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Use of Styrofoam Concrete in Construction Industry – A Review

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Abstract: Styrofoam concrete is one of the concrete innovations applied to the building. The focal points of styrofoam concrete are light and durable materials for construction work. The styrofoam was utilized to increments the compressive strength and flexural strength of the concrete. Styrofoam concrete is lightweight and has a lower thickness compared to ordinary concrete, that's the reason why lightweight concrete has been applied to framework buildings. Styrofoam was known as a critical part of waste issues since its non-biodegradable material leads to more prominent contamination, it's reusable in numerous forms but is difficult to crush. The main points for this literature review about styrofoam concrete were on mechanical and durability performance. Scopus was the platform to find the articles for this review. This review used the meta-analysis method which is incorporate a quantitative pooling of information. This review on styrofoam concrete shows that styrofoam concrete can be used in civil engineering works as lightweight concrete. Styrofoam can be a good substitute for the aggregates in the lightweight concrete but its need the correct percentage of styrofoam used.

Keywords: Styrofoam, Styrofoam Concrete, Lightweight Concrete

1. Introduction

Styrofoam is an "extended polystyrene," (EPS) in any case for the foremost portion known as styrofoam. Extended polystyrene may well be a solidified cell plastic texture made from the moulding of little circles or pearls of expansible polystyrene that shows up a closed structure made of this thermoplastic which contains trapped air in a 96-98% extent of the volume of the pearls [1]. Expanded polystyrene (EPS) foam bundling, which is the commonplace white texture, custom moulded to cushion, secured and secure all sorts of things during transportation [2]. Furthermore, styrofoam was commonly used in our daily activities, food container and packaging material for electronic devices, fragile kinds of stuff and health products were the examples that humans always use styrofoam [3]. For many years, the viability of styrofoam has been demonstrated in various packaging applications utilized by a wide assortment of businesses, customer item producers and catalogue and shipping companies due to its low cost and ease of production [5]. The deadweight of the building can be reduced if utilized styrofoam concrete on building walls. Reducing the loads on the building make the project cost more

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efficient within the utilize of its main structure. The others advantages of styrofoam concrete are little density, impermeable, energy effective, and have good compressive strength. Styrofoam concrete moreover contains a fast excess in shaping and applying to buildings [4].

This research aims to systematically review the effect of styrofoam as concrete material on mechanical performance and durability performance. For the mechanical performance was reviewed on compressive strength, flexural strength and density of styrofoam concrete. For the durability performance was reviewed on thermal coefficient and water absorption. The scope of this study is on the research paper about styrofoam concrete in civil engineering works that been published on the Scopus website and their publication language is English The scope was limit to the research paper that had been published between 2010 to 2021 and their subject area was engineering. This research covered lightweight concrete.

Styrofoam known as polystyrene expand has a unit weight of 13-22 kg/m^3, impermeable to water and light material, [4]. A key advantage of styrofoam is that it is recyclable and expected it can be illuminated the issue of styrofoam's waste [3]. Thermoplastic is one of the styrofoam's main physical properties. This means that the material melts as a liquid when heated to a specific point, but was solid at room temperature. The thermal conductivity coefficient of styrofoam was $\lambda = 0.03$ W/mK, which has led to the wide use of styrofoam panels for thermal insulation buildings [6].

2. Methods and Materials

The research design for this research is utilizing a review. A review is a synopsis of the critical literature review. A review is a basic appraisal and assessment of all research examines that address a specific clinical issue. The researchers utilize a coordinated strategy for finding, collecting, and assessing an assortment of literature on a specific point utilizing a bunch of explicit standards. A review normally incorporates a portrayal of the discoveries of the assortment of research considers.

The review may likewise incorporate a quantitative pooling of information, called a Meta-analysis. Meta-analysis is a method of joining information from various research contemplates and a factual cycle that consolidates the discoveries from individual studies.

In Figure 1 below, there is the flowchart for this review. For this review, the instrument needed is a keywords search from the Scopus website. So, the keyword that will be using is "Styrofoam Concrete". The results are listed will be retrieved for this research. Keywords search is generally simpler to get data identified with the theme. This will permit you to see the wider look of how terms are filed inside that information base however you don't need to utilize the inclusive terms. The requirement for a research protocol for review is for the thought of straightforwardness, transferability, and replicability of the work, which are the characteristics that make a writing review more efficient. This makes a difference to minimize the bias by conducting comprehensive literature searches.

