Development of the utilization methods of recycled PET as construction materials

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ABSTRACT: PET(Polyethylene terephthalate) was developed in 1941 is being widely used for bottle, film and electric component in whole industry because it has lightweight and good mechanical properties. As a bad results of its use in large quantities, million ton of PET garbage are being wasted every year only in Korea, numerous amount all around world. Many countries and relating companies are trying to develop the recycling technology for PET garbage. But, they are having a hard time because mechanical properties of recycled PET are becoming more inferior from an engineering point of view. Furthermore, recycling costs are expensive more than disposal expenses. A series of laboratory experiments were carried out to seek physical and mechanical properties of possible construction materials using recycled PET garbage. It was cleared that recycled PET materials could be used as various construction materials in terms of strength (uniaxial compressive strength is 30 MPa or more) and rigidity. But, recycled PET materials seems to have the great disadvantage of large brittleness. When recycled PET is mixed with glass fiber or carbon fiber, the brittleness of it is greatly reduced, and then it is likely to be used as some construction materials.

Keywords: Recycled PET, Brittleness, Construction material, Recycling technology, Compressive strength

1 INTRODUCTION

PET((polyethylene terephthalate) is using in various fields like bottle, fiber, filament and etc. because of its high strength, heat stability, chemistry proof. It is well known that about more than 15 million tons of PET are being consumed and almost thrown away after one use. As a result of it, as the amount of industrial waste of PET increases each year, special environmental problems occur in Korea and outside the country. So, various social efforts are underway to tackle the environmental problems including recycling it. In other to recycle PET, however, it is necessary to extract raw materials such as TPA(Terephthalic acid) and BHET(Bis hydroxyethyl terephthalate), through chemical processes such as Methanolysis and Glycolysis(Kim, 1994). However, according to the Ministry of Environment in Korea(2013), these costs are approximately 1.6 times higher than the average landfill cost, resulting in impractical issues when considering economic feasibility. Also, if plastic manufacturing is carried out at 250℃ or higher for recycling, it is difficult to use the material as a result of the oxidation of ethylene glycol, which causes the material showing brittleness and diminishing compressive strength. Currently, PET are being recycled in the clothing industry etc. in a small way. Therefore, it is judged that the development of new technologies is necessary in the engineering aspects that can be recycled PET on a large scale and economically viable. In this study, the exhausted PET bottle was cut into chips sized of a centimeter or less. Next, it was melted with a combination of carbon fiber, fiberglass. This material is used to produce samples for laboratory test. Finally, it was tried to find out the possibility of PET recycling in the construction site. PET is considerably lighter than concrete materials, including soil materials, and the weight of the unit is only $13kN/m^3$, 55 % of concrete materials and 70% of soil materials. Further the unconfined compressive strength of the PET specimen was showed to be approximately 30MPa (10 times higher than soil materials and almost equal to the concrete material). Thus, it is deemed that the recycled PET could be replaced soil materials (sand, aggregate) or concrete materials in large-scale construction site. If the materials that can be substituted with various construction materials are developed, it is judged that it could achieve innovative research outcomes and development achievements in terms of environmental engineering, material engineering, and especially civil engineering.

2 USED MATERIALS AND SPECIMEN PREPARATION

2.1 *Used materials*

2.1.1 *PET(Polyethylene terephthalate)*

PET is polycrystalline polyester formed by reaction of ethylene glycol and terephthalic acid or dimethyl terephthalate. It is used for textiles, film manufacturing and packaging materials such as various types of small containers. The rate of return after the consumer had consumed is 20 % or less, and 80 % of it are reclaimed or incinerated (Han et al., 2012). Washing and being crushed PET less than 3mm was used in this study. Figure 1 show PET have been crushed after collecting by recycling companies.

2.1.2 *Glass fiber*

PET are usually mixed with various foreign substances such as vinyl, scrap metal or aluminum, which degrades the properties of the materials. The glass fibers were mixed with PET to ensure minimum performance for strength and to achieve homogeneity of the mixed material. Glass fibers used in this study were less than 3mm from the glass fibers produced in the left and the right end during the glass fiber processing, which is mostly discarded materials. Fig. 2 shows the glass fibers used in this study

2.1.3 *Carbon fiber*

Carbon fiber consists of hundreds of filaments which are composed of 5 to 15μm diameter, which are used mainly for composite materials to improve material characteristics such as strength and elasticity (Lee et al., 2015). Carbon fiber less than 3 mm were used to increase compressive strength of PET which would be used as a construction materials. Fig. 3 shows the carbon fibers used in this study.


