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Optimization of Styrofoam as Concrete Replacement Material Subjected to Compressive Strength

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ABSTRACT

Nowadays, the construction sector is developing rapidly, and there is an increase in demand for innovative concrete technology. This is because concrete has many advantages over other building materials. Improving the quality of concrete can be done by providing replacement materials or adding several replacement materials, and one of the alternative materials that can be used is styrofoam. The purpose of this research is to evaluate the effect of styrofoam as high-quality concrete and compare the compressive strength between control concrete by using 1%, 2%, and 3% ratios of styrofoam. The experimental method is applied in this research, experiment was conducted and tested in accordance with SNI 03-6468-2000. The results of the study show that the compressive strength of styrofoam mixed concrete using ratios of 1%, 2%, and 3% obtained 23,30 MPa, 17,34 MPa, and 11,64 MPa. The results showed that Styrofoam replacement was used for K.350 high-strength concrete. It is not recommended for building or bridge construction because the compressive strength test results produced are meagre compared to standard concrete without a mixture of styrofoam. After all, the mass of concrete mixed with styrofoam is lighter than normal concrete so that it can be used for construction with low loads.

Keywords: Concrete; high quality; styrofoam

INTRODUCTION

Concrete is a construction widely applied worldwide, and the demand for concrete continues to increase (Rao & Kumar, 2022). Concrete has been commonly used in construction, with its ease of use and good performance (Abro et al. 2024). Concrete has become a staple in infrastructure development in Indonesia (Puspita et al. 2019). Concrete is a basic form of life in modern society that has a function for development and construction components that have sturdy and durable properties whose mixture consists of aggregate (fine and coarse), water, and cement, which form a solid mass (Cahyo et al. 2020), (Puspita, 2020). The quality of concrete constituent materials affects the concrete results (Tamayo et al. 2020). With good quality concrete, advantages are obtained, including being able to withstand compressive forces optimally. In addition, concrete also has many advantages, namely being able to withstand heavy loads, easy to shape as desired, and concrete stages against temperature (Maryanto et al. 2018), (Nisumanti 2016).

Concrete combines cement, fine aggregate, coarse aggregate, and water into a solid mass (Setiawati, 2018). Concrete has many advantages because it is made from local and affordable materials such as coarse and fine aggregates, cement, and water. Concrete also has a relatively high compressive strength compared to other construction or construction materials, effortless artistry,

strength, and relatively low concrete maintenance costs that make concrete more durable and long-lasting. In this case, concrete construction can be applied in various fields in the future (Singh et al. 2020).

High Strength Concrete is listed in the Indonesian National Standard (SNI 08-6468-2000), Defined as concrete with a required compressive strength ≥ 41.4 Mpa. High-strength concrete has special treatment and uniform requirements that cannot be routinely achieved using conventional materials and regular mixing, placement, and maintenance methods (American Concrete Institute). It can be said that in high-quality concrete, the compressive strength is above 40 Mpa. If the compressive strength is 80 Mpa, then the concrete is said to be very high-quality concrete. The compressive strength of high-quality concrete is influenced by several factors, including the ingredients that make it up; the ice factor of cement is too low while the density is high, which makes the concrete challenging to work with or the concrete becomes stiff (Blissett et al. 2012), (Sakar et al. 2016). To improve the strength of concrete, at least three basic concepts need to be followed, viz: Increasing the strength of cement paste, selecting suitable quality aggregates, and improving the bond between cement paste and aggregates (Rad et al. 2020).

Concrete has disadvantages such as smaller tensile strength than steel structures, a small strength-to-weight ratio, and low ductility (Yasniku, 2018). In addition, concrete has highly brittle properties, and its low tensile strain capacity causes cracks in building structures (Abbass et al. 2018). Admixtures are materials other than water, aggregate, and cement added to the concrete mix. These admixtures make concrete mixes more economical and reduce the amount of primary material (Rizk et al. 2010).

Styrofoam or expanded polystyrene is a white cork commonly used to wrap electronics. Polystyrene itself is produced from styrene (C6H5CH9CH2), which has phenyl groups (six carbon rings) arranged irregularly along the carbon line of the molecule (Purnama & Wicaksono 2021). As soon as styrofoam was created, it was widely used because it was not easy to leak, practical, and lightweight (Agung 2015). The use of styrofoam in the manufacture of concrete will be more effective than the manufacture of aerated concrete in general because styrofoam has a tensile strength and volume of air voids that are easier to control when compared to the air-blowing method in the manufacture of aerated concrete (Karolina et al. 2018). However, using styrofoam in making concrete can affect the strength of the concrete produced as the percentage of styrofoam in the concrete mixture increases (Hadi 2019).