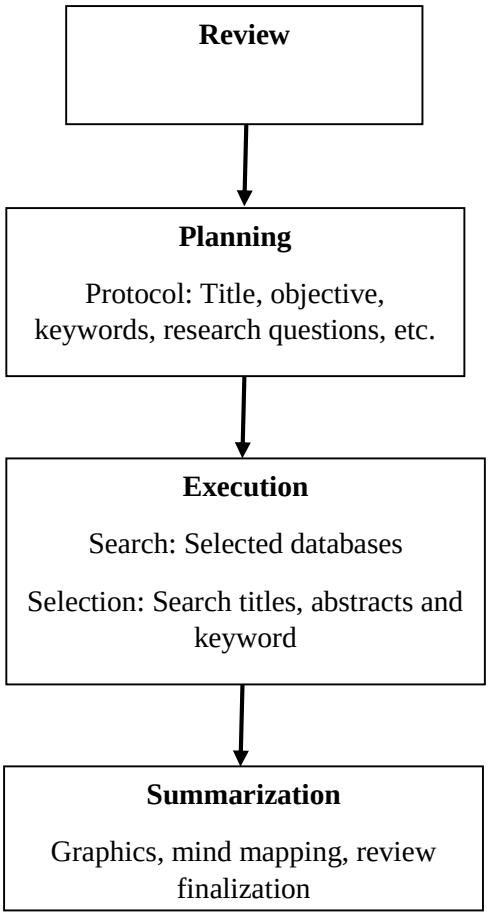

Figure 1: Review flowchart

3. Results and Discussion

This chapter discusses almost all the research findings of the information collected from the scope of the study. The findings had been displayed concerning the research goals expressed within the study. The method used to examine the information was already examined in the methods chapter.

3.1 The effect of styrofoam on fresh properties

From the 14 research papers that had been reviewed, only 4 research papers were used for the effect of styrofoam on fresh properties. According to the aim of the research, the subtopic could be reviewed in one category which is workability.

3.1.1 Workability

According to the aim of the research, the subtopic could be reviewed in slump flow T50 testing. Although this effect of styrofoam on fresh properties articles account only for 4 research paper of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. Article about the effect of styrofoam on fresh properties was summarized in Table 1.

3.2 The effect of styrofoam on mechanical performance

From the 14 research papers that had been reviewed, only 11 research papers were used for the effect of styrofoam on mechanical performance. According to the aim of the research, the subtopic could be reviewed in three categories: compressive strength, flexural strength and density.

3.2.1 Compressive strength

Although these compressive strength articles account only for 9 research papers of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. The article about compressive strength is summarized in Table 2.

3.2.2 Flexural Strength

Although these flexural strength articles account only for 5 research papers of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. The article about flexural strength is summarized in Table 3.

3.2.3 Density

Although these density articles account only for 4 research papers of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. The article about density is summarized in Table 4.

Table 1: Effect of styrofoam on workability

Item	Authors	Year	Workability of Styrofoam Concrete
[8]	Solikin et al.	2020	Slump Flow T50 for both 50% styrofoam content and 60% styrofoam content meet the requirements of the slump flow test standard for SCC.
[3]	Solikin et al.	2019	The slump value is between 73-67 cm, it can be concluded that the higher the content of styrofoam, the lower the slump value and the decrease of slump flow affect the higher content of styrofoam was possibly caused by the lower total weight of fresh SCC.
[11]	Ngene et al.	2019	The test was conducted with 4 specimens, group 1 (0% of styrofoam), group 2 (10% of styrofoam), group 3 (20% of styrofoam and group 4 (30% of styrofoam). The most elevated slump value is gotten by the group 4 specimen, which comprises concrete delivered with 30% coarse aggregate substitution with styrofoam by volume.
[12]	Solikin, M. and Ikhsan, N.	2018	The test was conducted with 4 specimens, specimen 1 (0% of styrofoam), specimen 2 (30% of styrofoam), specimen 3 (40% of styrofoam and specimen 4 (50% of styrofoam). All specimens test results of slump flow T50 meet the American Society for Testing and Material (ASTM) standard because they are above 500 mm (ASTM, 2005).

Table 2: Effect of styrofoam on compressive strength

Item	Authors	Year	Compressive Strength
[7]	Stefurak, L. and Stefurak, P.	2020	The results show when the mass of styrofoam per unit area increase, the strength (stress) of styrofoam also increase.
[8]	Solikin et al.	2020	The reduction in the volume of sand followed by the increase of styrofoam content decrease the compressive strength as the air cavity in the concrete becomes greater and lighter.
[9]	Widiyanto et al.	2019	The result showed that the highest content of styrofoam used, the lowest the compressive strength of the concrete.
[4]	Alfuady et al.	2019	The use of 3-4 mm in diameter styrofoam (11.34 MPa with 10% styrofoam used) has the highest compressive strength than the use of 2-3 mm and 5-6 mm styrofoam in diameter.
[10]	Mahdi et al.	2019	Compression strength decreased in minimal proportions up to a volume fraction of ¼ styrofoam panels
[11]	Ngene et al.	2019	The compressive strength of the styrofoam specimen is significantly smaller than the control example with the most reduced value happening at 30% substitution of coarse aggregate
[12]	Solikin, M. and Ikhsan, N.	2018	Concrete compressive strength diminishes in line with the increment of styrofoam content.
[13]	Pala et al	2017	The decrease in compressive strength of mortar cubes when the cement has been replaced by styrofoam
[14]	Strecker et al.	2016	The highest compressive strength is 18.71 MPa at the sample of 5% and 20% of sand with 20% of styrofoam used. The lowest compressive strength is 7.37 MPa at the sample of 20% of sand with 60% of styrofoam.

