Third International Conference on Sustainable Construction Materials and Technologies http://www.claisse.info/Proceedings.htm

A Study on Lightweight Multifunctional Concrete Made Using Waste PET bottles

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ABSTRACT

Polyethylene terephthalate containers (PET bottles) are recycled into fibers and sheets, but the complicated process requires a high level of technology and large cost resulting in a low recycling rate of PET. Weight reduction of concrete has been demanded for certain uses. In view of this, lightweight concrete embedding raw PET bottles is conceivable. It may be used for void slabs and lightweight wall panels for dwelling units. In this study, the basic physical properties of lightweight multifunctional concrete embedding used PET bottles were investigated. A method of placing concrete with embedded PET bottles was examined. The weight reduction of the reinforcing concrete panel embedding PET bottles was approximately 16%. The strength properties of concrete embedding PET bottles were examined and the compressive strength of the specimen embedding 6 bottles with the smallest intervals between bottles was 55% of that of the solid concrete specimen.

Keywords. PET bottle, recycle, concrete, void panel, wall

INTRODUCTION

Polyethylene terephthalate containers (PET bottles), which are widely used for containing drinking water and beverages, are recycled into fibers and sheets, but the complicated process requires a large cost. Recycling containers into containers also requires a high level of technology and large cost. For this reason, production from crude material, which costs less, is preferred, resulting in a low recycling rate of PET [1].

Weight reduction of concrete has been demanded for certain uses. It dates back to ancient times when jars called “amphora” were embedded in ancient concrete to reduce the weight of structures. In view of this, lightweight concrete embedding PET bottles is conceivable. It may be used for void slabs and lightweight wall panels for dwelling units. Such bottles filled with refrigerants, activated carbon, etc., can add a new function to concrete including temperature adjustment and VOC (volatile organic compounds) adsorption (Table 1). The uses of concrete aggregates manufactured from recycled waste PET bottles for concrete was reported [2], but there are few studies on the concrete embedding raw PET bottles.

In this study, the basic physical properties of lightweight multifunctional concrete embedding used PET bottles were investigated.

Table 1. Expected function of lightweight concrete containing PET bottles

Utilization of PET bottles	Expected function
Uses as void	Lightweight slab, Lightweight wall panel
	Soundproofing
	Adiabaticity
Filling with functional materials	Moisture control by moisture adsorbents
	VOC adsorption by activated carbon adsorbent
	Lowering an indoor temperature by a refrigerant
	Keeping an indoor temperature by a heat storage material

FABRICATING A PANEL SPECIMEN

Experiment overview. A concrete panel specimen embedding PET bottles was examined as to the spread of concrete to fill spaces during placing and the state of molded surfaces after demolding.

Materials and proportion of concrete. Tables 2 and 3 give the materials and mix proportion of concrete, respectively. The target slump and air content were 18 cm and 4.5%, respectively.

Table 2. Materials used for the experiment

Material	Type and physical properties
Cement	Ordinary portland cement : density3.16g/cm^3
Fine aggregate	Sand : density in saturated surface dried condition(2.49g/cm^3), density in oven dried condition(2.40g/cm^3), water absorption 4.12%
	Crushed sand : density in saturated surface dried condition(2.61g/cm3), density in oven dried condition(2.58g/cm3), water absorption 1.15%
Coarse aggregate	Tight crushed stone : density in saturated surface dried condition(2.63g/cm^3), density in oven dried condition(2.61g/cm^3), water absorption 0.75%
Chemical admixture	Air entraining and high-range water reducing agent: complex of lignosulfonic acid and polyol, density 1.0g/cm^3

Table 3. Mix proportion of concrete

Water-cement ratio (%)	Unit weight (kg/m^3)					Air entraining and water reducing agent (%)
	Water	Cement（C）	Sand	Crushed sand	Crushed stone	
60	180	300	231	563	994	C×0.25

Outline of specimen. The wall specimen fabricated in this study measured 650 by 900 by 150 mm. Forty-eight PET bottles were fixed to the mold as shown in Photo 1, and concrete was placed after arranging reinforcing bars to facilitate handling after demolding. Note that horizontal and vertical clearance between each bottle was 30 mm. The mold comprised a concrete panel having 48 holes with a diameter of 28 mm. Empty PET bottles with a capacity of 280 ml were washed with neutral detergent and fixed to the holes in the mold. Fig. 1 shows the method to fix a PET bottle for mold. PET bottle is fixed for a mold panel by tighten a cap of a PET bottle. 1. The method to fix a PET bottle for mold is shown in Fig. 1, a PET bottle is fixed for a mold panel by tighten a cap of a PET bottle. 1. Concrete proportioned with a water-cement ratio of 60% was then placed in the mold. Fig. 2 and Photo 2 show the outline and appearance of the specimen, respectively.