Figure 1. Recycling PET


Figure 2. Glass fiber


Figure 3. Carbon fiber

2.2 *Preparation of specimen*

2.2.1 *Compounding of materials*

PET represents the same behavior as the liquid being at melting temperatures of 250℃ or more. For smooth fusing of the PET particles and other materials, the compounding equipment was used and the temperature in the equipment was commenced at 220℃ and the final melting temperature was maintained at 260℃. After desiccating the mixed materials, it was cut into a uniform size and crushed into powder using grinding mill. The processes were outlined in Figure 4.

2.2.2 *Preparation of specimen*

To measure the compression tensile strength for mixed materials, the preparation of the specimens through injection and molding is required. For this purpose, a mold was manufactured for simultaneous injection of specimens for measurement of compressive and tensile strength as shown in Figure 5(a), (b). Ejaculator shown in Figure 5(c) was used for preparation of various types of specimens for laboratory tests.

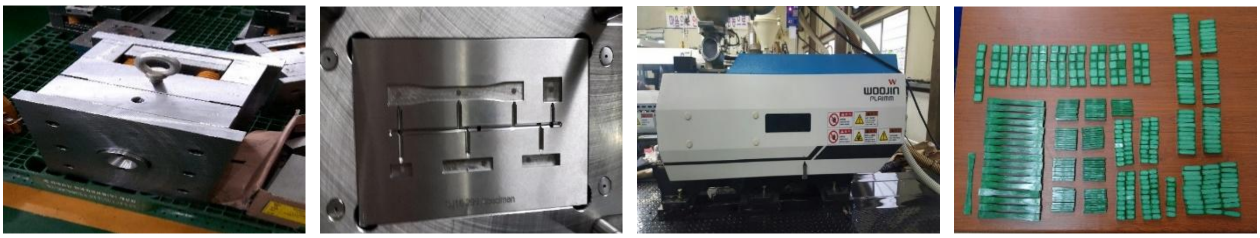
2.2.3 *Test method*

For evaluating the application possibility as construction material, test was performed on laboratory test equipment. Test method to measure the compression strength and elastic modulus was followed ASTM D 695(2010). And test method to measure the tensile strength was followed ASTM D 638(2010).

(a) Preparing Materials (b) Mixing (c) Compounding Machine (d) Insertion

(e) Melting and Cutting (f) Drying (g) Grinding (h) Completion

Figure 4. Manufacturing process of materials



(a) Mold (b) Inside of Mold (c) Ejaculator (d) Preparation of specimens

Figure 5. Manufactured mold and Ejaculator

3 TEST RESULTS AND COMPARISONS

3.1 *Unconfined compressive test results for various specimens*

3.1.1 *Test results for PET*

Figure 6 showed unconfined test results for PET itself. The average compressive strength was about 33MPa. The test results are showing that the recycling PET has a substantial compressive strength but indicates a strong brittleness. It was also founded that PET burst into a sudden catastrophe through the weakest part of specimen. Therefore, the same tests were carried out by mixing various materials to remove the brittleness and increase strength and rigidity. Figure 7 shows a toughness modulus which is usually used elastic energy (left half) and plastic energy (right half). In order to evaluate the change of brittleness, the increase tendency of the plastic energy was investigated through a series of experiments as follows. After calculating only the plastic energy in Figure 7, it is shown the decreasing tendency of brittleness in figure 10.

