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EXPERIMENTAL STUDY OF LIGHTWEIGHT CONCRETE MECHANICAL QUANTITY WITH HEATED STYROFOAM MATERIAL

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Abstract Research on lightweight concrete based on styrofoam aggregates has been carried out previously, namely by providing heat treatment to styrofoam before being used as a substitute for aggregate with fine grains. The Styrofoam used is Expanded Polystyrene (EPS) with a grain size of 5 – 8 mm before being heated. Styrofoam seeds were heated at a temperature of 1380 C for 7 minutes. The variation of the test object in this study was using styrofoam as a substitute for 100% coarse aggregate and 75% coarse aggregate replacement so that the remaining 25% coarse aggregate used gravel with sizes of 10x10 mm and 10x20 mm. To close the pores of the concrete in this variation of the test object, 30 % of the weight of the aggregate was also added with fly ash. To improve the workability, a superplasticizer of 0.6% of the cement weight was used.

The tests carried out are compressive strength, split tensile strength and flexural strength. The results obtained were the optimum value of the compressive strength test of 19.57 MPa on lightweight concrete with heavy coarse aggregate replaced by 100% heated styrofoam. For the optimum value of the split tensile strength test, it was found that 2.83 MPa in lightweight concrete, the weight of coarse aggregate was replaced by 75% styrofoam and 25% gravel with a size of 10x20 mm. For the optimum value of the flexural strength test, it was obtained at 3.27 MPa in lightweight concrete, the weight of coarse aggregate was replaced by 75% styrofoam and 25% gravel with a size of 10x10 mm.

Keywords : lightweight concrete, heated styrofoam, fly ash, concrete

I. INTRODUCTION

Indonesia is an area that is quite prone to earthquakes, this is triggered by the meeting path of 3 plates including the Pacific, Indo-Australian and Eurasian plates. Earthquake load is a load that should be taken into account in making building structures, especially in earthquake-prone areas. The magnitude of the earthquake load is strongly influenced by the condition of the building structure. Buildings have mass, so the mass inertia of the top of the building provides resistance to earthquake movements known as earthquake loads.

It can be seen that the magnitude of the earthquake load is strongly influenced by the mass of the building. Given this, the manufacture of concrete structures needs to think about innovations in the manufacture of lightweight and strong materials. The challenge of lightweight concrete production is to get the right composition where low concrete but high compressive strength and modulus of elasticity (which affects the stiffness of the material) meet the minimum requirements as a structural material.

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II.METHOD

Experimental study using the composition of heated styrofoam as a concrete mixture with a percentage of 56% or 42% of the aggregate weight and the use of Split size 10 x 10 mm or 10 x 20 mm by 25% of the weight of coarse aggregate as well as the use of adding fly ash 30% of the weight aggregate, the use of admixture 0.6% by weight of cement. Normal concrete as a comparison. Meanwhile, concrete with ages of 7, 14, and 28 days

The results of research analysis are used in the following ways:

a. The type of concrete for the test object is calculated with a diameter of 150 mm and a height of 300 mm by taking into account the mass of the concrete and then dividing the volume.

b. Performing concrete strength calculations for cylindrical specimens with a diameter of 150 mm and a height of 300 mm are presented in tabular form.

c. Calculation of the split tensile strength of concrete is carried out for cylindrical specimens with a diameter of 150 mm and a height of 30 mm and then tabulated.

d. Calculation of the flexural strength of concrete for testing beams with a size of 150 mm and a length of 600 is tabulated.

Here is a flow chart of the research to do:

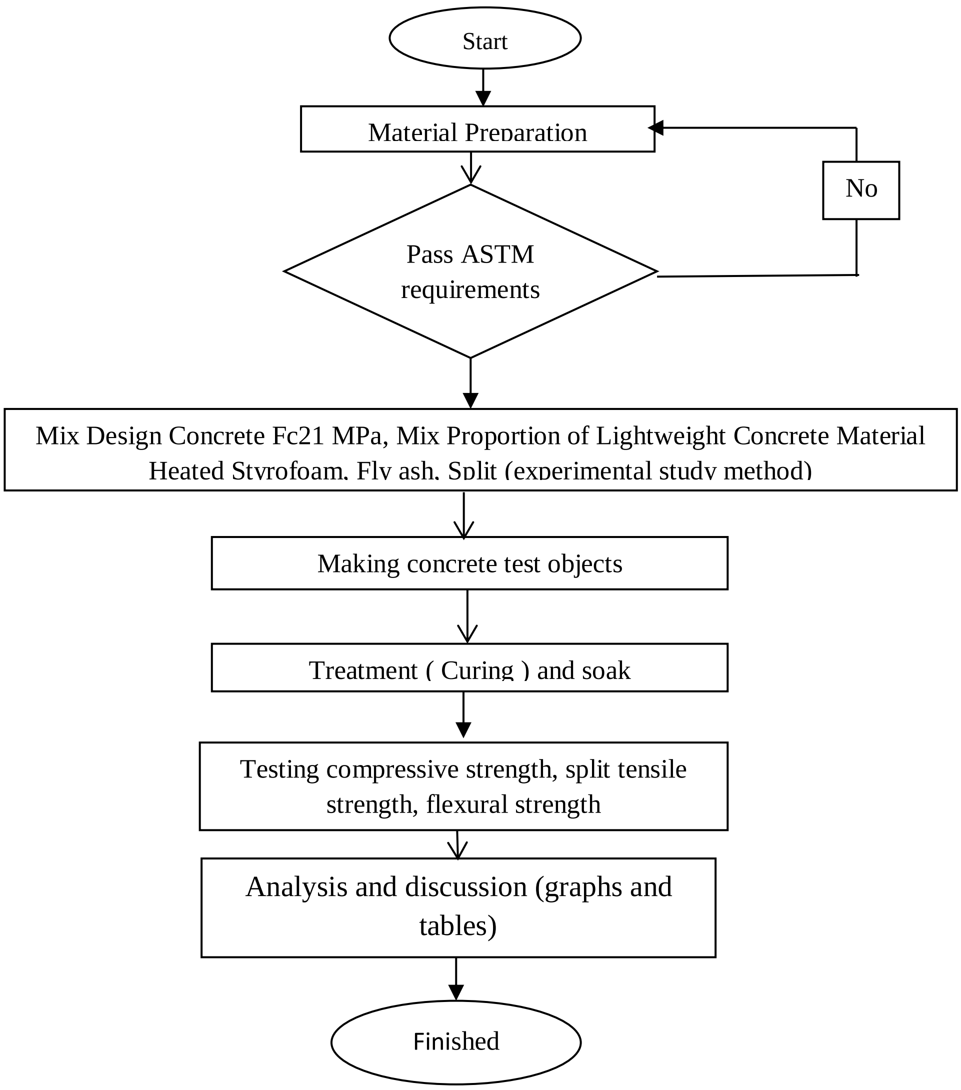

Chart 1. Research Flowchart Image

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III.RESULTS AND DISCUSSION

Aggregate Inspection. Aggregate inspection carried out is looking for volume weight, water content, mud content and nest analysis.Aggregate Inspection By Loose And Compaction
Aggregate inspection by loose and compaction is carried out to find the weight of fine and coarse aggregate by comparing the weight of the dry matter in volume. The following is the analysis of the test data:

Table 1. Aggregate inspection results

No	Container Code	Type Aggregat	Methode	aggregate weight (kg)	Aggregate Volume Weight (kg/m^3)	Average Aggregate Volume	Average
			Release And Compaction	(W3)	W3/V Wadah	(kg/m^3)	(kg/m^3)
1	Cube A	Fine	Release	4,62	1368,88	1352,615	1435,49
2	Cylinder A	Fine	Release	7,08	1336,35		
3	Cube B	Fine	Compaction	5,14	1522,96	1518,365	
4	Cylinder B	Fine	Compaction	8,02	1513,77		
5	Cube A	Rough	Release	4,67	1383,70	1390,22	1559,55
6	Cylinder A	Rough	Release	7,40	1396,75		
7	Cube B	Rough	Compaction	5,65	1674,07	1728,88	
8	Cylinder B	Rough	Compaction	9,45	1783,69		

Aggregate Sludge Level Check. The mud content inspection is carried out with fine and coarse aggregates with the aim of seeing the mud content as stipulated in SNI 2847: 2019 which is less than 5%. The data obtained can be seen in the table.

