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Light weight Concrete Making for Wall Panel Using Compression Technique

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Abstract: Indonesia is a country with relatively high earthquake activity. The selection and use of light weight building materials become very important in order to reduce building load when earthquake is occurring. There are several methods to produce lightweight concrete, including the use of lightweight aggregate like polystyrene waste. The use of concrete wall panel in houses or high-rise buildings construction aims to reduce construction cost and building time. Hence, study on the use of polystyrene for lightweight concrete wall panel with pre-compression technique would be very beneficial. This study deals with 3 specimen tests: group 1 is delaying with concrete compressive while group 2 is dealing with flexural strength and group 3 is dealing with compression strength. Group 1 consists of 3 pieces of cube specimen with dimensions of 7×7×7 cm while group 2 and 3 consist of 3 pieces of wall panel specimen with dimensions of 80×30×4 cm. The wall panel is reinforced with 2 layers of wire 0.6 mm grid 6×6 mm. In the specimens making process, a pressure of 2 MPa is applied. After 28 days, the specimens were tested by utilizing several equipment's such as primary loading frame, load cell, hydraulic jacks, LVDT and data logger. The test shows the average compressive strength polystyrene concrete is 2.72 Mpa with average of density is 1.332 kg m^{-3}. The elastic modulus of the polystyrene concrete is 278 MPa, the flexural strength of polystyrene concrete wall panel is 4.0423 MPa, the flexural rigidity of the polystyrene concrete wall panel is 897.37 Nmm^{-1} and the compressive strength of the polystyrene concrete wall panels is near to 4.1367 Mpa.

Key words: Compression waste polystyrene, wire counters, wall panel, polystyrene, Indonesia

INTRODUCTION

Concrete panel has length which longer than other building materials such as concrete brick and brick. Concrete panel is made from mix of cement, sand and gravel. In building activities, usually concrete panel is used for construction of wall and floor. Even though, wall construction using concrete panel would have heavy load of structure and earthquake but the use of concrete panel in house or high-wise building development could speed up the construction time and would affect to cost reduction. Therefore, lightweight concrete panel would be optimum solution in terms of structure load and construction time. Existing concrete panel in the market has density in average of >2.000 kg m^{-3} with pressure strength is varying from 3-50 MPa. Based on its density value, the existing concrete panel could be said quite heavy. A panel with size 240×60×6 cm would have weight around 150 kg. Heavy concrete panel would be hard to handle and takes longer time for installation. More lightweight concrete panel, easier to handle and faster to install. One of material alternatives that could be used to make lightweight concrete panel is Styrofoam particle. Lightweight Styrofoam concrete is a concrete that made by replacing all of rough and smooth aggregate with polystyrene. Material mix to make lightweight Styrofoam concrete consists of cement and compressed Styrofoam. Compressed means a loading process applied on lightweight materials with 2 MPa compression. Besides for getting lightweight concrete, replacing concrete aggregate with Styrofoam particle is named to utilize waste materials. Actually, Styrofoam is a trademark belongs to Dow Chemical Corps from USA. Therefore, in order to avoid misused of the trademark, in this study, general name of the Styrofoam which is Expanded Polystyrene (EPS) or polystyrene would be used to replace Styrofoam term. According to Standar Nasional Indonesia (SNI) 03- 3122-1992, the polystyrene concrete wall panel was categorized as medium-strength light weight concrete (moderate-strength light weight concrete) with average density 1.483 kgm^{-3}. Previous studies have been carried out and proven that polystyrene could be used as mix material for making lightweight concrete with wire mesh reinforcement. However, so far, the density of the

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concrete is still high which is around 1.400 kgm^{-3}. It caused by thick plastering and reinforcement dimension. In this study, making of concrete panel with thickness of 4 cm is investigated. Reinforcement using wire mesh with compression at mixing of 250 kg of cement and 100% of polystyrene is applied in order to get good pressure strength and to reduce the weight.

This study also aims to know characteristic of lightweight polystyrene concrete and its strength when holding loads at the wall, such as lateral loads and to know pressure strength and the density of the lightweight polystyrene concrete.

Literature review: With increasing of waste material, several previous researchers have conducted studies on the use of waste material to make lightweight panel concrete. Aslam *et al*. (2016) have reviewed several previous studies on the use of industrial waste, which is oil-palm-boiler clinker as a lightweight aggregate to produce structural lightweight aggregate concrete. In such paper, the physical, chemical and mechanical properties of oil-palm-boiler clinker aggregate and the mechanical properties and structural performance of oil-palm-boiler clinker concrete are addressed, discussed and compared with normal weight concrete. There are two types of aggregate concretes that have been investigated, which are coarse and fine aggregates contained oil-palm-boiler clinker and mixing between oil-palm-boiler clinker and normal sand for coarse and fine aggregates. Such study also discussed about sustainable production for concrete by using oil-palm-boiler clinker.

