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Lightweight interlocking blocks using expanded polystyrene foam as partial replacement to coarse aggregates

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ABSTRACT

This paper presents the properties of the developed interlocking blocks utilizing recycled expanded polystyrene (EPS) foam as partial substitute to coarse aggregates. This properties of the blocks. Further, a multi criteria decision model was employed in order study aimed to provide solution to waste problems and increasing cost of construction materials. The coarse aggregates were substituted by pulverized EPS by 10%, 15%, and 20% by volume. For comparison, a control specimen was prepared. Laboratory tests were carried out including density, slump, and compressive strength to evaluate the physical and mechanical to determine which alternative is better between a conventional concrete hollow block (CHB) and the proposed interlocking block in terms of its physical and mechanical properties, material cost, and time of construction. Results showed that the 15% EPS substitution is the optimum proportion with density of 1855 kg/m^3 and compressive strength of 14.03 MPa. Finally, parameters comparison between the conventional and proposed block indicated that the proposed block is a better alternative especially in terms of material cost and time of construction.

1. INTRODUCTION

One of the solid wastes produced worldwide is the Styrofoam or the Expanded Polystyrene (EPS). These materials are highly popular plastic packaging material which finds wide application in packaging of goods and in the construction industry due to its excellent insulating and protective properties. Polystyrene is a thermostatic polymeric material that is in unexpanded form (UEPS), in usual. This material can be expanded to ideal volume by heating in wet condition. EPS has low specific weight, therefore with changes in its amount in concrete mix design, different kinds of lightweight concretes with different specific weight and different mechanical properties are made, for use in structural or nonstructural aims (June, Politecnica, Momtazi, Langrudi, & Khodaparast, 2010). The problem is that these materials are often left to waste as its importance in the packaging industry is finished. This gives the problem of disposing these kinds of

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waste and utilizing it to be used in other processes can solve this problem. The utilization of industrial waste like EPS as a construction material is a big leap towards sustainable development (Nadesan & Dinakar, 2017). EPS wastes are recovered and electrospun into commercial textiles as filtration mats (Shin, 2005), used as mortars (Ferrándiz-Mas & García-Alcocel, 2013), as mosquito control (Curtis & Minjas, 1985), and others. These methods and researches give us the means to utilize waste and turn it into something that is workable and at the same time, environment-friendly.

With this dilemma, the researcher developed a way to reduce the cost of constructing a low rise residential house through the introduction of lightweight concrete interlocking blocks utilizing expanded polystyrene foam as substitute to coarse aggregates. The expanded polystyrene that was utilized in the study was recycled polystyrene in order to solve the problem of the world in waste reduction. These waste EPS is evident in the vicinity of the company, thus giving the company and local government benefit for the utilization of the material. Also, in order to determine the optimum choice between the proposed block and the standard hollow blocks currently in use of the company, a multi criteria decision matrix was used by the researcher in order to give the company the most feasible material that they can use in their projects taking into consideration all of the parameters of the construction materials. Multi criteria decision model has been utilized in the construction industry to select the best alternatives taking into consideration the qualitative ranking of construction materials to be selected (Temiz & Calis, 2017). With the developed criteria, paired with the quantitative comparison of the parametric and non-parametric differences of commercial hollow blocks currently used by the company with the proposed concrete block, the study gave the company a solid basis on the feasibility of the proposed block.

2. METHODS

The study performed an experimental research. Percentage of the expanded polystyrene foam as aggregates will be varied to determine the optimum composition of the lightweight interlocking concrete blocks. Also, the study employed a multi criteria decision model in order to assess the optimum option between the standard hollow blocks and the proposed interlocking blocks for the company to utilize.

Fig. 1 shows the proposed modification of the interlocking blocks to be utilized by the company in their construction. The block is proposed to be a non-load bearing block to be utilized on interior walls of a house construction. The design of the proposed interlocking block is based from the minimum size of a concrete hollow blocks that is 400 mm long, 200 mm high and 100 mm thick. Some modifications were done in order to increase the workability of using the blocks.

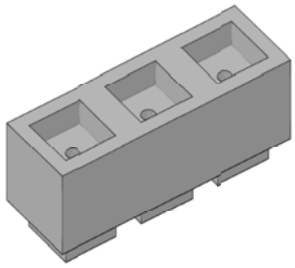

Fig. 1. 3-Dimensional view of the block

The materials to be utilized in the research are cement, aggregates, expanded polystyrene foam, and water. The cement and aggregates will be bought from a local construction materials provider that will be recommended by the company. The EPS wastes that were utilized were gathered from a company in the vicinity of the company in Cavite.