Photo 1. PET bottles fixed in the mold

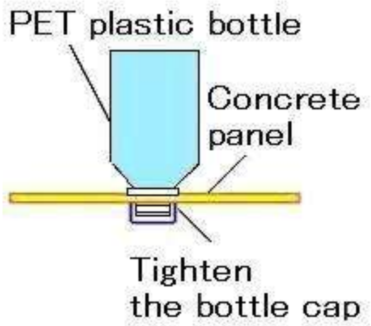

Figure 1. Method to fix the PET bottle to the mold

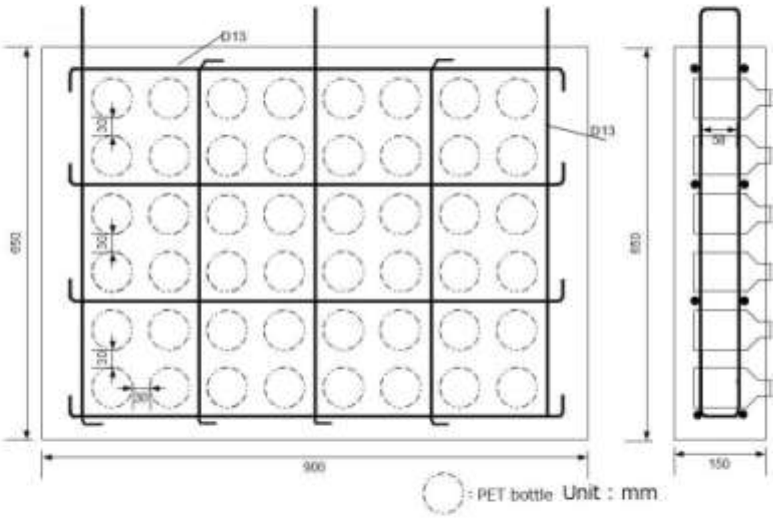

Figure 2. Outline of concrete panel specimen

Photo 2. Concrete panel specimen embedding PET bottles

Test results. PET bottles fixed to the mold at their caps withstood the impact of tamping with a rod and tapping on the mold with a mallet during concrete placing, as well as the pressure of concrete flowing in the mold, with no deformation, dislocation, or bending. Also, concrete was found to fill all spaces between bottles and between bottles and reinforcement. After demolding, the molded surfaces of the specimen were found smooth and uniform with no placement-related defects, demonstrating the filling capability of concrete around the caps as shown in Photo 4. The weight of the specimen was 169 kg, achieving a reduction of approximately 16% when compared with 202 kg, the weight of a concrete wall of the same size with no embedded bottles.

COMPRESSION TESTING

Experiment overview. Compression tests were conducted on block-shaped specimens embedding different numbers of PET bottles.

Materials and proportioning of concrete. The same materials of concrete as those stated in the concrete panel specimen were similarly proportioned with a target slump and air content of 18 cm and 4.5%, respectively. The nominal strength was 33 N/mm^2. Table 4 gives the fresh properties and strength of concrete.

Table 4. Properties of concrete

Slump (cm)	Air content (%)	Temperature of mixed concrete (°C)	Compressive strength (N/mm^2)
18	4.7	22.1	34.1

Outline of specimens and test procedure. Six block-shaped specimens measuring 150 by 300 by 200 mm were fabricated with different arrangements, intervals, and numbers of embedded PET bottles as shown in Fig. 3. A pan-type mixer with a capacity of 50 liters was used for mixing concrete. Specimens were demolded one day after placing and water-cured until an age of 4 weeks. After measuring the weight, width, depth, and length of each specimen, loads were applied to each specimen to failure using a hydraulic universal testing machine to determine the compressive strength. Note that the loading rate was adjusted to attain a compressive stress gain of 0.6 ± 0.4 N/mm^2 per second.

