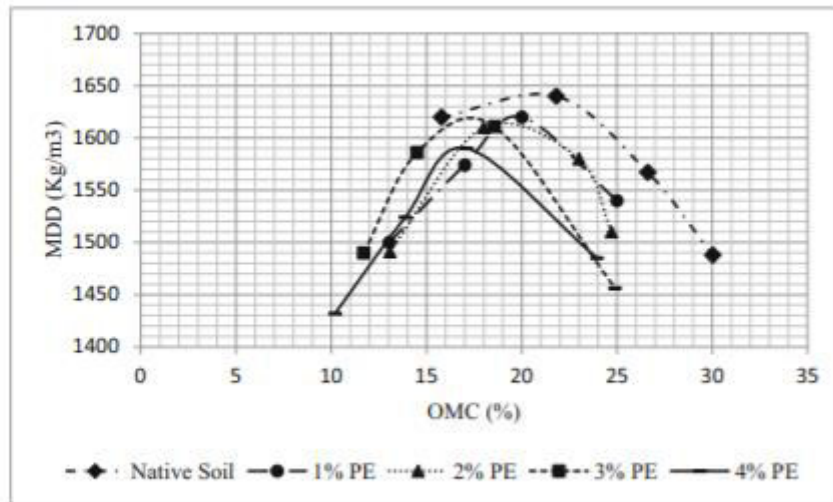


Fig. 4 Proctor test results for 1-cm length of PE at different stabiliser contents

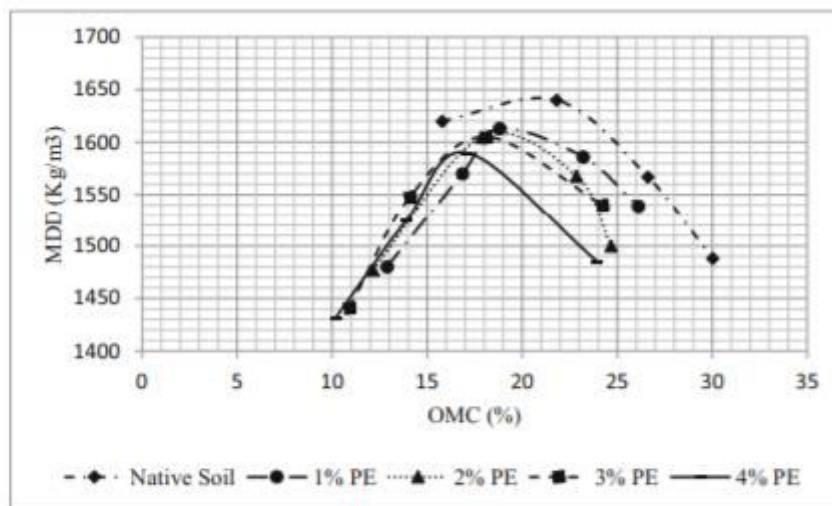


Fig. 5 Proctor test results for 2-cm length of PE at different stabiliser contents

