The utilization of plastic waste in a mixed pair of concrete brick walls

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Abstract. Plastic is a daily consumable material due to its easy accessibility and affordability. The high production of plastic waste contributes to the increase risk of hazardous environment which is difficult to be processed and decomposed. One of the solutions is to recycle plastic waste. In this study, the types of High Density of Polyethylene (HDPE) and Polypropylene (PP) were utilized as substation material with 10% of ratio to be mixed in pair with concrete brick walls. The sample study was concrete bricks characterized with dimensions of 40x20x10 cm$^3$ and 15x15x15 cm$^3$. The addition of admixture SikaPayer HC-ID and silica fume as additive was carried out to improve the performance of testing samples. Samples of concrete bricks were then attached on the wall as a mixed pair with dimension 105x95 cm$^2$, and compression properties were performed. The results showed that visual appearances, content weight, and adsorption ability of two samples were classified as concrete brick type I, and the addition of HDPE and PP to the concrete bricks walls contributed into type II which were able to withstand load around 2200 and 2800 Psi respectively. The other eminence that was observed from the addition of HDPE and PP was milder weight compared to neat concrete bricks.

1. Introduction

Plastic has been considered as hazardous material due to its difficulty to be processed and decomposed. The decomposition of plastic takes a high amount of time, which is to be disintegrated perfectly. During disintegrating, plastic wastes can contaminate soil, air, and water, such as decomposing in soil, these wastes damage soil fertilization and prevent underground water flow whereas plastic wastes burning produces hazardous smokes to any living things; waters that have been contaminated by plastics whose dissolved chemical substance could have damaged the marine ecosystems [1].

The re-utilization is the most prominent solution in solving plastic wastes [2]. Varied attempts have been performed such as in reusing these wastes in civil engineering sectors. The implementation of energy efficient building materials can be done as one of the example, which is the utilization of plastic wastes as replaceable aggregate materials in the construction of lightweight concrete bricks. A concrete brick is one of building materials composed of organized arrangement bricks molded by gluing materials such as sand, cement and water in certain ratio of volumes in constructing walls [3]. Concrete bricks are non-structural wall-building material, and polymeric concrete bricks befit to non-structural construction because of its affordability [4]. Nonetheless, concrete bricks must have standardized strength and
tolerating limits to obtain acceptable quality, which in Indonesia, they must comply Indonesia National Standard (SNI 03-0348-1989).

A lightweight plastic can be used as a replacement of conventional aggregates in reducing weight contents of concrete [4]. In addition to reduce the use of natural resources, reusing plastic wastes can reduce the high amount of waste themselves. Studies related to the utilization of recycled plastic wastes as aggregates have been extensively carried out from 1994 to 2015 [5]. Among these studies, Yun Wang Choi et. al., in 2009 have performed the development of lightweight aggregate concrete by utilizing fine aggregate prepared from polyethylene terephthalate (PET) of bottles [6]. In 2010, S. E. Chidiac and S. N. Mihaljevic have designed the mixing of plastic wastes into bricks to create dry concrete bricks [7]. On the other hand, Rahim et. al., in 2013 has substituted shredded HDPE plastic wastes which have been filtered out into length of 4.75 to 20 mm to be mixed with rough aggregates in concrete [8]. Bagus Soebandono, As’at Pujianto, and Danar Kurniawan in 2013 have measured compressive and tensile strength for concrete materials fabricated by using HDPE plastic wastes as rough aggregates [9]. Yang et. al., in 2015 has modified PET plastic wastes in various percentage (10%, 15%, 20% and 30%) to replace sand in fabricating self-compacting lightweight concrete (SCLC) [2].

In this study, HDPE and PP plastics wastes were utilized as a mixed pair of concrete walls. The HDPE is a common plastic material that has been used in producing bottles of milk, detergent, shampoo, lotion, oil, toys and several plastic wastes. HDPE plastics are considerably hard, not easily damaged by sunlight, able to withstand high heat and cold temperatures. On the other hand, PP plastics have similar properties to HDPE including lightweight and resistant to heat, and this type of plastic is usually used as food wrapping plastics to maintain dryness and freshness. Moreover, PP is also commonly used as plastic bucket for margarine and yogurt box, straws, string, insulation, and paint cans. A study conducted by Nursyamsi et al., and Kevin both in 2017 have reported the type III concrete bricks composed of 10% of HDPE and PP plastic wastes as from the total of sand weight [10], [11]. Regarding the addition of HDPE as constructing material which has been performed by Rahim et al., in 2013, it has found that the addition of 10% of HDPE contributed to more enhanced compressive strength compared to any various addition material [8]. In this study, the admixture of SikaPaver HC-1 ID and Silicafume additive materials were combined with 10% of HDPE and 10% PP as replaceable materials of sand to obtain higher quality of concrete bricks than those from previous studies.