Regarding the above discussion, research was conducted to analyze the compressive strength of high-strength concrete with the addition of styrofoam to determine the effect of styrofoam on the concrete mixture. This research aims to evaluate the impact of styrofoam on the compressive strength of high-quality concrete and compare the compressive strength between ordinary concrete and concrete using the addition of styrofoam.

METHODOLOGY

This research was conducted at the Faculty of Engineering Laboratory of Indo Global Mandiri University. This type of research is experimental research in the laboratory that analyzes the compressive strength of high-quality concrete with the addition of styrofoam.

MATERIALS

The materials used in this research are fine aggregate, coarse aggregate, Portland cement, water, and styrofoam. Styrofoam variations of 1%, 2%, and 3% compared with concrete without styrofoam. Another name for styrofoam is polystyrene. Styrofoam is often used in everyday life where it is usually used as a wrapper for electronic goods and food wrappers because it is not easy to leak and is practical and lightweight (Ala & Arruan 2018).

MATERIALS TESTING

Material testing aims to obtain data on the characteristics of the aggregate so that it can be mixed in manufacturing concrete. This material testing consists of content weight testing, gradation analysis testing, material testing through sieve 200, organic material study testing, moisture content testing, and Specific Gravity and Absorption testing. Material testing refers to the Indonesian National Standard (SNI) and is complemented by the American Society for Testing and Materials (ASTM).

MIX DESIGN

This mixture planning refers to SNI 03-2834-2000 with a concrete quality plan of K-350. This study uses cube test objects of 15 cm x 15 cm x 15 cm. The proportion of the mixture in this study is contained in Table 1.

TABLE 1. Concrete Mix Proportion

Sample	Composition (kg)
Cement	19,05
Fine aggregate	28,36
Coarse aggregate	42,52
Water	9,14
1% Styrofoam	0,19
2% Styrofoam	0,38
3% Styrofoam	0,57

Based on Table 1. It can be seen that the composition of the material mixture for high-quality concrete consists of cement, fine aggregate, coarse aggregate, water, and added ingredients in the form of styrofoam. For a more detailed percentage of the high-quality concrete mix can be seen in Figure 1.

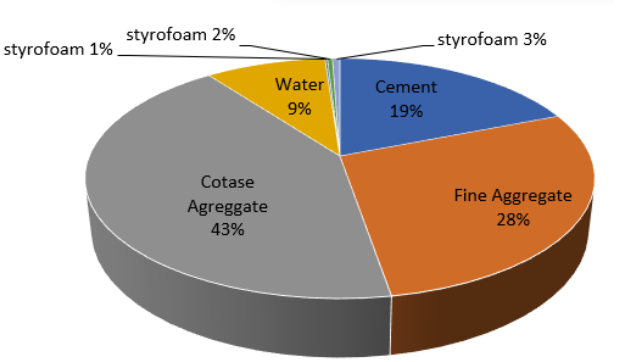


FIGURE 1. Percentage of Materials That Make up High-Strength Concrete

CONCRETE COMPRESSIVE STRENGTH

Concrete strength tests are conducted after curing using a Compression Testing Machine. In this study, concrete compressive strength testing was carried out at the Indo Global Mandiri University Laboratory using SNI 1974-2011 standards.

$$\delta bi = \frac{P}{A} \quad (1)$$

RESULTS AND DISCUSSION

MATERIAL TESTING RESULTS

The material testing of coarse and fine aggregates is carried out to determine whether the material to be used in the concrete mix meets the predetermined specifications. The results of material testing can be seen in Table 2.

TABLE 2. Results of material testing

Materials	Composition (Kg)	Specifications	Test Results
Sieve Analysis	Coarse aggregate	≤ 8,5%	7,10%
	Fine aggregate	2,2- 3,2%	2,55%
Specific gravity	Coarse aggregate	≥ 2,5%	2,54%
	Fine aggregate	≥ 2,5%	2,54 %
Absorption	Coarse aggregate	≤ 3%	1,84%
	Fine aggregate	≤ 3%	2,26%
Weight of contents	Coarse aggregate	≥ 1,4 Kg/m^3	1,462 Kg/m^3
	Fine aggregate	≥ 1,4 Kg/m^3	1,495 Kg/m^3
Sludge content	Fine aggregate	≤ 5,0%	1,07%
Organic matter content	Fine aggregate	Maks No. 3	No.3

SLUMP TEST RESULTS

The purpose of the slump test is to determine whether the water in the concrete mixture is less, excess, or sufficient or to determine the consistency of the fresh concrete mixture commonly known as Fresh Concrete (Qubro et al. 2021). The results of the slump test can be seen in Table 3.