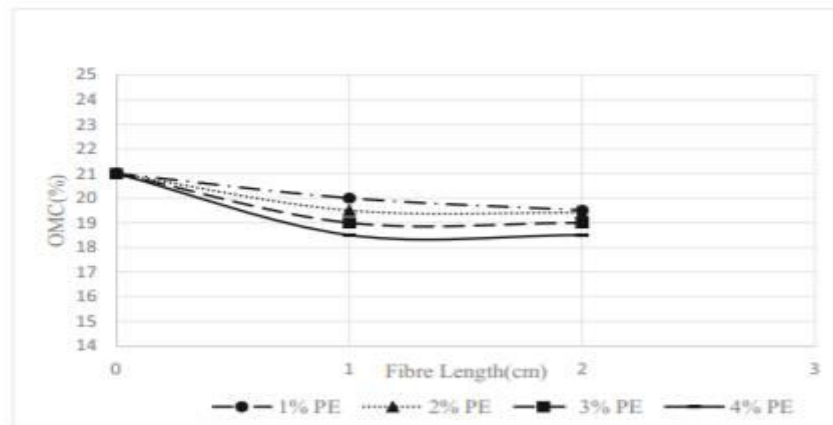


Fig. 6 Effect of the PE ratio on OMC

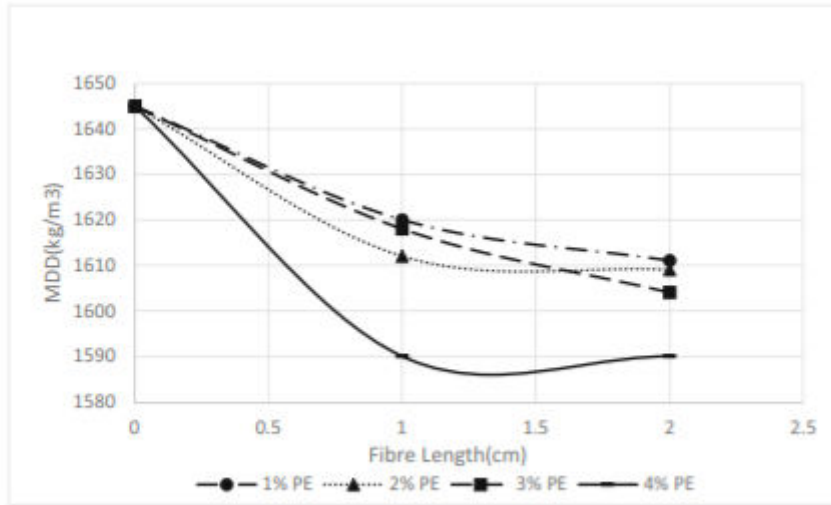


Fig. 7 Effect of the PE ratio on MDD

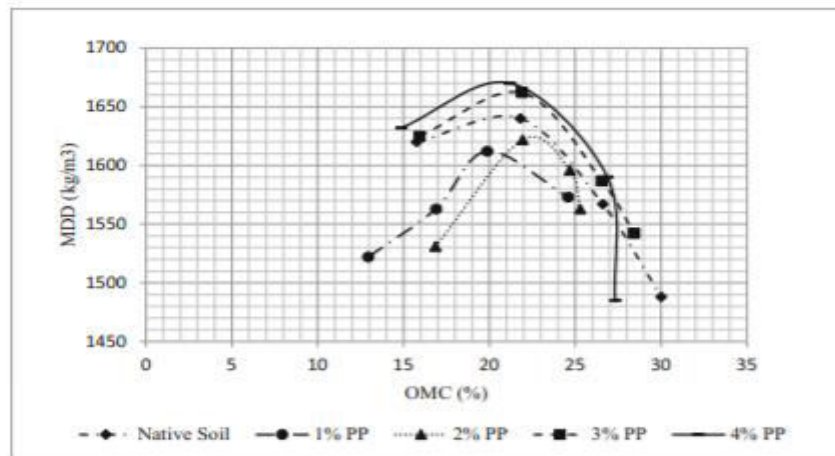


Fig. 8 Proctor test results for 1-cm length of PP at different stabiliser contents

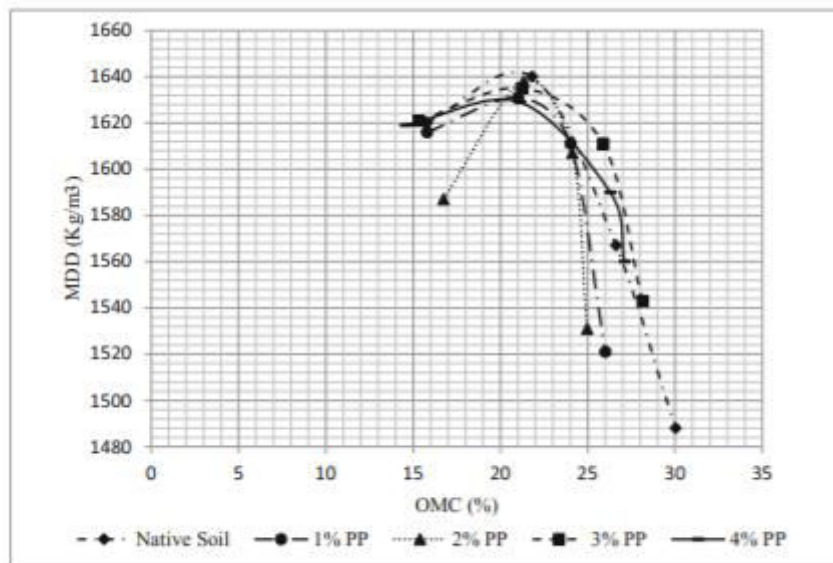


Fig. 9 Proctor test results for 2-cm length of PP at different stabiliser contents