2. Materials
As aggregate materials in fabricating the concrete bricks, Portland Cement type I (OPC-1) which was purchased from PT. Semen Padang was utilized with number of 50 Kg. Whilst, the reinforced material was river sand collected from Binjai, North Sumatera. Sand grains distribution was investigated to befit accordingly to SNI 03-1968-1990, while the organic compositions test was performed throughout colorimetric test based on SNI 03-2816-1992. The examination of sand sludge and clay contents were performed in accordance of ASTM C 117-98 and ASTM C 142-78 respectively as well as sand weight measurements accordingly to ASTM C 29. The investigation of sand characteristics is Sieve analysis FM= 2.1, Weight content 1527.89 kg/m3, Relative density 2.65, Absorption 2.82 %, Sludge level 1.9 % and Sand organic content 0.51 %. As admixture SikaPaver HC-1 ID was projected to support compression condition in high and efficient performance. This admixture commonly is used for constructing concrete, mortar cement, and dried slump, and the additive material was silicafume.

3. Methods
The plastic wastes of HDPE and PP that has been shredded were cleansed by using water. These wastes were utilized to substitute sand which accounted for 10% by the total volume of sand, and this percentage was applied for two samples of concrete bricks. Both of these samples were fabricated by ratio of 1:6 for cement and sands respectively with FAS 0.32, and 0.4% of SikaPaver HC-1 ID and 10% of silicafume which were mixed based on the total weight of cement. In the process of making the specimens compacted by being struck with a hammer, the specimens are coated with a steel plate first so that they will produce a flat and elbows surface. Then after the specimens are formed, treatment is
done by watering the specimens with water regularly every day. After 28 days, visual examination was performed, and the measurement of weight contents, absorption, and compression strength of samples were examined. Afterwards, these brick samples were used to construct a pair of wall with dimension of 105 x 95 cm mixed by mortar cement aggregates and sands with ratio 1:3 respectively for 2.5 cm of thickness. Seven days onward after the wall being constructed, compressive strength tests were performed by setting up hydraulic jack supported by steel plate on the walls’ surface which was given loads. To measure the water absorption of concrete walls, the measurement was performed based on SNI Standard 03-03490-1989 and the measurement of compressive strength, the test was performed in accordance of SNI 03-0349-1989.

4. Results and analysis
4.1 Visual examination
4.1.1 Physical appearance examination

| Summary     | Average samples condition | HDPE Concrete | PP Concrete |
|-------------|---------------------------|---------------|-------------|
| 1. Plane    |                           |               |             |
| a. Uniformity | Uniform                   | Uniform       |             |
| b. Cracking  | No cracking               | No cracking   |             |
| c. Sheers    | Smooth                    | Smooth        |             |
| 2. Sides    |                           |               |             |
| a. Framing square | 90°                      | 90°           |             |
| b. Sharpness | Sharp                     | Sharp         |             |
| c. Strength  | Strong                    | Strong        |             |

The samples study of concrete bricks have qualified the Indonesia national standard SNI 03-0349-1989 which is indicated to have no defect in the uniformity as well as cracking, perpendicular angle sides, and sturdiness.

4.1.2 Dimensional measurements
The next examination is the measurement of dimension to sample concrete bricks. The data from the measurements were analysed to follow the standard based on SNI 03-0349-1989.

| Samples (400 x200 x 100 mm) | Length* | Width* | Height* |
|----------------------------|---------|--------|---------|
| Brick with 10% of HDPE     | 40.006  | 20.004 | 10.004  |
| Brick with 10% of PP       | 40.007  | 20.005 | 10.003  |

*average measurements

According to tolerance limit of SNI 03-0349-1989, the results of measurements showed that the deviations were 0.006 and 0.007 cm for the length of both samples, 0.004 and 0.005 cm of both sample in width, and 0.004 and 0.003 cm for the height of both samples, and these dimensions have befitted the SNI standard. This achievement was due to the process of fabricating concrete bricks which was per-
formed manually. A firm moulding equipment in fabricating bricks is one of another factor that can affect the strength of bricks.

