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# The Strength of Mortar Mixed with Polystyrene Beads

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**Abstract** : The use of polystyrene beads as a lightweight aggregate in cement mortars is the subject of this research. This is because fully mortar has issues such as being heavy, leaking, and mossy due to high water absorption. The purpose of this research is to look at the qualities of the proposed good water absorption and high strength lightweight concrete mix. The replacement of construction material for mortar roof tiles have been conducted with replacement of 0% as control sample, 5%, 10% and 15% as new sample with polystyrene beads. Concrete slump test, cube preparation, curing process and compressive strength test were performed. The material that was used to complete this research is cement mortar, fine aggregates and polystyrene beads. The outcomes were compared on the amount of material mixture and testing day. Polystyrene beads is strongly suggested for future research as a micture with mortar concrete.

**Keywords**: Polystyrene Beads, Mortar, Fine Aggregates, Water Absorption, Compressive Strength

## 1. Introduction

Concrete is hardening construction material made of cement, fine aggregates (sand), and coarse aggregates combined with water [1]. Amount of water used in the concrete mix is normally determined by the cement water ratio which is commonly 0.4 to 0.6 according to IS 10262 (2009). A proper mortar mix is required to obtain a suitable mix for masonry construction works. Masonry work is the laying of bricks to form an external wall, a partition, or an internal wall in a house, as well as retaining walls and boundary walls.

As the world's development activities increase, the demand for construction materials increases at an exponential rate. This tendency will undoubtedly have a greater impact on any country's economic system. Due to its comparatively high cost and other limitations, construction materials are quite limited

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in availability currently. The goal of this study was to develop a novel blended ingredient for construction materials that would improve the properties of the materials.

The purpose of this research is to look at the qualities of the proposed good water absorption and high strength lightweight concrete mix. In addition, lightweight aggregate concrete is more durable than typical concrete [2]. Compressive strength and permeability were among the properties tested for durability while keeping high workability. In addition, the resistance of the concrete mix against chemical attack have been investigated in this research. After that, this investigation also covers water absorption testing and detecting compressive strength to determine the percentage of water absorption and the compressive strength for the new mixed concrete. The size of polystyrene beads used are from 1 mm to 5 mm as a partial replacement of aggregate.

Rooftiles with fully mortar concrete face problem in terms of quality of compressive strength and water absorption. The compressive strength is used to determine the strength of concrete.. The test that has been perform for the compressive strength test is cube test. By doing these tests, we can investigate either the new mixed roof tiles provided adjustment in compressive strength and water absorption better than the roof tiles with fully mortar or not. Introducing the new materials in the roof tiles will indirectly provide advantages in waste material. Most of the waste materials added as fine aggregates in concrete have increased the amount of water absorption. Research on the partial replacement of fine aggregates replaced with waste materials is needed more extensively to provide more confidence about their use in concrete mortars, especially on roof tiles [3]. In other hand, polystyrene beads have a good percentage of water absorption due to the material that we used before which has low water absorption. It can be extended work in the future with a variation of percentage of the mixture in order to produce maximum strength [4].

## 2. Materials and Methods

The materials and methods, otherwise known as methodology were described in next sub-section.

### 2.1 Materials Preparation

Raw materials come in a variety of shapes and sizes and are used in a wide range of products. The raw material is the product or inventory that an industry wants to manufacture its product.

#### 2.1.1 Mortar

Mortar is a material used to fill the gaps between bricks and blocks in masonry construction and, on occasion, to add decorative colours or patterns to masonry walls. Mortar is a paste-like mixture of sand, a binder such as cement or lime, and water that is applied as a paste and then hardens. Moreover, mortar distributes gravity loads uniformly from one unit to the next and increases the shear strength of the assemblage structurally. On the other hand, mortar reduces the assemblage's moisture permeability [5]. In ASTM C270 Mortar for Masonry Units, it have been specifies mortar requirements.

#### 2.1.2 Polystyrene Beads

Polystyrene was discovered in 1839 by Eduard Simon, an apothecary from Berlin. It is a thermoplastic substance that is solid at room temperature and melts when heated. It is synthetic aromatic hydrocarbon polymer made from the monomer known as styrene [6]. Polystyrene is not biodegradable according to ASTM C578 standards. Usually, polystyrene is naturally clear, but sometimes it can be coloured.

### 2.2 Mechanical Testing

There are several methods that we used to conduct water absorption and compressive strength test. Several steps must be taken, including mixing concrete according to specifications and performing a new concrete test before moving on to the next phase.