Table 2. Slurry test results

No	Test	Methode	how to do washed	Average Sludge Content	Average
1	Uji I	Sediment	0,55 %	0,615 %	1,14 %
2	Uji Ii	Sediment	0,68 %		
3	Uji Iii	Washed	1,88 %	1,66 %	
4	Uji Iv	Washed	1,44 %		

Aggregate Moisture Check. The water content inspection test is useful so that the appropriate water content conditions are obtained. Tests conducted with the water content of the aggregate can be used in work related to planning the mixture by controlling the quality of the concrete. The water content in the aggregate is a measure of the ratio between the weight supported by the dry aggregate, expressed as a percentage (%). The data obtained can be seen in table **:**

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Table 3. Aggregate water content inspection results

Test	Aggregat type	Cup Weight (A) (Gram)	Cup Weight + Aggregate Before Oven (B)(Gram)	Cup Weight + Aggregate After Oven (C)(Gram)	Water content (%)	Average water content (%)
I	Agrega Halus (Pasir)	25	255	240	6,97	5,70
II		25	401	385	4,44	
I	Agregat Kasar (Kerikil)	25	340	335	1,61	1,59
II		25	345	340	1,58	

Sieve Analysis Check. The purpose of the sieve inspection analysis is to find the grain gradation of the aggregate. Routine distribution is carried out to nail the concrete mix and the determination of fine and coarse aggregates is carried out. A set of filters with a certain size variation is used. The results of the aggregate inspection are listed in the following table.

Table 4. Fine aggregate (sand) sieve inspection results

No	Sieve Size (C)(Gram)	Percentage of Aggregate Lagging (D)(%)	Lagging Aggregate Cumulative (E)(%)	Present Finer (F)(%)	Astm C33	
					Min (%)	Max (%)
1	9,5	15	1,39	98,62	100	100
2	4,76	55	5,09	93,53	95	100
3	2,38	145	13,43	80,11	80	100
4	1,18	175	16,20	63,91	50	85
5	0,59	160	14,81	49,1	25	60
6	0,27	175	16,20	32,9	5	30
7	0,14	210	19,44	13,46	0	10
8	0,07	130	12,04	1,42	0	0
9	Alas (0,0)	15	1,39	0	0	0
FINE MODULUS FM				3,7	1,5<FM<3,8 SAND	
SII.0052 FINENESS MODULUS						

Table 5. Coarse (Gravel) Aggregate Sieve Examination Results

No	Sieve Size (C)(Gram)	Percentage of Aggregate Lagging (D)(%)	Lagging Aggregate Cumulative (E)(%)	Present Finer (F)(%)	Astm C33	
					Min (%)	Max (%)
1	24	20	0,83	99,17	78	100
2	19	625	25,93	73,24	78	100
3	12,7	870	36,10	37,14	25	100
4	9,5	295	12,24	24,90	0	85
5	4,7	285	11,83	13,07	0	60
6	2,38	115	4,77	8,30	0	0
7	1,19	55	2,28	6,02	0	0
8	0,59	145	6,02	0	0	0
9	0,27	0	0	0	0	0
10	Alas (0,0)	0	0	0	0	0
FINENESS MODULUS FM				6,3816	6<FM<7,1 Coarse	
SII.0052 FINENESS MODULUS						

Styrofoam and Fly ash Material Inspection. Styrofoam material inspection is to determine the specific gravity, both the specific gravity obtained before in the oven or after being baked or processed.

So the specific gravity of styrofoam before being baked is 10 kg/m3. The specific gravity of Styrofoam after being baked is 100 kg/m3. For fly ash Inspection, it is known that it is 2,150 kg/m3.

Concrete mix planning or mix design

Design concrete compressive strength

f'c 21 MPa / K 250 $= 250 \times \frac{0,83}{9,81}$ = 21,15 MPa age 7 day
Deviasi standart = 6,5 MPa
Margin added value = 1,64 x 6,5 = 10,66 MPa
fcr = 21,15 + 10,66= 31,80 MPa
Pebble size 20 mm crushed stone, slim (100 – 300) mm
Clean water level = 190 (in table)
Water cement factor $= \frac{cwl}{wcf} = \frac{190}{0,42}$ = 452, 38 kg/m^3
% sand to combined aggregate = 44%
Mixed Aggregat $= \frac{1}{2}$ (specific gravity of sand + specific gravity of gravel)
$= \frac{1}{2}$ (1.435,49 kg/m^3 + 1.559,55 kg/m^3)
$= \frac{1}{2}$ (2.995,04 kg/m^3) = 1.497,50 kg/m^3
Concrete fill weight = 2320 kg/m^3 (in the table)
Combined aggregate rate = specific gravity of concrete – (cement content + clean water level)
= 2320 – (452,38 + 190)
= 2320 – (642,38)
= 1677,62 kg/m^3
Fine aggregate content = 0,44 x 1677,62 = 738,15 kg/m^3

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Coarse aggregate content = 1677,62 – 738,15= 939,47 kg/m^3
water = 190 liter
cement = 452,38 kg/m^3
coarse = 939,47 kg/m^3
sand = 738,15 kg/m^3

Concrete mix planning aims to find the proportion of the mixture and determine the composition of the components or elements of concrete with the provisions of the desired character, namely fc. The following results obtained for the need for 1m3 can be seen in the table below.