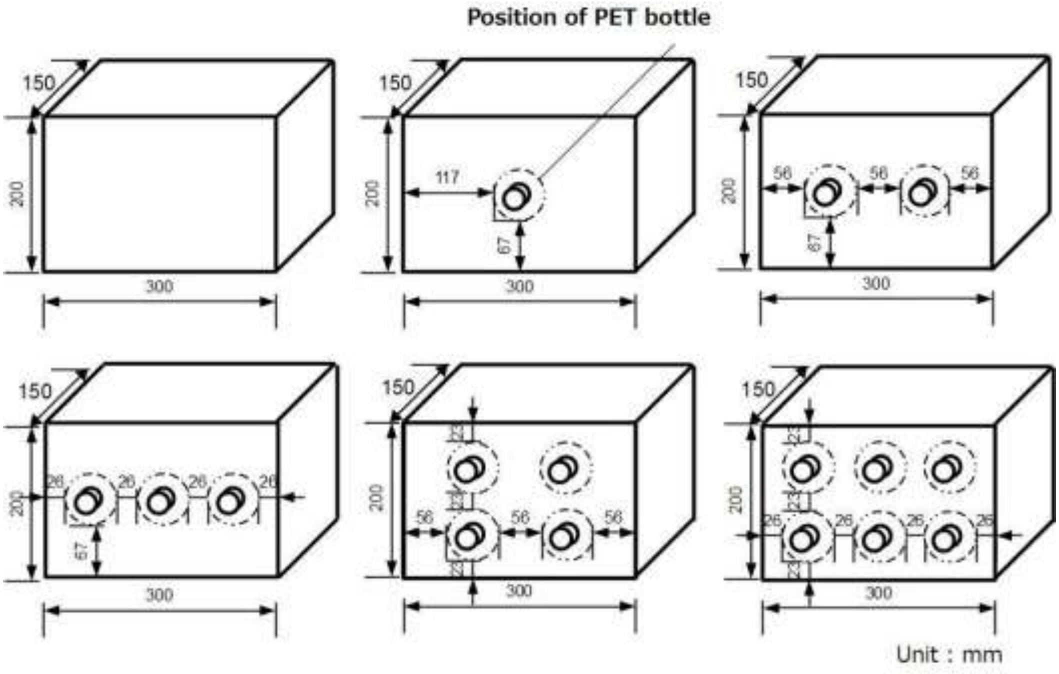

Figure 3. Outline of specimen subjected to compression test

Results and discussion. Fig. 4 shows the weight of each specimen. This figure reveals that the weight of a specimen decrease as the number of embedded PET bottles increases. The weight of the specimen embedding 6 bottles with the smallest intervals between bottles was almost 75% of that of the solid concrete specimen. The density of the specimen embedding 6 bottles was almost 1.8 as equal as the ordinal light-weight concrete.

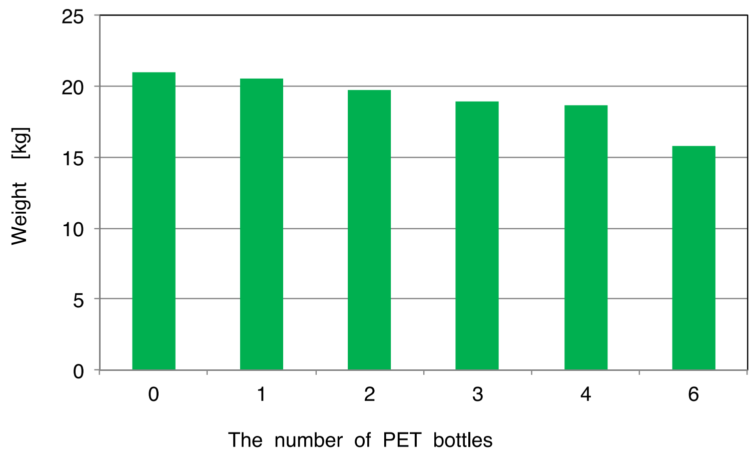

Figure 4. Weight of specimen and the number of PET bottles

Fig. 5 shows the compressive strength of each specimen. This figure reveals that the compressive strength of concrete decrease as the number of embedded PET bottles increases. It was also found that the strength of the specimen embedding 6 bottles with the smallest intervals between bottles was not less than 18 N/mm^2, being 55% of that of the solid concrete specimen.