2.2.1 Concrete Slump Test

Slump test was conducted in just seven stage using some materials such as slump cone (height: 300 mm), a steel rod (diameter:16 mm) , a measuring slump, and non-porous base plate. This slump is carried out as per procedures mentioned in ASTM C143 in the United States, IS: 1199 – 1959 in India and EN 12350-2 in Europe.

2.2.2 Cube Preparation

A concrete cube test entails taking a sample of freshly mixed concrete, allowing it to cure, crushing it, and measuring its compressive strength. Many concrete suppliers have this process performed at a certified test house, which is located outside of their facilities. Usually, a minimum of 3 cubes are taken from each sample because the average result was be taken from all the cubes.

2.2.1 Water Absorption Test

This is a method of controlling the amount and quantity of moisture loss from concrete during the hydration process. Concrete typically takes 24 to 48 hours to dry, but after 28 days it reaches its optimum strength. Immersion curing is the most effective method for curing laboratory samples. By doing this process, the water absorption from the cube can be calculated.

2.2.1 Compressive Strength Test

Compressive strength, also known as tensile strength, is the ability of a material or structure to withstand loads that cause it to shrink in size. Compressive strength is an important factor to consider while designing structures. Compression test equipment measure properties such as ultimate compression strength, yield strength, deflection, and modulus.

2.3 Equations

Numerous equations were employed in this study to generate the data and results that we obtained. This is an example equations to calculate water absorption and density as **Eq.1** and **Eq.2**.

$$\textbf{Water absorption} = \frac{\textbf{Saturated weight} - \textbf{dry weight}}{\textbf{dry weight}} \times \textbf{100\%} \qquad \textbf{Eq.1}$$

$$\textbf{Density} = \frac{\textbf{Wet Weight}}{\textbf{Volume of cube}} \qquad \textbf{Eq.2}$$

## 3. Results and Discussion

The results and discussion section presents data and analysis of the study.

3.1 Water Absorption

**Table 1** shows our results of on the water absorption. The results demonstrate water absorption tests on our control sample and a new sample containing 5%, 10% and 15% polystyrene beads. The water absorption test was performed to determine the water-tightness of concrete. The lower the strength of the concrete mortar that may be accommodated, the bigger the water absorption value. This result allows us to compare a new sample to a control sample to see if it has a low or high water absorption value following the curing process, which takes 7 and 28 days, respectively.

**Table 1: Water absorption of mortar mixed with percentages of polystyrene beads for 7 & 28 curing days**

| | 7 days | | | 28 days | | |
|---|---|---|---|---|---|---|
| | **Dry weight (kg)** | **Wet weight (kg)** | **Water absorption** | **Dry weight (kg)** | **Wet weight (kg)** | **Water absorption** |
| Control Sample (1) | 0.226 | 0.248 | 9.37 | 1.841 | 2.036 | 10.59 |
| Control Sample (2) | 0.229 | 0.249 | 8.46 | 1.817 | 2.027 | 11.56 |
| Control Sample (3) | 0.225 | 0.250 | 11.16 | 1.807 | - | - |
| PB 5% (1) | 0.207 | 0.232 | 12.26 | 1.740 | 1.952 | 12.18 |
| PB 5% (2) | 0.217 | 0.243 | 11.88 | 1.784 | 1.991 | 11.60 |
| PB 5% (3) | 0.215 | - | - | 1.801 | 2.002 | 11.16 |
| PB 10% (1) | 0.218 | 0.240 | 9.91 | 1.794 | 1.997 | 11.32 |
| PB 10% (2) | 0.216 | 0.238 | 10.49 | 1.836 | 2.115 | 15.20 |
| PB 10% (3) | 0.217 | 0.240 | 10.66 | - | - | - |
| PB 15% (1) | 0.239 | 0.262 | 9.45 | 1.766 | 1.966 | 11.33 |
| PB 15% (2) | 0.232 | 0.255 | 9.76 | 1.776 | 1.969 | 10.87 |
| PB 15% (3) | 0.238 | 0.263 | 10.46 | 1.738 | 1.937 | 11.45 |

Based on **Table 1**, the new sample failed to outperform the control sample because the control sample's water absorption value was lower than the new sample's, which consisted of 5%, 10%, and 15%. Next, based on data, cube mortar concrete soaked for 7 days generated better results than cube mortar concrete soaked for 28 days because the amount of water absorption in the cube 7 days is lower, but the average of the 28 days outcomes is better than the 7 days results. From water absorption tests that the maximum quantity of polystyrene beads that can be placed on roof tiles is only 5% to avoid degrading their quality. **Figure 1** shows the comparison between polystyrene beads and water absorption for 7 days and 28 days.