4.2 Weight content and absorption tests

4.2.1 Weight content analysis

**Table 3.** The comparison of weight content of bricks

| No. | Bricks Sample  | Volume (m$^3$) | Average weight (Kg) | Density (Kg/m$^3$) |
|-----|----------------|----------------|---------------------|---------------------|
| 1   | Normal bricks*| 0.008          | 16,399              | 2049.875            |
| 2   | HDPE bricks   | 0.008          | 14,293              | 1788.831            |
| 3   | PP bricks     | 0.008          | 14,908              | 1862.913            |

*The measurements conducted by Nursyamsi et al., and Kevin (2017)[10][11]

Based on table 3, the samples composed of shredding plastic wastes of PP had higher average weight than that in HDPR bricks. This demonstrates that PP had higher density than that PP. A similar result was confirmed by the studies conducted by both Vincent and Kevin in 2017, in which bricks fabricated from 10% of PP contributed higher average weight compare to those composed of 10% of HDPE without the addition of admixture and any additive materials. In study conducted by Vincent who utilized HDPE, the density was accounted for 1750 kg/m$^3$, while in Kevin it was measured for 1760 kg/m$^3$ of PP concrete bricks.

From the measurements of weight content that has been performed, both HDPE and PP contributed to smaller density value than normal bricks. This implies to the utilization of HDPE and PP plastics reduced the weight of brick, while the addition of Sika Paver HC-IID as admixture and Silicafume as additive materials contributed to the increasing weight and density of HDPE and PP bricks.

4.2.2 Absorption test

**Table 4.** Absorption measurements of bricks

| Samples          | Wet mass (Kg) | Dried mass (Kg) | Average absorption (%) | Class |
|------------------|---------------|-----------------|------------------------|-------|
| 10% of HDPE bricks | 15.241 | 14.311  | 6.509  | 25 | I |
| 10% of PP bricks  | 15.829 | 14.903  | 6.211  | 25 | I |

According to Table 4, it can be seen that the absorption ability of both bricks which are composed of HDPE and PP with the addition of SikaPaver HC-1ID and Silicafume have corresponded to the SNI standard of SNI-03-0349-1989. The bricks were categorized as class I bricks which indicated the tolerance limit under 25%. The water absorption occurred in 10% of PP bricks, in which the smaller density of PP (0.90-0.91 gr/cm$^3$) than that in HDPE (0.94 gr/cm$^3$) influences the absorption ability of bricks to have greater absorption value compared to normal bricks which is composed of 100% of sand.
4.3 Compressive strength of bricks

In the compression tests, the samples were given load to obtain maximum load which can be maintained by both bricks and cubes. The samples which were prepared for compression tests were bricks with 40 x 20 x 10 cm of dimensions, and cubes with 15 x 15 x 15 cm of dimension. Both of these samples were prepared accordingly to the methodology which was 28-days of preparation, and both of these samples were fabricated for 10% of HDPE and PP from total of sand weight. The use of HDPE and PP which were 10% from the total ratio was carried out in accordance of study conducted by Nursyamsi et al., and Kevin. The following table 5 and 6 display the results of compression tests of bricks and cubes of samples.

Table 5. The compression test results of HDPE (First test) Nursyamsi [10]

| No | Samples | Ages (days) | Load (kN) | Area (cm²) | Average force (kg/cm²) | Class Samples SNI 03 – 0349 - 1989 |
|----|---------|-------------|-----------|------------|------------------------|-----------------------------------|
| HDPE Bricks |
| 1 | Normal | 7 | 192.57 | 280 | 70.15 | 70 | II |
| 2 | HDPE 10% | 7 | 135.28 | 280 | 49.28 | 40 | III |
| 3 | HDPE 20% | 7 | 122 | 280 | 44.44 | 40 | III |
| 4 | HDPE 30% | 7 | 76.56 | 280 | 27.89 | 25 | IV |
| HDPE Cubes |
| 5 | Normal | 7 | 196 | 280 | 71.4 | 70 | II |
| 6 | HDPE 10% | 7 | 138.13 | 280 | 50.32 | 40 | III |
| 7 | HDPE 20% | 7 | 136.27 | 280 | 49.64 | 40 | III |
| 8 | HDPE 30% | 7 | 126.93 | 280 | 46.24 | 40 | III |

Table 6. The compression test results of PP (First test) Kevin [11]

| No | Samples | Ages (Days) | Load (kN) | Area (cm²) | Average force (kg/cm²) | Class Samples SNI 03 – 0349 - 1989 |
|----|---------|-------------|-----------|------------|------------------------|-----------------------------------|
| PP Bricks |
| 1 | Normal | 7 | 192.57 | 280 | 70.15 | 70 | II |
| 2 | PP 10% | 7 | 143.43 | 280 | 52.25 | 40 | III |
| 3 | PP 20% | 7 | 113.86 | 280 | 41.48 | 40 | III |
| 4 | PP 30% | 7 | 77.71 | 280 | 29.87 | 25 | IV |
| PP Cubes |
| 5 | Normal | 7 | 17.50 | 280 | 71.40 | 70 | II |
| 6 | PP 10% | 7 | 12.83 | 280 | 52.36 | 40 | III |
| 7 | PP 20% | 7 | 11.00 | 280 | 44.88 | 40 | III |
| 8 | PP 30% | 7 | 6.67 | 280 | 27.20 | 25 | IV |

