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Research paper



Effect of Pressure on Expanded Polystyrene (EPS) Dry Mix Mortar Block

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Abstract

Nowadays, there is more demand than supply on the uses of material in the construction. Thus, the need to use alternative materials should be widely used and practiced among the construction and development to pro-longed the material for future generation supply. The objective of this study is to investigate the effect of different pressure exerted between 700 kPa, 900 kPa and 1100 kPa to the replacement of Expanded Polystyrene (EPS) at 20 %, 25 %, 30 %, 35 % and 40 % of sand replacement in achieving target strength of 5 N/mm² to 7 N/mm² of EPS dry mix mortar block. The tests were conducted at 7 and 28 days of curing with various replacements of EPS in the dry mix Besides, the study is also to identify the density of EPS Dry Mix Mortar Block due to pressure exerted (700 kPa, 900 kPa and 1100 kPa) as a lightweight block. From the result that obtained, it was found that the most suitable pressure to be exerted is 700 kPa since it was the less required pressure needed to achieve the target strength of 5-7 N/mm² at 20 % of EPS replacement which is 5.74 N/mm². Besides, it was shown that the increase of pressure exerted to the EPS dry mix mortar block also will increased its density thus resulted in higher compressive strength.

1. Introduction

Normally, construction of building is made from concrete as main components. Concrete is a mixture of materials like sand, gravel, and small rocks combined with any type of cement and water. The mixture is then allowed to dry and harden. Basically, concrete is the stone-like structure formed after cement and other materials are mixed together. However, beside widely used all over the world for building construction, concrete also has some disadvantages. Concrete is very heavy, rigid, and its thermal and acoustical qualities are not very high (Mindess and Young, 1981). Therefore, due to innovation in modern building design, a mortar application was later introduced to be used as the replacement for wall and bricks. A mortar is a cement, fine sand and water that mix together to form lightweight concrete.

Dry mix mortar main ingredient consists of cement, sand and additive. Dry mix mortar blocks are lightweight, strong and can be produce for mass production in term of large panel of block. Expanded Polystyrene (EPS) is waste material that is suitable to be incorporated in the mortar mix to form dry mortar. EPS possess suitable properties such as low density, thermal insulation, hydrophobicity and chemical resistance when exposed to acids and alkalis. Besides, EPS is granulated into small particles that can be considered as non-absorbent and lightweight polymeric aggregate (Ferrandiz-Mas and García-Alcocel, 2013). Thus, in this study, EPS has been used to replace the sand proportion in the dry mix mortar due to extensive use and consumption of sand for mortar and concrete application in construction industries can lead to the reduction in amount of sand on the earth.

2. Literature Review

There are many efforts been carried out by researchers to utilize waste and reuse as replacement to the materials in mortar application such as cement and sand. For examples, there are many waste materials that been incorporated in producing construction materials such as plastic (Neville, 2002), rice husk and paper sludge ash (Ferrándiz-Mas and García-Alcocel, 2013) and many more. According to Noguchi et al. (1998), there were three (3) alternative ways on how to manage the EPS waste. First, the EPS waste can be managed by recycling method in which the volume of EPS is deducted either by friction, solvent or heating. Secondly, by chemical recycling of EPS waste by retreating process of the biological characteristic of polystyrene to be reutilize as the chemical resources. Besides, EPS waste that had been contaminated can be used for energy production by thermal recycling through combustion method. However, all of these options had contributed to the presence of contaminants and reduce the quality of recycle EPS.

In daily use, EPS been recycled and used for fish boxes, packaging for electrical consumer goods and for insulations panels for building (Ferraris et al., 2000) While in construction industries, The Plastic Portal (2014) reported that the major usage of EPS as for building panels and other construction parts. Kathirvale et al. (2004) stated that the major usage of EPS is for insulation foam for walls, roof and floor insulation and also as sound proof elements in bridge, road construction, retaining walls and also base-

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ment. There were not many studies that have been done in term of pressure applied to the dry mix mortar especially focusing on its effect to the replacement of material and compressive strength of the mortar itself. However, there is a study conducted on effect of pressure after casting on high strength fibre reinforced mortar but this study only focuses on the effects on the flexural response of high strength fibre reinforced mortar and together with its toughness by using Universal Testing Machine. According to Short and Kinniburgh (1978), the application of short term (about 15 minutes) pressure of up to 1,300 psi (9 MPa) to a freshly cast fibre reinforced mortar leads to a slight increase in the proportional limit and elastic modulus of the resulting composite. However, it may also lead to a decrease in its modulus of rupture and its toughness.

3. Methods and Material

The materials used in this study were: Ordinary Portland cement conforming to BS 12:1978, grading test by sieve analysis showed the mining sand with complying to BS 933-1:2012 with fineness modulus of 0.15 mm. The density of cement and sand obtained that has been tested using gas pycnometer method was 3,101 kg/m3 and 2,654 kg/m3 respectively. While density of EPS powder tested by using bulk density test was 18 kg/m3.

