Compressive strength and truck run over ability of plastic/sand paving block composites

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Abstract. Plastic waste has a negative effect on the environment since it could not be decomposed easily, and it could decrease soil fertility. One way to decrease plastic waste is by mixing it with sand to make paving blocks, because the characteristic of plastic is elastic and flexible, so it is expected that the material will be ductile and strong. Material of this study used LDPE (Low Density Polyethylene) plastic which was chopped and mixed with 6 mesh sand with variation of 1 kg (plastic): 5 kg (sand) and 1 kg (plastic): 7 kg (sand) (1:5 and 1:7). The sand was inserted into mixing machine with 200 °C temperature for 5-10 minutes, after that the chopped plastic was inserted and mixed for 30-35 minutes. Molding process was done by pressure tool. After that testing was done by using compressive machine and run over vehicle. The research result showed that the lowest damage occurred on plastic and sand composition of 1:5 as much as 0.113% and had compressive strength 16.667 MPa, and the highest damage occurred on plastic and sand composition of 1:7 as much 0.267% and had compressive strength 12.963 MPa.

Key words: paving block, LDPE plastic, run over vehicle testing, compressive strength

1. Introduction

Waste problem has not been solved comprehensively in Indonesia until now, by the increase of population, the volume of waste is increasing as well as the consequence of human activity. Most of human activities produce organic waste as much as 60-70% and non-organic waste of 30-40%, in which 14% from the non-organic wastes are plastic wastes [1]. At the first time, plastic was invented in 1907, since then the use of plastic and plastic-based material are increasing. Plastic could not be separated from industrial and consumerism development. Many industries in this world use plastic to pack their products. Instant food industry for instance choose to use aluminum foil-coated plastic or multilayer plastic for their packages because it is considered safe and keep the product consumable [2]. At the same time, the industrial products increase, the human needs become more complex, the people keep shopping, and needs bag for carrying their goods. Plastic bag became the answer for this issue because it is inexpensive, strong, light, not rusty, thermoplastic, could be labeled with many creations, and it could be an effective branding media.

In other side, the plastic wastes bring negative effect on the environment and human health. It has negative effect on environment because it takes longer time to be decomposed and it could decrease soil fertility. Littering plastic waste will also block drainage, sewer and river so there will be flood. The burnt plastic waste will produce Volatile Organic Compounds (VOCs), smoke (particulate), heavy metal...
bonded particles, polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzofurans (PCDFs) and
dioxin, in which those substances are dangerous for human and environment [3]. The increasing of
plastic users will trigger many problems for environment. The common way of reducing plastic waste
used by people is 3R (Reuse, Reduce, and Recycle).

Other alternative to solve plastic waste problem is mixing plastic waste with concrete, paving block
and asphalt because the characteristic of plastic is elastic and flexible, so it is expected that the material
will be stronger. Nowadays many people use paving block as building construction, especially for road
pavement in the neighborhood, houses, parking lot and other places. Paving block is widely used because
it could withstand load within certain limits and easily installed. Besides that, paving block is better than
other pavements concerning the economic value of maintenance, exterior artistic aspect of the building,
do not need heavy tool, and it can be massively produced as well as concerning the environmental
sustainability it could preserve water. The use of cement as the main material of paving block is
relatively expensive. Therefore, this study used plastic bag waste as the replacement of cement, which
is expected that low density polyethylene (LDPE) plastic bag waste could produce paving block that is
able to withstand loads of public vehicle. Many researchers studied the mixing bitumen with plastic, but
in the present work plastic bag waste and sand pavement are studied with different compositions.

2. Research Method
This study used LDPE plastics which were washed and dried under sunshine for 24 hours, and then they
were chopped by using plastic chopper. Besides plastic waste, other main material of this study was
sand. It was a river sand that had been cleaned and sifted using a 6-mesh sieve. The sifted sand was put
into mixer machine and was heated in 200 °C for 5-10 minutes, after that the chopped plastic was put
into the mixer and mixed for 30-35 minutes with composition comparison of plastic: sand (1 kg:5 kg
and 1 kg:7 kg).

The mixture of plastic and sand was molded by using a beam-shaped iron plate with a size of 20 ×
20 × 6 cm in accordance with the shape and size of the paving [4] then it was pressed by using hydraulic
jack and thick plate as a cover to avoid voids. After cooling, the specimen was pulled out from the mold
and keep on the room temperature minimum for 24 hours before testing and labelled based on the molded
mixture.

For compressive test, paving block was cut into cubes sized 6 × 6 × 6 cm in accordance with the
ASTM D695 [5] and compressive testing was done by using mortar compression machine UT200/50EL.
For run over testing, the paving block was installed on field in accordance with standard of paving
installation [6] and then it was run over using a truck without a load with variations in the run of 10,
50,100, 200, 400 times. For every run variation, the paving was measured to know the damage and the
damage mean score was calculated in form of percentage.