Based on the data on Table 7, compression strength of HDPE and PP bricks as well as HDPE cubes were categorized as class II of bricks, and the PP cubes were included as class I bricks in accordance of SNI 03-0349-1989 in which class I and II respectively have 100 kg/ cm² and 70 kg/ cm². The cubes shape samples had higher strength compared to bricks samples which were based on the dimensional aspect to receive force area [1].
The following Table 7 displays the results of testing compression strength test of Brick-Wall

| No. | Samples            | Code | Age (days) | Load (kN) | Compression area (cm$^2$) | Average compression force (kg/cm$^2$) | Class |
|-----|--------------------|------|------------|-----------|---------------------------|---------------------------------------|-------|
| 1   | Bricks composed of 10% HDPE | B1.1 | 28         | 206       | 280                       | 75.04                                 | II    |
| 2   | B1.2               | 28   | 184        | 280       |                           | 67.03                                 | II    |
| 3   | B1.3               | 28   | 190        | 280       |                           | 69.03                                 | II    |
| 4   | B1.4               | 28   | 182        | 280       |                           | 66.30                                 | II    |
| 5   | B1.5               | 28   | 188        | 280       |                           | 68.49                                 | II    |
|     | Average            |      | 190        | 280       |                           | 69.21                                 | II    |
| 1   | Bricks composed of 10% PP | B2.1 | 28         | 236       | 280                       | 85.97                                 | II    |
| 2   | B2.2               | 28   | 254        | 280       |                           | 92.53                                 | I     |
| 3   | B2.3               | 28   | 230        | 280       |                           | 83.79                                 | II    |
| 4   | B2.4               | 28   | 236        | 280       |                           | 85.97                                 | II    |
| 5   | B2.5               | 28   | 228        | 280       |                           | 83.06                                 | II    |
|     | Average            |      | 236.8      | 280       |                           | 86.26                                 | II    |
| 1   | Cubes composed of 10% HDPE | K1.1 | 28         | 154       | 225                       | 69.81                                 | II    |
| 2   | K1.2               | 28   | 176        | 225       |                           | 79.79                                 | II    |
| 3   | K1.3               | 28   | 164        | 225       |                           | 74.35                                 | II    |
| 4   | K1.4               | 28   | 182        | 225       |                           | 82.51                                 | II    |
| 5   | K1.5               | 28   | 158        | 225       |                           | 71.63                                 | II    |
|     | Average            |      | 166.8      | 225       |                           | 75.62                                 | II    |
| 1   | Cubes composed of 10% PP | K2.1 | 28         | 254       | 225                       | 115.15                                | I     |
| 2   | K2.2               | 28   | 226        | 225       |                           | 102.45                                | I     |
| 3   | K2.3               | 28   | 270        | 225       |                           | 122.40                                | I     |
| 4   | K2.4               | 28   | 264        | 225       |                           | 119.68                                | I     |
| 5   | K2.5               | 28   | 238        | 225       |                           | 107.89                                | I     |
|     | Average            |      | 250.4      | 225       |                           | 113.51                                | I     |

The brick wall with the composition of HDPE as the substitution material had lower compression strength compared to those composed of PP. The HDPE wall was able to withstand load to 2200 Psi or 154.67 kg/cm$^2$, while the PP wall had ability to with-stand load accounted for 2800 Psi or 196.86 kg/
Related to the test results of both PP and HDPE concrete bricks, wall samples composed of HDPE and PP had directly proportional ratio to the test results of a unit of concrete bricks of each sample of HDPE and PP, which indicate that a unit of HDPE had lower compression strength to that composed of PP.

5. Conclusions
From the results and discussion, it can be concluded that:
1. The bricks composed of shredding plastic wastes of HDPE and PP had visual appearances in accordance to the Indonesia National Standard (SNI-03-0439-1989).
2. Both bricks composed of shredding plastic wastes of HDPE and PP had smaller weight compared to normal concrete bricks, even though the composition was added by admixture (SikaPaver HC-1ID) and Silica Fume.
3. Based on weight content and absorption ability, the HDPE and PP concrete bricks with the addition of SikaPaver HC-1ID and Silica Fume were classified as class I concrete bricks.
4. The absorption level of HDPE and PP with the addition of SikaPaver HC-1ID and Silica Fume had ≤25%
5. The compression strength of HDPE and PP with 10% composition with the addition SikaPaver HC-1ID and Silica Fume contributed the strength into class II concrete bricks based on SNI 03-0349-1989

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