TABLE 3. Slump Test

Sample	Slump value (cm)
Normal Concrete	9,5
Concrete + 1%Styrofoam	9,8
Concrete + 2%Styrofoam	10,5
Concrete + 3%Styrofoam	11

CONCRETE COMPRESSIVE STRENGTH RESULTS

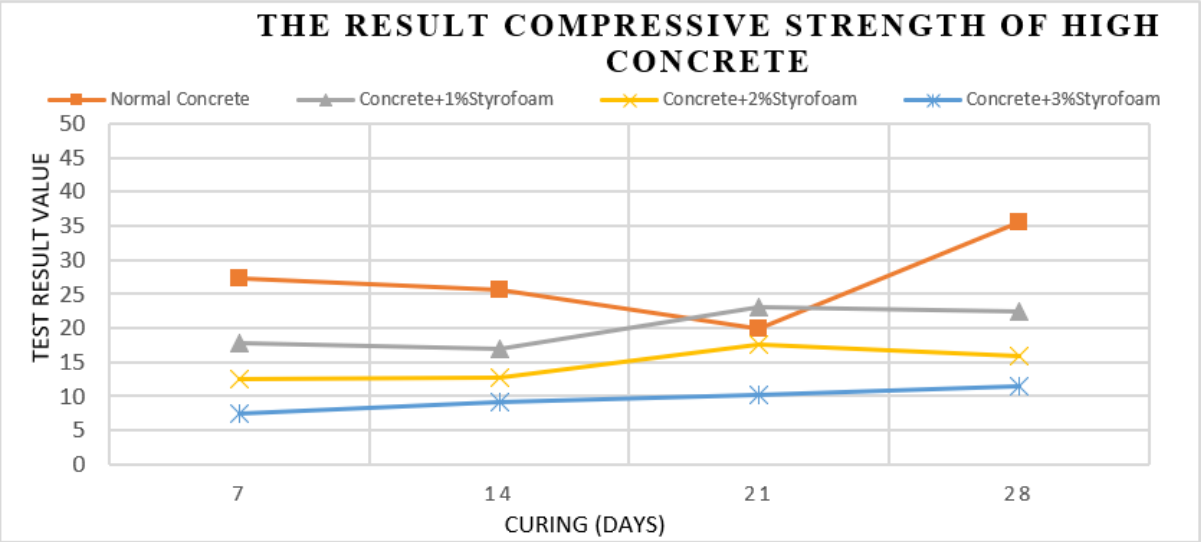
Testing the compressive strength of concrete cubes with the age of concrete 7 days, 14 days, 21 days, and 28 days after mixing. Concrete compressive Strength testing is carried out to produce concrete compressive strength values in each concrete mix variation.

TABLE 4. Recapitulation of Concrete Compressive Strength

Concrete Mix Variations	Concrete compressive strength (Mpa)			
	7 days	14 days	21 days	28 days
Normal Concrete	27,30	25,67	20,03	35,58
Concrete + 1%Styrofoam	17,82	16,94	23,01	22,37
Concrete + 2%Styrofoam	12,43	12,79	17,51	15,96
Concrete + 3%Styrofoam	7,15	9,07	10,21	11,47

FIGURE 2. Concrete compressive strength recapitulation

From the graph above, it can be concluded that the addition of styrofoam can reduce the results of the compressive strength of concrete characteristics where at the time of regular concrete, the average compressive strength of 28 days reached 35,58 MPa when compared to the 28-day concrete compressive strength with the addition of 1% styrofoam which is 22,37 MPa which means that the percentage strength of concrete compressive strength



has dropped 33%. The cumulative value of concrete compressive strength decreased by 39% with the addition of 2% styrofoam, namely 15,96 MPa. With the addition of 3% styrofoam, the compressive strength of concrete decreased further, namely 11,47 MPa, which means that the percentage of concrete compressive strength decreased by 40%. So, the more styrofoam mixed material mixed in concrete can reduce the compressive strength of the concrete itself due to the nature of styrofoam, which cannot absorb water to make small cavities in the concrete, thus reducing the level of concrete strength. However, the more styrofoam is added, the lighter the concrete is produced compared to the other materials.

CONCLUSION

The results of the research and discussion that has been carried out using styrofoam-added materials can be concluded as compressive strength of concrete is influenced by the volume of Styrofoam in the concrete mixture. Where the more significant the volume of Styrofoam, the lower the compressive strength produced. The compressive strength value with 0% styrofoam volume is 35,60 MPa, 1% is 23,30 MPa, 2% is 17,34 MPa, and 3% is 11,64 Mpa. Regular concrete meets the requirements of K.350 or 34,32 MPa quality concrete where the compressive strength value of concrete reaches 35,60 MPa, while concrete with styrofoam mixture does not reach K.350 or 34,32 MPa quality concrete. However, adding styrofoam can also make the concrete lighter because of its impermeable nature, which forms small cavities in the concrete.

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DECLARATION OF COMPETING INTEREST

None

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