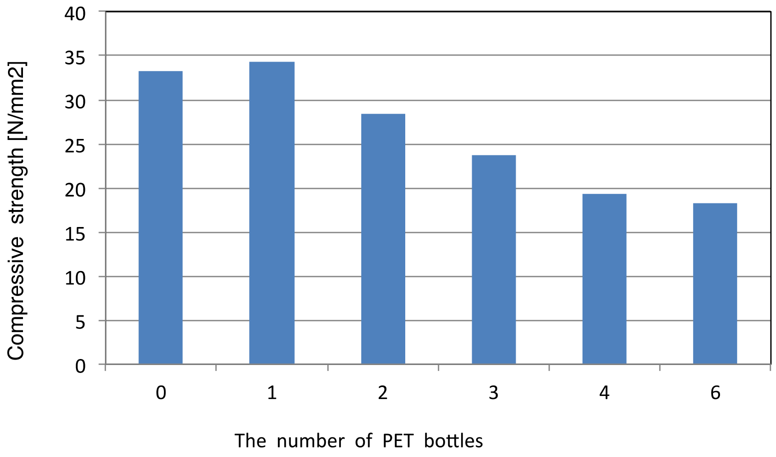

Figure 5. Compressive strength of specimen and the number of PET bottles

Fig. 6 shows the FEM analysis result of a compression test of a specimen including 6 PET bottles. We assumed the space of the PET bottles were the perfect voids and no stress transmission. The strain is indicated by the contour of different colors. This figure reveals that the strain caused by compression is localized between the four PET bottles so it will be better to strengthening these areas by the reinforcement such as a fiber.

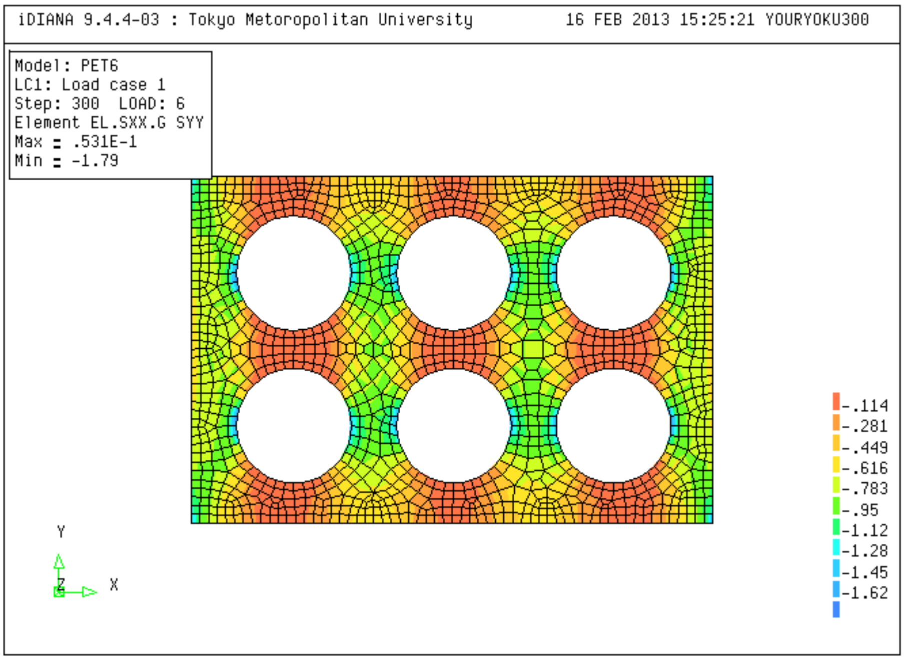

Figure 6. Analysis result of 6 bottles specimen subjected to a compression test

SUMMARY

(1) A method of placing concrete with embedded PET bottles was examined. PET bottles fixed to the mold at their caps withstood the impact and the pressure during concrete placing with no deformation and the filling capability of concrete was confirmed.

(2) The weight reduction of the reinforcing concrete panel embedding PET bottles was approximately 16%. The density of the specimen embedding PET bottles was almost 1.8 as equal as the ordinal light-weight concrete.

(3) The compressive strength of the specimen embedding PET bottles with the smallest intervals between bottles was 55% of that of the solid concrete specimen

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