Table 1 *Concrete mix volume for one test specimen*

Specimen	Total (m^3)	Cement (m^3)	Sand (m^3)	Gravel (m^3)	EPS foam (m^3)
0%	0.01320	0.0033	0.00660	0.01320	0.00000
5%				0.01254	0.00066
10%				0.01188	0.00132
15%				0.01122	0.00198
20%				0.01056	0.00264

Table 1 shows the volume of one test specimen interlocking block used in the study. The percent substitution of EPS foam to coarse aggregate is also shown in the table. The total volume of one interlocking block is 0.01320 cubic meter.

Materials should be prepared in accordance with the ASTM Standards. Aggregate must meet the requirements of ASTM C 331 (ASTM_C331-04, 2002) with bulk density less than 70 lb/ft3 (1120 kg/m3) for fine aggregate. This includes aggregates prepared by expanding, pelletizing, or sintering products; aggregates prepared by processing natural materials; and aggregates derived from and products of coal or coke combustion.

4. RESULTS

Fig. 2.a Underside of the prototype

Fig. 2.b Side view of the prototype

Fig. 2.c Top view of the prototype

Fig. 3 Perspective of the prototype

Fig. 2.a-c and Fig. 3 show the constructed prototype of the proposed interlocking block for the company. Each percentage substitution was considered in the fabrication of the prototype specimens.

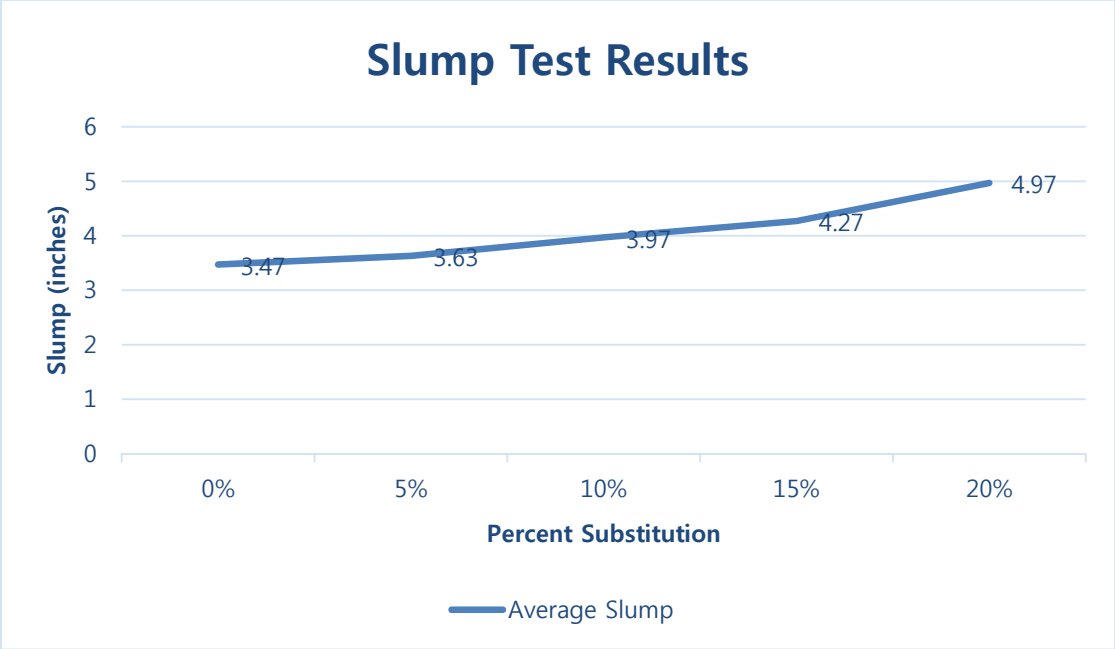

Fig. 4 Slump test Results

Fig. 4 shows that the average slump of each of the mixtures during testing is in good working condition and passed the standards which was 3 to 5 inches of slump. The maximum slump that was gathered was 4.97 inches for 20% EPS foam substitution that shows high workability for the concrete mix during fabrication and experimentation.