Table 6. Normal concrete requirement within 1m3

Cement	**Sand**	**Coarse**	**Water**
452,38	738,15	939,47	190 ltr
Cement : Sand : Coarse : water 1 : 1,63 :2,07 : 0,42			

Table 7. Proportion of mixture to be researched

	Code	**Cement (kg)**	**Sand (kg)**	**Coarse (kg)**	**Heated Styrofoam (kg)**	**Fly ash (kg)**	**Water (ltr)**	**Note**
	BN	452,38	738,15	939,47	0	0	190	Normal of Concrete f'c 21 MPa
	BR	452,38	738,15	0	56	238,25	190	Lightweight Concrete No Gravel
	BM 251	452,38	738,15	234,87	42	238,25	190	Gravel 10x10 mm (25% of Coarse Aggregate Weight)
	BM 252	452,38	738,15	234,87	42	238,25	190	Gravel 10x20 mm (25% of Coarse Aggregate Weight)

Slump Test Inspection. Slump test inspection aims to determine the size of the degree of viscosity of fresh concrete mix, so that it is easy to work with. Performed with the Abrahams cone tool, slump checks are carried out for each mixing. The results can be seen in the table

Table 8. Slump test measurement results.

code	Measurement	High (mm)	low (mm)	Average (mm)
1	BN	120	80	100
2	BR	660	620	640
3	BM 251	680	620	650
4	BM 252	700	620	660

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Concrete Volume Weight Check. The inspection is carried out to determine the volume weight of the concrete test object in the form of a block or cylinder which is a comparison of the weight of the test object with the volume. The following is the analysis of the test data.

Table 9. Concrete weight inspection results

Weight Results of Lightweight Concrete Test Objects					
NO	**CODE**	**Age Day**	**Weight (kg)**	**Average (kg/m³)**	**specific gravity (kg/m³)**
1	BN 1	7	13,18	12,90	2.434,53
	BN 2	7	12,94		
	BN 3	7	12,72		
	BN 4	14	12,80		
	BN 5	14	12,74		
	BN 6	14	12,92		
	BN 7	28	13,16		
	BN 8	28	12,84		
	BN 9	28	12,80		
2	BR 1	7	8,34	9,14	1.725,77
	BR 2	7	8,50		
	BR 3	7	8,42		
	BR 4	14	9,60		
	BR 5	14	9,56		
	BR 6	14	9,32		
	BR 7	28	9,60		
	BR 8	28	9,54		
	BR 9	28	9,42		
3	BM 2511	7	9,52	9,75	1.840
	BM 251 2	7	9,24		
	BM 251 3	7	9,92		
	BM 251 4	14	9,40		
	BM 251 5	14	9,56		
	BM 251 6	14	9,20		
	BM 251 7	28	11,10		
	BM 251 8	28	10,04		
	BM 251 9	28	9,82		
4	BM 252 1	7	8,50	9,94	1.876,33
	BM 252 2	7	12,06		
	BM 252 3	7	8,30		
	BM 252 4	14	9,20		
	BM 252 5	14	8,46		
	BM 252 6	14	11,90		
	BM 252 7	28	10,90		
	BM 252 8	28	10,24		
	BM 252 9	28	9,92		

It is known from the data obtained that the weight of BR coded concrete/lightweight concrete without split aggregate is 1,725.77 kg/m3 and BM251/lightweight concrete with 25 % split with 10 x 10 mm gradation

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size is 1,840 kg/m3 . Meanwhile, BM252/light concrete with a 25% split with a gradation size of 10 x 20 mm is 1,876.33 kg/m3.

Concrete Treatment Process or Curing. After the concrete specimen is weighed and slightly dry and the mold can be disassembled, then the concrete specimen is treated or cured by soaking the specimen in a tub filled with clean water for several days according to the concrete age target of 7 days, 14 days and 28 days

Value of Concrete Compressive Strength.