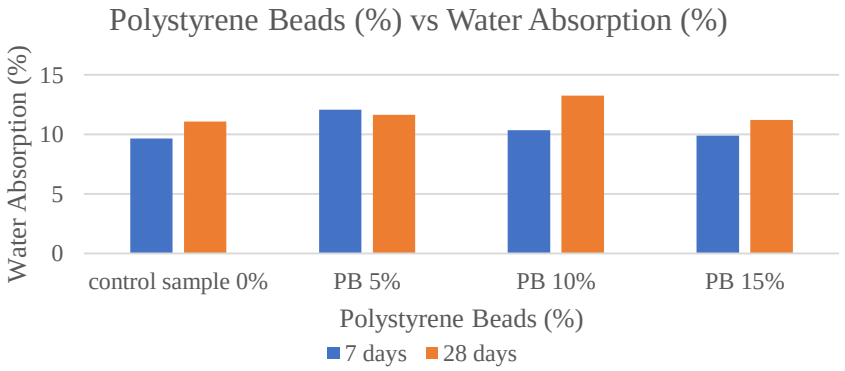


**Figure 1: Comparison of water absorption with various percentage of polystyrene beads for 7 days & 28 days**

### 3.2 Density

The density of normal weight concrete lies within the range of 2,200 to 2,600 kg/m³ [7]. Concrete density, bulk density, or unit weight of concrete is defined in the equation below. It is the mass or weight needed to fill a container with a given unit volume.

**Table 2: Density of mortar samples mixed with various percentages of polystyrene beads for 7 days and 28 days.**

| | 7 days | | 28 days | |
|---|---|---|---|---|
| | **Wet Weight (kg)** | **Density (kg/m³)** | **Wet Weight (kg)** | **Density (kg/m³)** |
| Control Sample (1) | 0.248 | 1.984 | 0.225 | 1.800 |
| Control Sample (2) | 0.249 | 1.992 | 0.253 | 2.024 |
| Control Sample (3) | 0.250 | 2.000 | - | - |
| PB 5% (1) | 0.232 | 1.856 | 0.244 | 1.952 |
| PB 5% (2) | 0.243 | 1.944 | 0.249 | 1.992 |
| PB 5% (3) | - | - | 0.250 | 2.000 |
| PB 10% (1) | 0.240 | 1.920 | 0.250 | 2.000 |
| PB 10% (2) | 0.238 | 1.904 | 0.264 | 2.112 |
| PB 10% (3) | 0.240 | 1.920 | - | - |
| PB 15% (1) | 0.262 | 2.096 | 0.246 | 1.968 |
| PB 15% (2) | 0.255 | 2.040 | 0.246 | 1.968 |
| PB 15% (3) | 0.263 | 2.104 | 0.242 | 1.936 |

**Table 2** shows the result of density on a control sample and new sample mixed with 5%, 10% and 15% polystyrene beads for 7 days and 28 days. Based on the result shows in the table, for 7 days, mortar mixed with 15% polystyrene beads has a higher value than others which is 2.104 kg/m$^3$. For 28 days, mortar mixed with 10% polystyrene beads has a higher value than others which is 2.112 kg/m$^3$. In addition, compacted concrete will produce a high density.The higher the density value of a concrete, the higher its quality. From **Table 2,** based on the table, there are some samples that do not have data because during the experiment the sample was damaged or broken because of this, the data cannot be retrieved.

### 3.3 Compressive Strength

The initial preparation is dimensions (diameter and height) and weight of the concrete cube must be measured. The weight or density of th e concrete will be determined using this compressive strength test. A Compression Testing Machine (CTM) was used for this test. The results of a compressive strength test on a control sample and a new sample with varied amounts of polystyrene beads (5%, 10%, and 15%) are shown in the tables below. Compression testing is used to assess how a material reacts to a compressive load by measuring fundamental factors including strain, stress, and deformation.