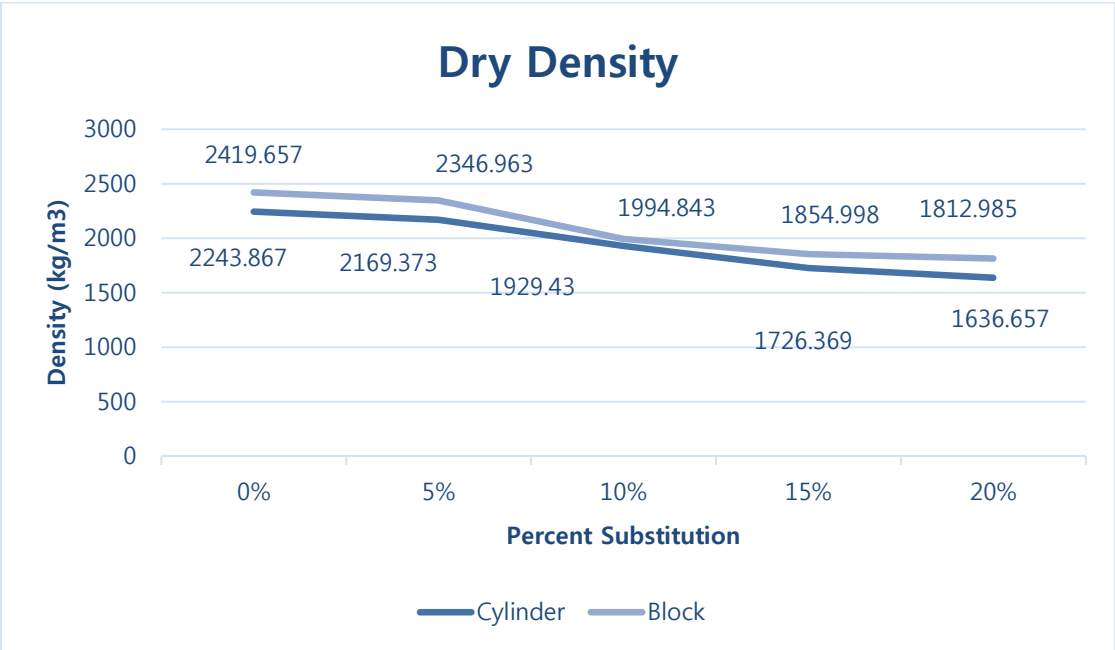

Fig. 5 Dry Density of specimens

Fig. 5 shows that the mixture for 15% and 20% substitution can be considered lightweight while 0%, 5% and 10% substitution is found out to still be normal weight (ASTM_C331-04, 2002). The results showed that the more percentage of EPS that is substituted to the aggregates, the less weight the concrete mixture becomes which can conclude that the percent substitution has an inverse proportionality with the dry density of the mixtures. Also, Fig. 5 shows that the cylindrical and block specimens follow a downward slope and that the block specimens has a higher density than that of the cylindrical specimens.