The value of the compressive strength of characteristic concrete with a cylindrical heated Styrofoam mixture made in the Unissula laboratory. Tests were carried out at the age of 7 days, 14 days, and 28 days of concrete. the following results were obtained.

Table 10. The result of lightweight concrete compressive strength

Lightweight Concrete Compressive Strength Results						
NO	**CODE**	**Age 7 Days**	**Average age 7 Days**	**Age 14 Days**	**Average age 14 Days**	**Age 28 Days**
1	BN 1	22,70	**22,36**	23,57	23,53	26,73
	BN 2	22,67		21,23		
	BN 3	21,72		25,78		
2	BR 1	10,55	10,64	20,19	17,23	19,57
	BR 2	10,74		16,64		
	BR 3	10,63		14,86		
3	BM 251 1	10,12	10,65	14,30	13,37	15,19
	BM 251 2	9,96		15,02		
	BM 251 3	11,88		10,8		
4	BM 252 1	2,44	9,25	9,89	10,29	11,69
	BM 252 2	23,15		8,03		
	BM 252 3	2,17		12,96		

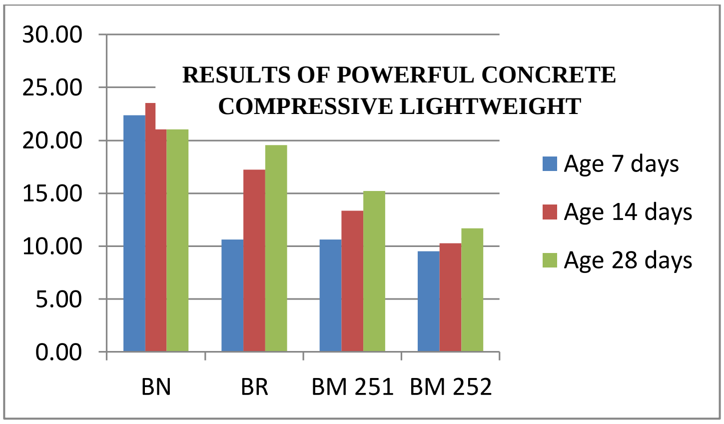

Chart 2. Compressive strength of lightweight concrete

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It is known from the data obtained that the compressive strength of lightweight concrete coded BR/lightweight concrete without split aggregate is 19.57 MPa and BM251/lightweight concrete with Split 25% gradation size 10 x 10 mm is 15.19 MPa while BM252/lightweight concrete with Split 25% gradation size 10 x 20 mm by 11.69 MPa.

Value of Split Tensile Strength of Concrete

Table11. Results of Split Tensile Strength at 28 Days

Results of Split Tensile Strength at 28 Days			
NO	**CODE**	**MPa**	**Average MPa**
1.	BN 7	3,575	3,44
	BN 8	3,574	
	BN 9	3,158	
2.	BR 7	1,903	2,15
	BR 8	2,165	
	BR 9	2,373	
3.	BM 251 7	3,386	2,74
	BM 251 8	2,611	
	BM 251 9	2,209	
4.	BM 252 7	3,110	2,83
	BM 252 8	2,813	
	BM 252 9	2,559	

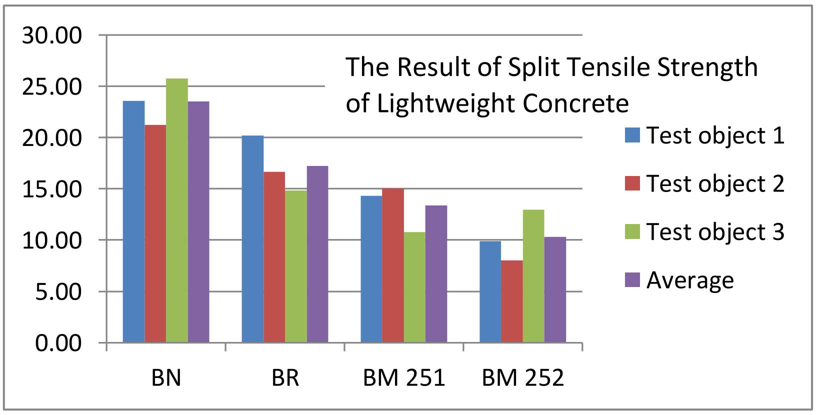

Chart 3. The results of the tensile strength of concrete

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It is known from the data obtained that the split tensile strength of lightweight concrete coded BR/lightweight concrete without split aggregate is 2.15 MPa and BM251/lightweight concrete with Split 25% grading size 10 x 10 mm is 2.74 MPa while BM252/lightweight concrete with Split 25% gradation size 10 x 20 mm by 2.83 MPa.