**Table 3: Compressive strength on mortar sample mixed with various percentages of polystyrene beads in 7 days & 28 days**

| | 7 days | | | 28 days | | |
|---|---|---|---|---|---|---|
| | **Dry Weight (kg)** | **Wet Weight (kg)** | **Compressive Strength, (MPa)** | **Dry Weight (kg)** | **Wet Weight (kg)** | **Compressive Strength, (MPa)** |
| Control Sample (1) | 0.226 | 0.248 | 4.53 | 1.841 | 2.036 | 8.70 |
| Control Sample (2) | 0.229 | 0.249 | 5.12 | 1.817 | 2.027 | 7.52 |
| Control Sample (3) | 0.225 | 0.250 | 3.17 | 1.807 | - | - |
| PB 5% (1) | 0.207 | 0.232 | 3.64 | 1.740 | 1.952 | 2.93 |
| PB 5% (2) | 0.217 | 0.243 | 4.14 | 1.784 | 1.991 | 3.99 |
| PB 5% (3) | 0.215 | - | - | 1.801 | 2.002 | 4.98 |
| PB 10% (1) | 0.218 | 0.240 | 4.27 | 1.794 | 1.997 | 7.63 |
| PB 10% (2) | 0.216 | 0.238 | 3.98 | 1.836 | 2.115 | 10.30 |
| PB 10% (3) | 0.217 | 0.240 | 4.57 | - | - | - |
| PB 15% (1) | 0.239 | 0.262 | 5.88 | 1.766 | 1.966 | 3.21 |
| PB 15% (2) | 0.232 | 0.255 | 4.74 | 1.776 | 1.969 | 4.27 |
| PB 15% (3) | 0.238 | 0.263 | 5.12 | 1.738 | 1.937 | 2.21 |

According to **Table 3**, cube mortar concrete soaked for 28 days outperformed cube mortar concrete soaked for 7 days. Sample 2 (28 days) of mortar concrete cube mix with 10% polystyrene beads had the maximum compressive strength of 10.30 MPa, while sample 3 (28 days) of mortar concrete cube mix with 15% polystyrene beads had the lowest compressive strength of 2.21 MPa. The value of compressive strength does not depend on the number of polystyrene beads added, but this compressive value can be seen by compacting the mortar concrete cube. This is done to avoid empty cavities in the concrete mortar which will reduce and break the durability of the roof tiles. **Figure 2** shows comparison between polystyrene beads (%) and compressive strength (MPa) for 7 days and 28 days of curing.

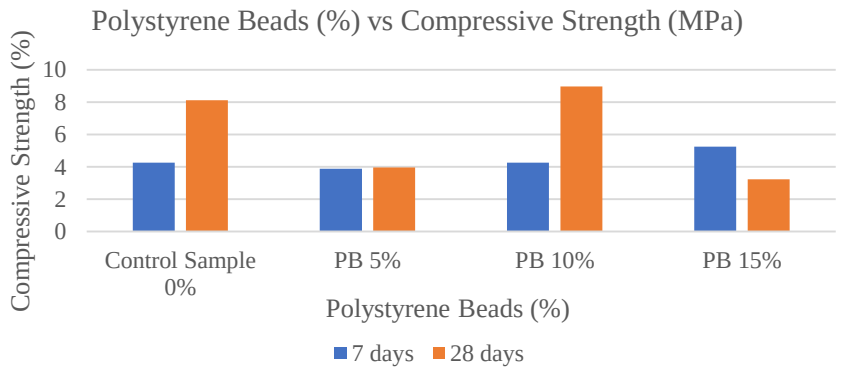


**Figure 2: Comparison of compressive strength (Mpa) with various percentages of polystyrene beads for 7 days and 28 days**

## 4. Conclusion

This study observed the strength of mortar mixed with polystyrene beads for rooftiles in the world's development activities. All the experimental have been done to make sure all the problems such as being heavy, leaking, and mossy due to high water absorption can be solved to improve the quality of roof tiles in the future. We chose polystyrene beads instead of coarse aggregates because there are some features that are appropriate and will improve all of the current problems in our industry.

All samples for each test were cured for 7 and 28 days to ensure that the amount and quantity of moisture loss from concrete during the hydration process was controlled. Based on the findings, can conclude that polystyrene beads have both advantages and disadvantages when used in rooftiles in our industry. This can help to alleviate some of the problems encountered in control sample. The advantage of sample with polystyrene beads is that just a specific quantity is required to realize the experiment's goals. The disadvantage is that most samples that are added to the polystyrene beads are poorer to samples that do not contain polystyrene.

There are still many things that can be developed from this research. Use high quality mortar to achieve a better mixture in the future. Make sure the mixture calculations comply with the specifications in the mortar manufacturing standards. In addition, to ensure that the results obtained are accurate, the curing process is preferably carried out with all cubes soaked in water.

## Acknowledgement

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