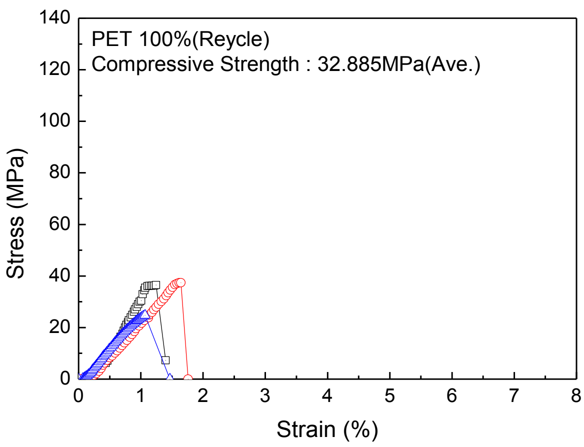


Figure 6. Unconfined test results for PET

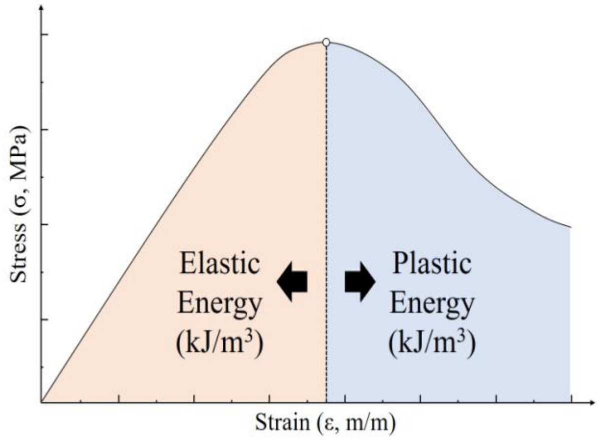


Figure 7. Elastic Energy and Plastic Energy

3.1.2 *Test results for carbon fiber mixture*

Figure 8 showed unconfined test results for carbon fiber mixture in which the mixing ratio of carbon fiber changes from 1% to 5%. The test was performed 10 times for each of the same mixing ratio specimen. The compressive strength in the figure means the average of 10 test values. The average compressive strength increased from 34.5MPa to 73.7MPa according to mixing ratio of carbon fiber. The mixing ratio was determined by considering the compressive strength(about 60MPa or more) of the high strength concrete. The test results are showing that compressive strength of the carbon fiber mixture increases in proportion to the increase in mixing ratio even if the ratio is less than 5%. The figures also showed that the brittleness decrease and the plasticity increase compared with PET itself.

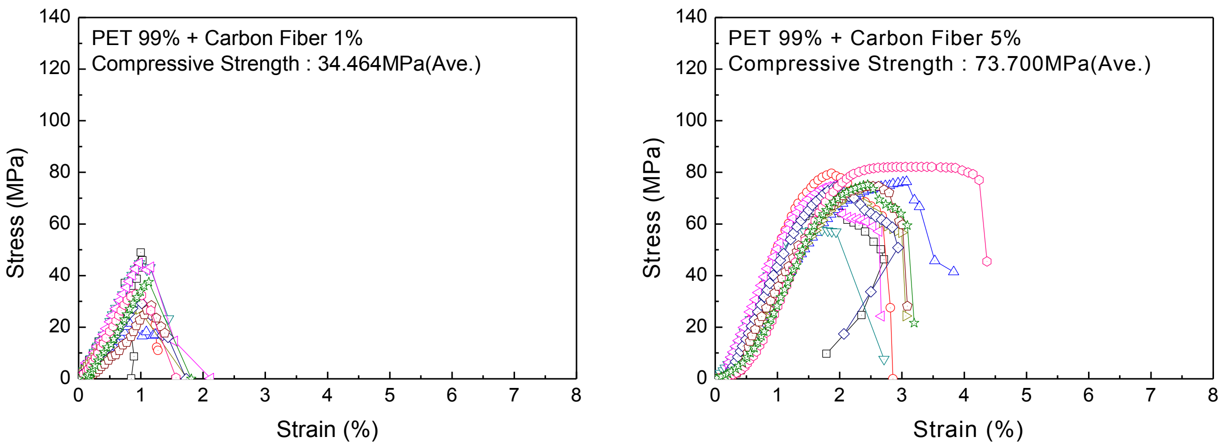


Figure 8. Unconfined test results for carbon fiber mixture

3.1.3 *Test results for glass fiber mixture*

Figure 9 showed unconfined test results for glass fiber mixture in which the mixing ratio of glass fiber changes from 10% to 30%. The test was performed 10 times for each of the same mixing ratio specimen. The compressive strength in the figure means the average of 10 test values. The average compressive strength increased from 78.4MPa to 84.9MPa according to mixing ratio of glass fiber. The test results are also showing that compressive strength of the glass fiber mixture do not increase in proportion to the increase in mixing ratio even though the mixing ratio increases threefold. The figures also showed that the brittleness decrease and the plasticity increase compared with PET itself. It could be founded that the plasticity increases due to the increase in the mixing ratio. Table 1 lists the intensity of strength increase according to the mixing ratio in each case.