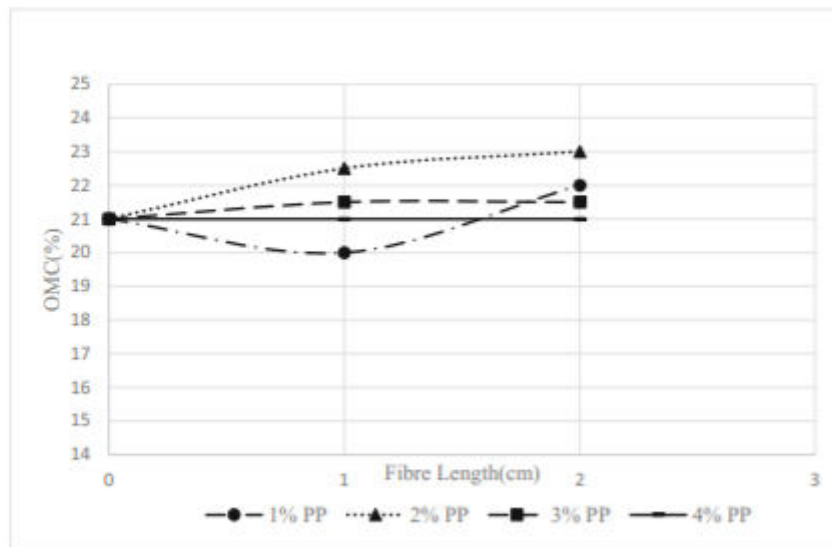


Fig. 10 Effect of the PP ratio on OMC

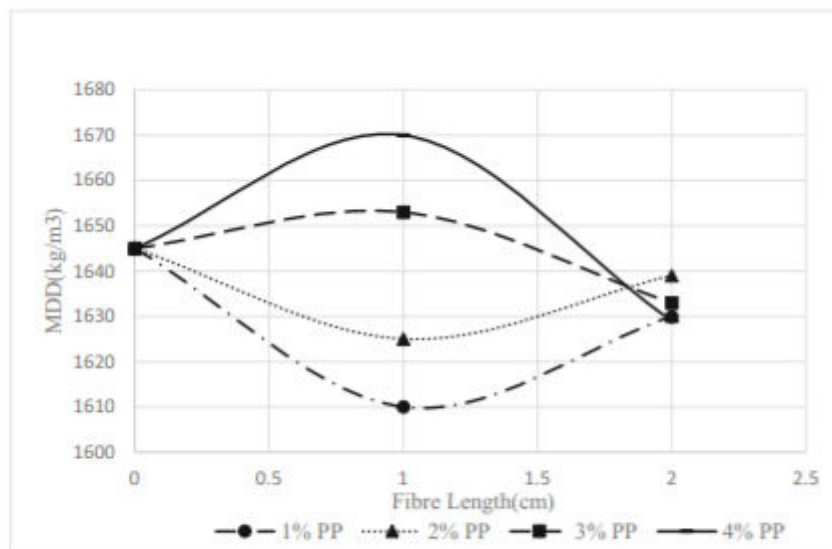


Fig. 11 Effect of the PP ratio on MDD

### Unconfined Compressive Strength (UCS) Test :

The addition of PE and PP fibre increased the stabilised soil strength considerably compared to the native soil strength, which was 148 kPa, can be seen as shown by the results of UCS in Table 3. However, this increase in UCS has an optimum based on the ratio of fibre content, as can be seen in Fig. 8, in which the increase in fibre content is up to 1%; thereafter, the curve flattens and continues at the same strength with the increase in fibre content. The comparison between PE and PP shows that the former has higher UCS values than the latter for 1.0-cm and 2.0-cm lengths of the fibre. In all cases, the 2.0-cm-length fibre results are higher than 1.0-cm-length fibre results. For soil stabilised with 1.0-cm and 2.0-cm-length PE fibre, the optimum fibre content was 1%. The value of UCS increased from 148 kPa (native soil) to 261 kPa (1.0-cm fibre length) and 291 kPa (2.0-cm fibre length) with an improvement by 76.4 and 96.6%, respectively. The lowest increase in UCS was at 4% fibre content for 1.0-cm fibre length and 2% fibre content for 2.0-cm fibre length. Similarly, for soil stabilised with 1.0-cm and 2.0-cm lengths of PP fibre, the optimum fibre content was 1%. The value of UCS increased from 148 kPa (native soil) to 233 kPa (1-cm fibre length) and 256 kPa (2.0-cm fibre length) with an improvement by 57.4 and 73%, respectively. The lowest increase in UCS was at 4% fibre content for 1.0-cm fibre length and 2% fibre content for 2.0-cm fibre length.





**Table 3** UCS test results for PE and PP fibres

Fibre content (%)	Fibre length (cm)	UCS (kPa) PE	UCS (kPa) PP
0	–	148	148
1	1	261 (+76.4%)	233 (+57.4%)
	2	291 (+96.6%)	256 (+73%)
2	1	246 (+66.2%)	223 (+50.7%)
	2	266 (+79.7%)	238 (+60.8%)
3	1	245 (+65.5)	221 (+49.3%)
	2	272 (+83.8)	242 (+63.5%)
4	1	242 (+63.5)	220 (+48.6%)
	2	276 (+86.5)	245 (+65.5%)

The numbers in parenthesis are representing the percentage of improvement in UCS

**California Bearing Ratio (CBR) Test Results :**

The bearing capacity of the soil was measured indirectly by conducting the CBR test. The Soaked CBR is only tested in this study because it is the only test that simulates actual site condition. Also, the study was focused on investigating the effect of water on expansive soils CBR value. The load penetration curve has shown that there is an improvement in the CBR value. The soaked CBR of unreinforced soil was found to be 1.58 which is small. The