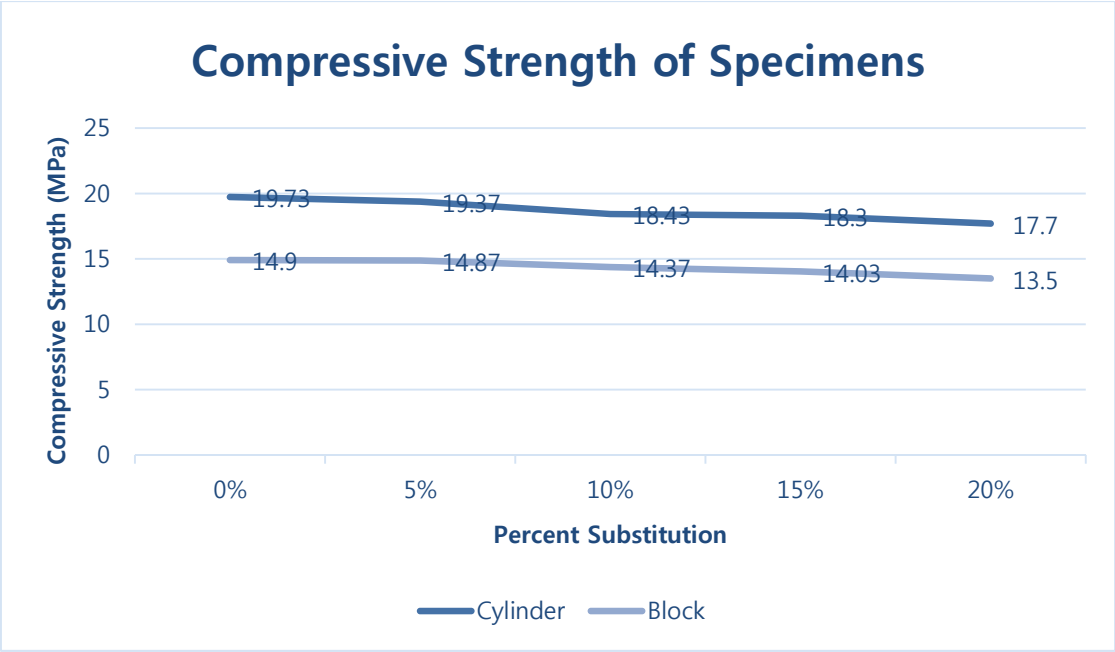

Fig. 6 Compressive Strength of Specimens

Fig. 6 shows that there is a trending downward slope in the compressive strength of the concrete mixtures as the substitution of EPS foam goes up in percentage which can conclude that there is an inverse proportionality between the percent substitution and the compressive strength. From a 19.73 MPa strength for the control specimens to 17.70 MPa strength for 20% EPS foam substitution. With this, it can be said that the higher the percentage of EPS foam that is substituted to aggregates, the lower the strength of the concrete mixture becomes (Abd et al., 2016; Setiawan et al., 2013). Also, as the figure suggests, it can be concluded that the lowering of compressive strength accounts for the increase in the porosity of the concrete mix with the addition of the EPS. The strength difference between the cylindrical specimens and the block specimens was also evident because of the configuration of the proposed block that has holes through its entire height. Studies regarding the strength of the specimen with regard to the volume of the specimen suggests that more solid specimens give the higher strength than that of irregularly shaped specimens (Jasim & Zain, 2016; Kaya & Kar, 2016; Mandlik, Sood, Karade, & Naik, 2015).

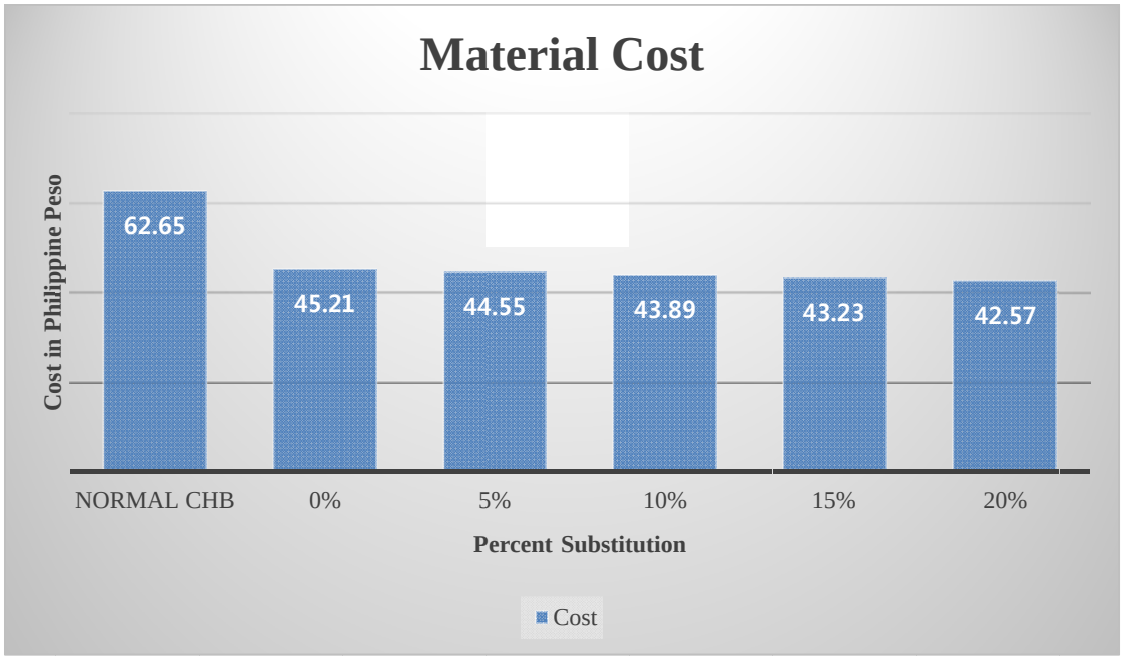

Fig. 7 Material Cost Comparison

Fig. 7 shows the material cost of producing one block of specimen versus that of the conventional method of CHB laying. One block for conventional CHB costs Php 73.65 which includes mortar and plastering while for 20% EPS substitution specimen, one block costs Php 42.57 with a difference of Php 31.08. With this, it can be said that the proposed block will not only help in the fight for the control of pollution, but also give more profit for the company with the introduction of mortar-less interlocking blocks.