Bending Strength of Concrete

The value of the flexural strength of concrete with a rectangular heated Styrofoam mixture made in the Unissula laboratory. The test was carried out at the age of 28 days of concrete.

Table 12. The results of the flexural strength of lightweight concrete aged 28 days

NO	Code	Flexural strength (MPa)	Average (MPa)
1	BR a	2,361	2,14
	BR b	1,936	
2	BM 251 a	3,059	3,27
	BM 251 b	3,493	
3	BM 252 a	3,512	2,84
	BM 252 b	2,158	

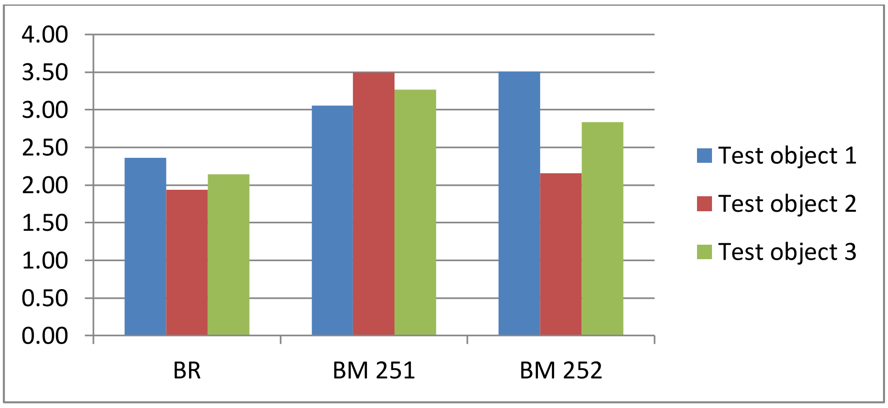

Chart 4. Flexural strength of concrete age 28 days

It is known from the data obtained that the flexural strength of lightweight concrete coded BR/lightweight concrete without split aggregate is 2.14 MPa and BM251/lightweight concrete with Split 25% gradation size 10 x 10 mm is 3.27 MPa while BM252/lightweight concrete with Split 25% gradation size 10 x 20 mm by 2.84 MPa.

IV.CONCLUSIONS

Based on the results of the analysis and discussion of research, the following conclusions are obtained:

1. The specific gravity of heated Styrofoam lightweight concrete without coarse/split aggregates obtained an average weight of 1,725.77 kg/m3 and lightweight mixed heated Styrofoam 25% split with a size of 10 x10

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mm obtained an average weight of 1,840 kg/m3, has comply with SNI 2847:2019 regarding the specific gravity of lightweight concrete with a maximum of 1,840 kg/m3.

2.a. The compressive strength of heated Styrofoam lightweight concrete without split mixture is 19.57 MPa, which meets the requirements in the SNI 2847:2019 lightweight concrete compressive strength of at least 17 MPa. Meanwhile, heated styrofoam mixed split 10 x 10 mm at 15.19 MPa and lightweight concrete heated styrofoam split 10 x 20 mm at 11.69 MPa did not meet the compressive strength requirements of lightweight concrete SNI 2847:2019 because it was below 17 MPa.

b. The split tensile strength of heated styrofoam lightweight concrete without split mix is 2.14 MPa, for lightweight concrete heated styrofoam split 10x10 mm it is 2.72 MPa and lightweight heated styrofoam split 10x20 mm is 2.82 MPa, all meet the requirements The split tensile strength of lightweight concrete SNI 2847:2019 is at least 2.1 MPa.

c. The flexural strength of lightweight concrete is obtained by heating styrofoam lightweight concrete without split aggregate of 2.14 MPa, lightweight heated styrofoam mixed split 10 x10 mm at 3.27 MPa, lightweight heated styrofoam split 10 x 20 mm concrete at 2.83 MPa. For the flexural strength of lightweight concrete, it is better that the lightweight concrete is heated styrofoam split mix 10 x 10 mm.

3. From the comparison of the three lightweight concrete mixtures, it is concluded that heated Styrofoam lightweight concrete without split aggregates is better in terms of compressive strength, than lightweight concrete using split mixtures. However, lightweight heated Styrofoam mixed split 10 x 10 mm is better in terms of tensile strength and flexural strength

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