principal enhancement is attained at a strip size and content of 15 × 20 (mm) and 1% respectively and is of value 3.23. This is a total of 104% increment. The results are summarized in Table 8. Increase in plastic size for the same percentage has resulted in an increase in soaked CBR value but increase in plastic content for the same plastic size increases the soaked CBR then decreases. The improvement in CBR can be attributed to the ability of the strips in resisting swelling prior to penetration and load exerted by the plunger during penetration.

**Table 8.** CBR values (%).

Treatment Level	Strip Sizes (mm)		
	5 * 7.5	10 * 15	15 * 20
0	1.58	1.58	1.58
0.5	1.71	2.28	2.85
1	2.09	2.66	3.23
2	1.96	2.47	3.04

**Concluding Discussion:**

Stabilisation considerably improves the engineering properties of soils, and this includes physical, strength, and mechanical properties. This paper has investigated these properties through an experimental laboratory test programme on two different waste materials that can be found in disposal bins, namely, polyethylene and polypropylene. The main conclusions from the study carried out herein are summarised as follows:

- (1) Soil stabilisation with fibre has different trends for UCS, as the increase in fibre content is not resulting in the increase in UCS ascendingly. Therefore, optimum fibre content shall be sought for stabilisation with fibres for the highest values of UCS.



(2) PE and PP can efficiently be used to improve the physical and strength properties of soil materials as a foundation for engineering projects.

(3) The length of the fibre showed to have an effect on the strength properties of the stabilised soil, as the increase in length resulted in higher strength properties. This may require more research to find the optimum fibre length that gives the highest strength properties.

(4) For those road pavement design codes of practice that use the CBR as design parameters, the fibre stabilisation is cost-effective and it can be used successfully for a sustainable road construction if compared with chemically stabilised soils. The stabilisation with chemical agents is accompanied by carbon dioxide emission, while fibre stabilisation is not; this is one of the advantages of fibre stabilisation over chemical stabilisation.

(5) While for CBR, the increase in fibre content resulted in the increase in value, for UCS, the optimum fibre content could be found between 1% and 2% fibre content for both PE and PP.

Conflict of Interest :

The authors declare that they have no conflict of interest.

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