3.1. Preparation of Specimens

In this study, the basic mix proportion of dry mix mortar with EPS powder replacement was cement: sand with ratio of 1:2.5. The content of EPS applied in this study were with the replacement proportion of 20%, 25%, 30%, 35 % and 40 % to the sand volume. The EPS powder ratio was calculated as the ratio of the mass of the total dry mix content to the mass of the sand in the in the dry mix content.

Mixing of cement, sand and water to form control mix. Then, addition of EPS as a sand replacement at 20 %, 25 %, 30 %, 35 %, and 40 %. The ratio of the cement in the mix remains the same in all mix while the ratio of the sand will be differing as the increasing of EPS powder ratio replacement in the mix. The procedure was repeated until 40 % of EPS powder replacement. Mix were cast into cubes 100x100x100 mm and placed under hydraulic press machine for designated pressure of 700 kPa, 900 kPa and 1,100 kPa. The specimens were demoulded approximately 24 h after casting and then subjected to 7 and 28 days of curing.

3.2. Compressive Strength Test

The specimens were tested for compressive strength according to BS EN 12390-3:2000. The pace or loading rates of compressive strength test was 3 kN/s.

3.3. Section Headings

No more than 3 levels of headings should be used. Other headings must be in 9pt font. Only the first word in a heading must be capitalized and other word should be in small case.

3.4.1. Figure Captions

Figures must be numbered using Arabic numerals. Figure captions must be in 8 pt Regular font. Captions of a single line (e.g. Figure 2) must be centered whereas multi-line captions must be justified (e.g. Figure 1). Captions with figure numbers must be placed after their associated figures, as shown in Figure 1.

4. Results and Findings

There were two findings that has been obtained in this study which are compressive strength and the relationship between pressures exerted and density of EPS Dry Mix Mortar Block.

4.1 Compressive Strength at 7 and 28 Days of Curing

The compressive strength test result for control (EPS 0 %), dry mix mortar with EPS powder replacement (20 %, 25 %, 30 %, 35 % and 40 %) at 7 and 28 days were shown as shown in Figure 1. The trend of data is similar for 7 and 28 days. Therefore, the graph plotted only for compressive strength at 28 days as theory of concrete design stated that the concrete will gained its strength rapidly until 28 days after casting. From Figure 2, it can be seen that the increased in amount of EPS replacement resulted in increased of compressive strength. For example, the compressive strength of control mix is the lowest compared to mix design with EPS replacement of 20 %, 25 %, 30 %, 35 % and 40 %. The target strength of 5-7 N/mm² for mix with applied pressure of 700 kPa and 900 kPa achieved at mix with minimum EPS replacement of 20% which the result is 5.74 N/mm² and 5.947N/mm² respectively. However, for mix applied with 1,100 kPa, the target strength already achieved at control mix which is 7.53 N/mm² and mix with 20 % of EPS replacement surpass target strength which is 12.83 N/mm. This result indicates that the pressure applied to the mix also play a greater role in affecting the compressive strength of the mix.

Figure 4 shows the compressive strength for design mix with applied pressure of 700 kPa and 900 kPa at 7 and 28 days of curing. The exclusion of mix with applied pressure of 1100kPa is because the target strength already achieved at control mix which is 5.27 N/mm² at 7 days and 7.53 N/mm² at 28 days. In term of relation between pressure applied to the mix and percentage of EPS replacement, the more pressure applied resulted in higher compressive strength obtained for those mix with higher percentage of EPS replacement. For example, the compressive strength for mix with 20 % of EPS replacement with applied pressure of 900 kPa was 5.947 N/mm² and were higher than mix with 20 % of EPS replacement with applied pressure of 700 kPa valued at 5.74 for both 7 and 28 days. This may due to the composition of the mix in the mould being well compacted when pressed with higher pressure resulted in improve bonding between cement, sand and EPS thus increased in compressive strength. From the result that obtained, it was found that the most suitable pressure to be exerted is 700 kPa since it was the less required pressure needed to achieve the target strength of 5-7 N/mm² at 20 % of EPS replacement which is 5.74 N/mm².

EPS Replacement (%)	Compressive Strength (N/mm²)					
	700kPa		900kPa		1100kPa	
	7d	28d	7d	28d	7d	28d
$EPS_{0\%}$	2.695	4.36	4.212	4.545	5.27	7.53
$EPS_{20\%}$	4.165	5.74	4.725	5.947	7.44	12.83
$EPS_{25\%}$	5.91	8.075	6.194	9.338	12.68	17.15
$EPS_{30\%}$	7.15	9.23	7.519	10.775	21.09	28.75
$EPS_{35\%}$	7.435	9.515	7.835	11.580	19.00	25.74
$EPS_{40\%}$	8.77	10.34	9.480	12.770	13.57	21.09

Figure 1: Compressive Strength and EPS Replacement Percentage with different pressures exerted at 7 and 28 days of curing