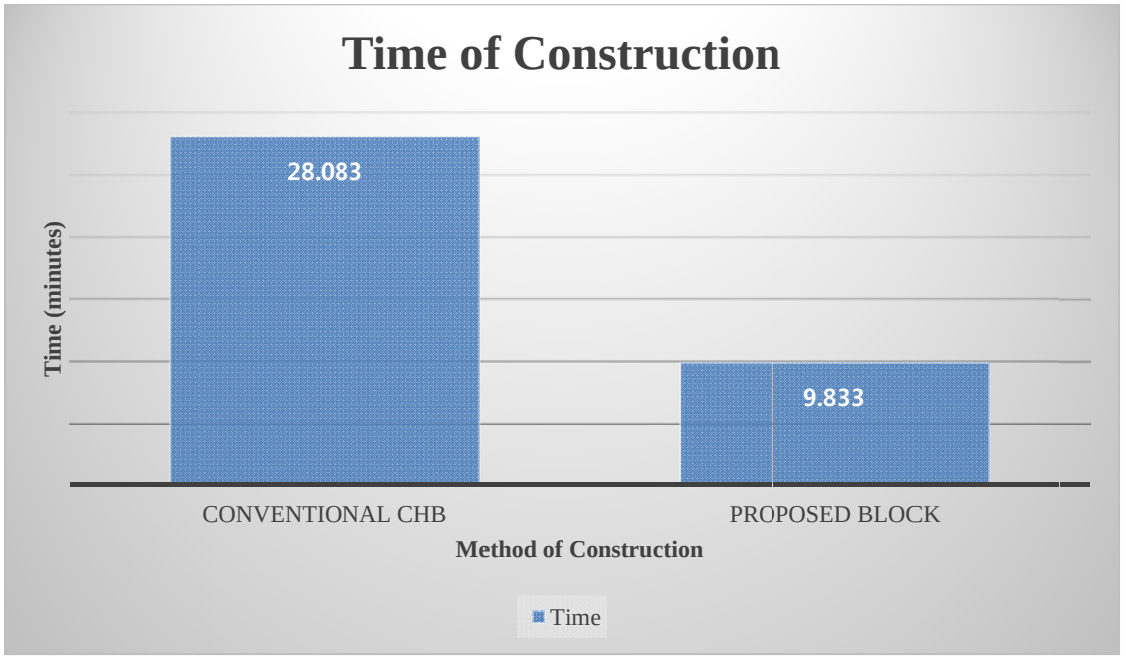

Fig. 8 Time of constructing a 1.6 x 1.4 m wall

Fig. 8 shows that there is a big difference when it comes to time of construction between the two methods. The proposed block ended after 9 minutes 50 seconds while the conventional method ended at 28 minutes 5 seconds. There is a 185.60% decrease in time between the two methods. This time reduction can help ease the work for the company and make them utilize the saved time for other works for the early completion of a project.

3. CONCLUSIONS

This industry project studied the feasibility of utilizing EPS wastes in construction as an aggregate substitution. With this, various parameters were set in order to assess the viability of the proposed product in conjunction with the standards set by ASTM. The parameters that were considered in the study are: Air dry density of concrete (ASTM_C331-04, 2002), concrete slump (ASTM, 2014), compressive strength (Abd, Gh., & Hattem, 2016; Setiawan, Hidayat, Bintaro, Jaya, & Tangerang, 2013; The, States, Inter-, & Astm, n.d.), cost of materials, and time of construction. These parameters were tested using different methods as presented in the results section of the study. The study also utilized a multi criteria decision model in order to determine the rank of each parameters in terms of their importance by consulting to experts in the field of construction materials.

The proposed concrete interlocking blocks were designed in order to help the company in building low cost housing units. With the results that the proposed block has a lower price than that of the conventional CHB, it can be concluded that the proposed interlocking block is a better alternative for low cost housing.

The physico-mechanical characteristics of the block were also tested in order to determine its viability in the construction industry. The proposed block passed the standards on concrete slump, dry density for lightweight concrete, and compressive strength thus solidifying the claim that the proposed block can be used by the company in their projects.

Taking into consideration all of the parameters and their ranks and using the multi criteria decision model that was used by the researcher, it can be concluded that the proposed blocks can be a good alternative for the company to be used in their future projects for low cost housing. Also, the 15% EPS foam substitution concrete mixture can be considered the best mixture as it passed the standards for light weight concrete in terms of density and has a higher compressive strength than that of the 20% substitution. The 15% substitution has an average cost of Php 43.23 per block compared to Php 62.65 per block of conventional hollow blocks.

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