3. Results and Discussion

3.1. Compressive Test
Compressive test was done by using mortar compression machine UT200/50EL to know the
compressive strength of the paving block. The following (Table 1) is the table of paving compressive
strength calculation:
Then, the data were plotted into graphic to describe the mean score of the compressive strength comparison of plastic paving and concrete paving as follows:

| Comparison          | Sample | Compressive load (KN) | Area (cm²) | Compressive strength (MPa) | Mean score (MPa) |
|---------------------|--------|------------------------|------------|----------------------------|------------------|
| Plastic: sand (1:5) | Specimen 1 | 60                     | 36 | 16.667                      | 16.667           |
|                     | Specimen 2 | 65                     | 36 | 18.056                      |                  |
|                     | Specimen 3 | 55                     | 36 | 15.278                      |                  |
| Plastic : sand (1:7)| Specimen 1 | 55                     | 36 | 15.278                      | 12.963           |
|                     | Specimen 2 | 40                     | 36 | 11.111                      |                  |
|                     | Specimen 3 | 45                     | 36 | 12.500                      |                  |
| Cement : sand (1:5) | Specimen 1 | 95                     | 36 | 26.389                      | 23.148           |
|                     | Specimen 2 | 70                     | 36 | 19.444                      |                  |
|                     | Specimen 3 | 85                     | 36 | 23.611                      |                  |
| Cement : sand (1:7) | Specimen 1 | 55                     | 36 | 15.278                      | 17.129           |
|                     | Specimen 2 | 80                     | 36 | 22.222                      |                  |
|                     | Specimen 3 | 50                     | 36 | 13.889                      |                  |

Table 1. Compressive strength of plastic paving and concrete paving.

Based on the above mean score of compressive strength from every samples as shown in Table 1 and Figure 1, the difference of plastic and sand or cement and sand mixture affected the paving compressive strength. The highest compressive strength occurred in cement paving with comparison of cement and sand 1:5, as much as 23.148 MPa. Meanwhile, the lowest compressive strength occurred in plastic paving with comparison of plastic and sand 1:7, with compressive strength of 12.963 MPa. It is in line with research conducted by Frigione [7] who replaced the sand with polyethylene waste that the compressive and tensile strength of the plastic concrete was 0.4 – 1.9% which was lower than control but with slightly higher ductility.
Figure 1 shows that compressive strength of plastic paving is lower than cement paving, but plastic paving specimens were not destroyed after compressive testing as shown in Figure 2 and Figure 3, while concrete paving specimens were destroyed as shown in Figure 4 and Figure 5. It means that plastic paving block was more persistent than cement paving block.

Based on National Standardization Agency of Indonesia (BSN) [8] compressive strength qualities for paving block standard B (for parking lot) and standard C (for pedestrian) are 17.0 MPa and 12.5 MPa, respectively. Therefore, plastic paving with mixture 1:5 and compressive strength 16.667 MPa almost meet the BSN standard and plastic paving with mixture 1:7 and compressive strength 12.963 MPa has already met BSN standard. In Agyeman et.al [9] research, composite paving blocks less in plastic (LP) has compressive strength 7.31 N/mm² (MPa) and composite paving blocks high in plastic (HP) has compressive strength 8.53 N/mm² (MPa). So, plastic paving with mixture 1:5 and 1:7 have higher compressive strength.

3.2. Run Over Vehicle Test
This test was conducted by using double ankle truck Hino Dutro Dump 130 HD without loading with weight 2,355 kg and standard tire pressure of 100 psi. The truck run over the specimen by going forward and backward, on every variation of run, the specimens were measured to know the damage.

Mean score of damage was changed into damage percentage and plotted into graphic of the relation between number of run and the damage occurred as follows:
The data of run over test which was done with mixture variation of LDPE plastic and sand, produces data of damage percentage as shown in Figure 6. It shows that the difference of plastic and sand mixture affects the number of damage percentages. Based on Figure 6, it can be seen that the lowest damage occurred in concrete paving with composition of cement and sand 1:5 as much as 0.073%, yet in the testing the concrete paving was damaged in two parts on run 200th while the plastic paving with composition of plastic and sand 1:5 has damage average 0.113%. The highest damage occurred in plastic paving with composition of plastic and sand 1:7 as much as 0.267%, but there is no broken. From all data, there is no big difference of damage percentage or not too significant for unbroken specimens. Kosmatka et al. [10] argued that concrete resistance upon impact and abrasion related to compressive strength and aggregate type. From this argument, it can be proven that plastic paving mixture 1:5 which has compressive strength 16.667 MPa has lower damage than plastic paving 1:7 which has compressive strength 12.963 MPa.

3.3. The result of material characteristic using SEM (Scanning Electron Microscope) Type Phenom G2 Pro.

Both results of testing were supported by SEM photo of plastic paving with mixture comparison variation 1:5 and 1:7 as the following Figure 7 and Figure 8.
In which plastic paving with composition comparison of plastic and sand 1:5 has lower damage compared to plastic paving which has comparison plastic and sand 1:7. It is because on plastic paving 1:5 almost all of the sands were bonded (as shown in photo SEM Figure 7) so the strength to hold the load is better than plastic paving 1:7, in which paving with comparison 1:7 has more cavities caused by less of matrix to bond all surfaces of sand as shown by photo SEM Figure 8.

4. Conclusion
Based on the finding and discussion, some conclusions can be drawn as follows:
1. The higher mixture composition of plastic and sand, the lower compressive strength produced. The highest compressive strength of plastic paving was gained from mixture of plastic and sand 1:5 as much as 16.667 MPa, while the lowest compressive strength was gained in comparison 1:7 as much as 12.963 MPa.
2. The higher mixture composition of plastic and sand, the higher damaged occurs. The highest damage was gained from mixture of plastic and sand 1:7 as much as 0.267%, while the lowest damage was gained from comparison 1:5 as much as 0.113%.
3. Plastic-sand paving is lesser compressive strength but more ductile than cement-sand paving.

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