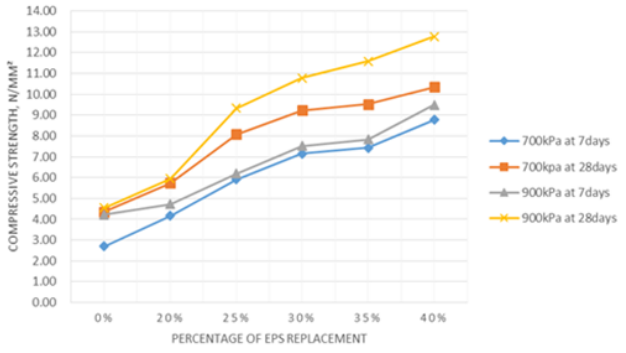


Figure 2: The graph of compressive strength of dry mix mortar tested at 28 days

4.2 Relationship between Pressures Exerted and Density of EPS Dry Mix Mortar Block

Figure 3 showed the pressures, EPS replacement percentage, density and compressive strength of dry mix mortar taken at 28 days of curing. Figure 5 shows the relationship between density and the pressure exerted for each design mix at 28 days. The blue line indicates mix design with pressure of 700 kPa, while orange and grey indicate for mix design with pressure of 900 kPa and 1100 kPa respectively. It was shown that the increase of pressure exerted to the EPS dry mix mortar will increased the density. As the pressure applied on a material increases, the material density increases as the atoms or molecules of the material are pushed more closely together. However, EPS dry mix mortar with exerted pressure of 700 kPa is the lowest density and suitable since the purpose is to produce lightweight block because the higher density will result in higher weight thus will not contribute in forming a lightweight EPS dry mix mortar block.

EPS Replacement (%)	700kPa		900kPa		1100k	
	Density (kg/m³)	Comp. Strength	Density (kg/m³)	Comp. Strength	Density (kg/m³)	Comp. Strength
$EPS_{0\%}$	1570	4.36	1656	4.545	1650	7.53
$EPS_{20\%}$	1595	5.74	1624	5.947	1910	12.83
$EPS_{25\%}$	1675	8.075	1703	9.338	1950	17.15
$EPS_{30\%}$	1694	9.23	1792	10.775	2070	28.75
$EPS_{35\%}$	1728	9.515	1839	11.580	1940	25.74
$EPS_{40\%}$	1784	10.34	1846	12.770	1990	21.09

Figure 3: The pressures, EPS replacement percentage, density and compressive strength of dry mix mortar taken at 28 days of curing.

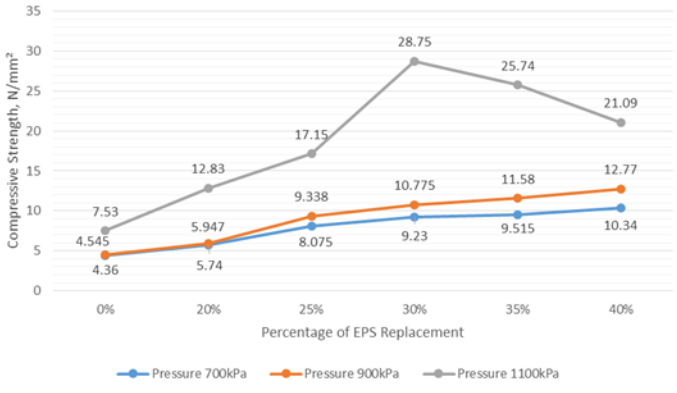


Figure 4: The graph of compressive strength tested at 28 days

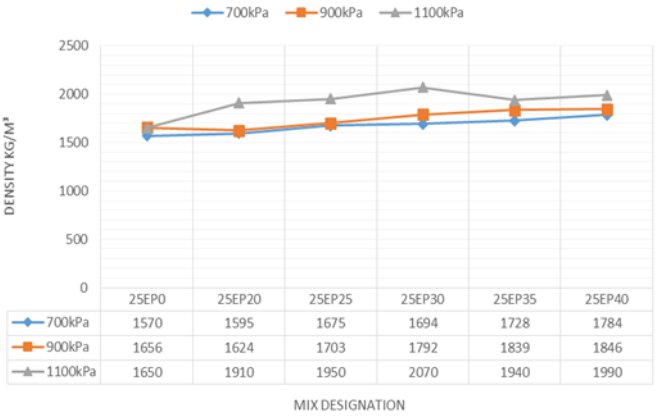


Figure 5: Relationship between pressures exerted and density and EPS Dry Mix Mortar Block

5 Conclusion

From the results of the test that have been conducted, it can be concluded that: The increase amount of EPS replacement will increase the compressive strength of EPS dry mix mortar. Target strength of 5-7 N/mm² for mix with applied pressure of 700 kPa and 900 kPa achieved at mix with minimum EPS replacement of 20 % which the result is 5.74 N/mm² and 5.947N/mm² respectively. The suitable pressure exerted to achieve target strength of 5-7 N/mm² is 700 kPa since it was the less required pressure needed compared to 900 kPa and 1,100 kPa. Therefore, less pressure required, save time and cost when it comes to production of mortar block. The increase of pressure exerted to the EPS dry mix mortar will increased the density. Therefore, EPS dry mix mortar with exerted pressure of 700 kPa is the lowest density and most lightweight thus suitable for lightweight mortar block.

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