Table 3: Effect of styrofoam on flexural strength

Item	Authors	Year	Flexural Strength
[8]	Solikin et al.	2020	The wall panel with double reinforcement can act as a flexural element of and less styrofoam content lead to a higher load capacity of the panel and after the maximum load, the panel can perform as a ductile structural element as the deflection keep increase after the maximum load.
[4]	Alfuady et al.	2019	Styrofoam concrete with 2-3 mm and 3-4 mm in diameter of styrofoam as much as 10% by volume has a highest flexural strength than the usage of 5-6 mm in diameter styrofoam.
[12]	Solikin, M. and Ikhsan, N.	2018	The flexural strength of concrete decreases when the addition of styrofoam is increased.
[15]	Wibowo et al.	2017	The use of styrofoam also reduced the thickness of the concrete layer surrounding the bamboo bars, and hence reduced the bond-slip resistance
[16]	Wariyatno et al.	2017	The stiffness of the structural element is influenced by several factors, among these are the performance of the materials (steel and concrete), the bonding between the different materials and the load condition and load increment.

Table 4: Effect of styrofoam on density

Item	Authors	Year	Density
[8]	Solikin et al.	2020	The density of the sample decrease when the percentage of styrofoam increase
[3]	Alfuady et al.	2019	The lowest density showed at 30% variation of styrofoam, influenced by the cavities in the styrofoam concrete more due to the greater percentage of styrofoam usage
[12]	Solikin, M. and Ikhsan, N.	2018	The higher the percentage of the styrofoam, the lower the decrease of weight/volume
[13]	Pala et al.	2017	Three samples and tested their density within 7, 14 and 28 days. The result was the higher density was in 28 days for the sample.

3.3 The Effect of Styrofoam On Durability Performance

From the 14 research papers that had been reviewed, only 7 research papers will be reviewed for the effect of styrofoam on durability performance. According to the aim of the research, the subtopic could be reviewed in two categories: thermal coefficient and water absorption.

3.3.1 Thermal Coefficient

Although these thermal coefficient articles account only for 3 research papers of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. The article about thermal coefficient is summarized in Table 5.

3.3.2 Water Absorption

Although these water absorption articles account only for 4 research papers of all selected papers, the studies in this group were reviewed, and this, therefore, shows the relevance of the topic. The article about water absorption is summarized in Table 6.

Table 5: Effect of styrofoam on the thermal coefficient

Item	Authors	Year	Thermal Coefficient
[7]	Stefurak, L. and Stefurak, P.	2020	Results of measuring the density and temperature of heat flows, the thermal parameters of the test part of the superblock deck were calculated.
[10]	Mahdi et al.	2018	Showed the inclusion of styrofoam balls in a concrete cast and the consequence of changes in compression and thermal conductivity.
[17]	Lim et al.	2018	Utilized a numerical recreation utilizing Finite-difference time-domain (FDTD) to analyze the three-dimensional heat flux in a concrete piece inserted with plate-shaped meta-structures, which is made of ordinary highly-thermal-insulating styrofoam. Thermal conductivity was mimicked by changing the plate-shaped meta-structures to discuss, aerogel, and paraffin rather than styrofoam as the thermal metamaterial.

Table 6: Effect of styrofoam on water absorption

Item	Authors	Year	Water Absorption
[9]	Solikin et al.	2019	The higher content of styrofoam is directly proportional to the higher level of water absorption
[12]	Solikin, M. and Ikhsan, N.	2018	The higher the percentage of styrofoam, the higher the water absorption. This wonder may be a result of more void within the aggregate compared with the utilize of fine aggregate.
[18]	Steidl, T. and Krause, P.	2018	Make a laboratory test to determine the moisture level in the walls. The walls are made from cellular concrete and insulated with styrofoam, it is not recommended to apply steel connectors without any additional protective device.
[19]	Wibowo, A. P.	2017	The test results on the water absorption of the concrete styrofoam cube specimen that the average water absorption is 11.97%. Therefore, this styrofoam concrete has a waterproof capability.

4. Conclusion

In conclusion, this review on styrofoam concrete can prove that styrofoam concrete can be used in civil engineering works on lightweight concrete. Styrofoam can be a good substitute for the aggregates in the lightweight concrete but its need the correct percentage of styrofoam used. The correct percentage of styrofoam in the concrete lead to better result in compressive strength, flexural strength and water absorption.

From the three main criteria of styrofoam concrete that had been reviewed in this review, the following conclusions may be derived from the findings of this study. The increased amount of styrofoam substitute in the concrete, the decrease in the compressive strength of the concrete. It's because of the softness of styrofoam, air cavity and void bubbles inside the styrofoam concrete. The flexural strength of concrete decreases when the addition of styrofoam is increased. It's because of the increases in the bubble void and softness of styrofoam. A higher percentage of styrofoam as a substitute to aggregate, the lower density of the concrete. It's because the properties of styrofoam were lightweight make the density lower. Styrofoam concrete had better thermal conductivity behaviour than normal concrete. The higher content of styrofoam is directly proportional to the higher level of water absorption. It is also due to higher content of styrofoam will increase the number of cavities in styrofoam concrete. The higher the content of styrofoam, the lower the slump value and the decrease of slump flow. It's due to the lower total weight of styrofoam.

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