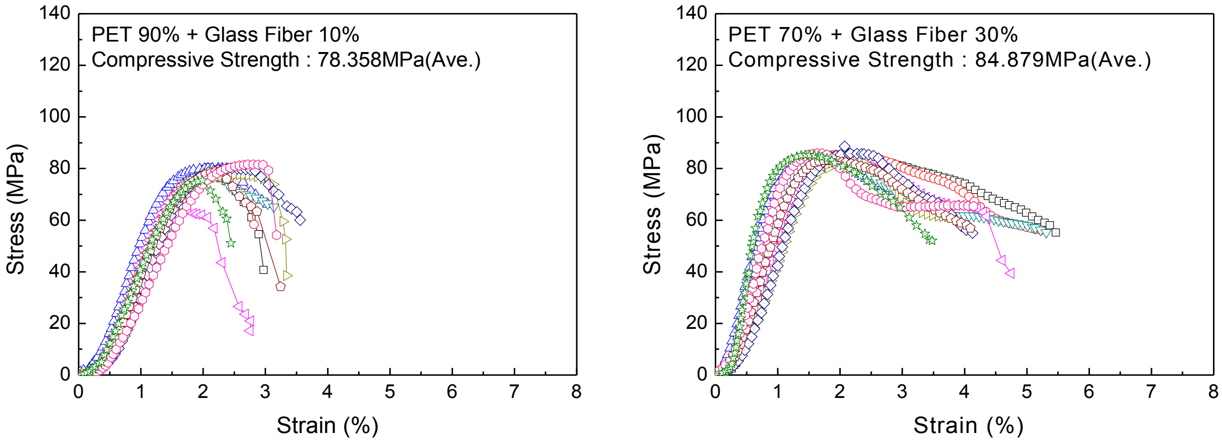


Figure 9. Unconfined test results for glass fiber mixture

Table 1. Unconfined compressive test results for various mixtures

Mixing material	Carbon fiber			Glass fiber		
Mixing ratio (%)	1	3	5	10	20	30
Average Compressive strength (MPa)	34.5	47.1	73.7	78.4	71.0	84.9

3.2 *The increase tendency of plastic energy and compressive strength of mixture*

Figure 10 shows increasing tendency of plastic energy of mixtures. It is showing that the brittleness which is great disadvantage of PET is reducing in proportion to the amount of mixing. This is likely to prove that recycled PET could be used as a construction material. Figure 11 shows increasing tendency of the unconfined strength of mixtures. This figure also shows that there is a remarkable increase in compressive strength in proportion to the amount of mixing.

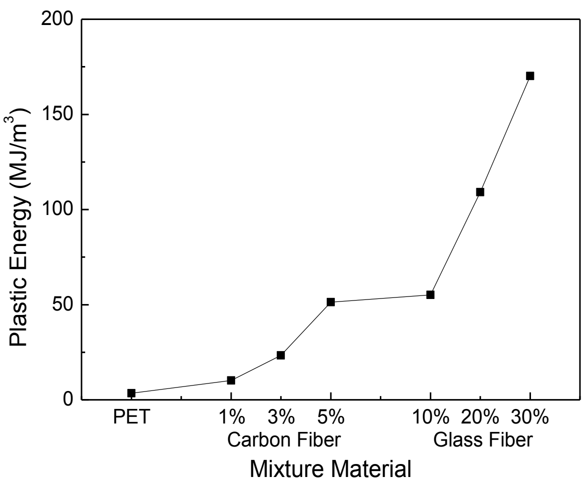


Figure 10. Plastic energy of mixtures

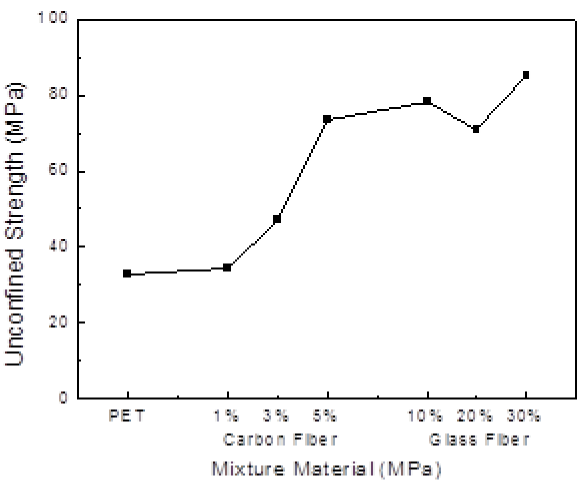


Figure 11. Unconfined strength of mixtures

4 CONCLUSION

The results obtained from the above series of experimental studies are as follows.

1) In terms of compressive strength and rigidity, recycled PET materials might be used as a concrete replacement material.

2) Due to the disadvantages of having a large brittleness, it is insufficient to use recycled PET itself as a construction material, if there are no supplementary measures.

3) When the PET is mixing with glass fiber or carbon fiber, the brittleness of it is greatly reduced, and then it is likely to be used as some construction materials, like to concrete piles.

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