Feasibility study about the use of waste material for making lightweight concrete has been conducted by Nikbin *et al*. (2016). In such study, the use of waste Poly Ethylene Terephthalate (PET) for Normal PET Concrete (NPC) and Lightweight PET Concrete (LWPC) have been investigated based of their resistance against sulphuric acid erosion. There are 3 factor levels of the use of PET which are 5, 10 and 15% substitute fine natural aggregate and 3 factor levels of curing and immersing specimen in 5% sulphuric acid which are 15, 30 and 60 days. There are several test for the feasibility study which are crushing load, mass measuring and ultrasonic wave velocity tests. Based on that tests, result shows feasible and superiority performance compared to normal concrete. Besides, the use of large amounts of PET in lightweight PET concrete compensates for its disposal issues, protects natural resources, decreases the dead load of buildings due to its low unit weight and led to improving acid resistance.

The use of lightweight concrete has at least two benefits which are flexibility and cost. However, sufficient information about the structural performance such as the bond properties of lightweight concrete become very important in order to avoid a hindrance to the application of lightweight concrete in the construction industry. Mo have investigated the bond properties of lightweight aggregate concrete, foamed concrete and no-fines concrete in order to give sufficient information before application of lightweight concrete in industry. Potentiality of lightweight concrete has received major attention and has been developed by researchers. Vakhshouri and Nejadi (2016) have investigated mix between lightweight and self-compacting concrete. Lightweight concrete is an excellent solution for dead load problem while self-compacting concrete eases the pouring and removes construction problems. Combination of both advantages would be very beneficial for construction industries. Information from such study were very useful for next researchers to choose the proper components with different ratios and curing conditions to attain the desired concrete grade according to the planned application. Experimental study on strength and durability of lightweight concrete has been investigated by Youm *et al*. (2016). Such study details mechanical property and durability performance of high strength lightweight aggregate concrete with silica fume for 91 days. Compressive strength design of the high strength lightweight concrete is 60 Mpa at 28 days and the oven-dry density is below 1.900 kgm^{-3}. Results of such study indicate that the durability against chemical deterioration for LWAC incorporated to silica fume depends on the compositions of hardened cement pastes in concretes, while the durability against physical attack depends on the types of aggregates. Lotfy *et al*. (2016) have investigated durability properties of lightweight self-consolidating concrete. There are three types of light-weight aggregates which are Furnace Slag (FS), Expanded Clay (EC) and Expanded Shale (ES). The study shows fair result which mention advantages and disadvantages of the investigated the lightweight self-consolidating concrete. The advantages, it shows enhanced resistance against sulphuric acid attack due to proper formation of the cementitious paste matrix while the disadvantages, it shows unable to withstand severe freezing and thawing cycles.

MATERIALS AND METHODS

The research on wall panel is conducted by experimenting trials in laboratories. Flow diagram of the research is illustrated by Fig. 1.

Basic materials employ cements, polystyrene, wire counters and water. Polystyrene with diameter of ±1 is applied. While, wire counters that that will employed are depicted in Fig. 2.

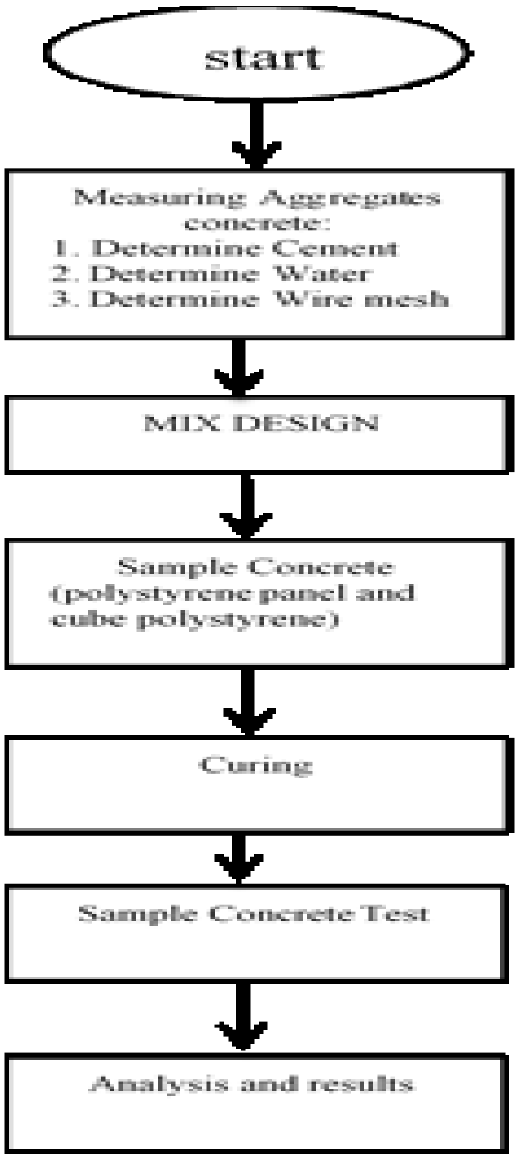

Fig. 1: Methodology

Fig. 2: Wiremash

This research is conducted in laboratories with several work steps. They include:

- Preparation stage, covers materials and tools preparation for research. Preparation and observation for stacked materials of polystyrene wall panel
- Material testing stage to identify characteristics of each material of Polystyrene wall panel
- Stirring planning stage, to discover correction on initial stirring after compression. Hence, on the manufacturing of specimen, correction composite will be employed
- Manufacturing of polystyrene wall panel specimen, covers calculation and weighing of each material, stirring and casting on moulds
- Maintenance stage, it conducted by covering specimen of polystyrene wall panel for 14 days with wet sack
- Specimen testing, both vertical compressive strength test and flexural test on polystyrene wall panel
- Data analysis stage

RESULTS AND DISCUSSION

Density of polystyrene concrete is listed in Table 1 as follows: from Table 1, it can be concluded that averagely, the density of polystyrene is 1332 kg m^{-3}. Therefore, concrete with polystyrene can be classified as lightweight concrete as the volume is less than 1800 kg m^{-3}.

While based on test, each panel is weighed 1483 kg m^{-3} averagely hence, according to Drobowolsky (1998) it included to structural lightweight concretes. If it is compared with products of Yumenboard (density of 570 kg m^{-3}) and panel M-system (density of 700 kg m^{-3}), Polystyrene panel still considered as heavier. Thus, yumenboard and M-System products have become business product with high strength specification and expensive. While, this research is emphasized to polystyrene waste utilization for construction purposes so, it is expected to produce construction materials which are cheap and environmental friendly.

Compression with 2 MPa, influences the weight of polystyrene panel hence, it becomes highly compressible with less hollow space. The calculation result of polystyrene concrete panel density is bigger than polystyrene concrete itself because the wire counters as reinforcement, the difference of thickness and the compression of specimen have already included in calculation. By using data of wire counters with diameter of 0.60 mm and grid 6×6 mm, yield stress (fy) is obtained

Table 1: Density of polystyrene concrete

Code	L (m)	W (m)	H (m)	V (m3)	Wght (kg)	WV (kg m^{-3})	AWV (kg m^{-3})
KB-1	0.738	0.734	0.734	0.0004	0.535	1346	1332
KB-2	0.730	0.730	0.767	0.0004	0.533	1304	
KB-3	0.739	0.737	0.725	0.0004	0.532	1347	

Table 2: Volume of polystyrene wall panel

Material test	L (m)	W (m)	H (m)	V (m^3)	Wght (kg)	WV (kg m^{-3})	AWV (kg m^{-3})
PL-1	0.8	0.3	0.040	0.0097	14.8	1523	1483
PL-2	0.8	0.3	0.041	0.0098	14.5	1474	
PL-3	0.8	0.3	0.041	0.0098	14.6	1491	
PT-1	0.8	0.3	0.040	0.0096	14.4	1493	
PT-2	0.8	0.3	0.040	0.0096	14.0	1458	
PT-3	0.8	0.3	0.040	0.0096	14.0	1458	

Table 3: Compressive strength of polystyrene concrete

Code	L (m)	W (m)	A (m^2)	ld (N)	Compressive Strenght (Mpa)	A-average compressive strenght(Mpa)
KB-1	0.074	0.0734	0.5417	15510	2.86	2.72
KB-2	0.073	0.0730	0.5329	11950	2.24	
KB-3	0.074	0.0737	0.5446	16640	3.06	

averagely 913.52 MPa. The result of test indicates that wire counters are considered as high qualified steel as their yield stress are higher than concrete steel that calculated around 400 MPa. Hence, they are suitable to be used as structure reinforcing. Compressive strength of polystyrene concrete on the day of 28th is resumed on the Table 3.

From Table 3, it can be concluded that average compressive strength of concrete cylinder on the day of 28th for specimen KB-1, KB-2 and KB-3 are 2.86, 2.24 and 3.06 MPa, consecutively. Varied results are obtained due to different densities of polystyrene in the manufacturing process of specimen. Therefore, it can be concluded that average compressive strength of concrete cylinder is 2.72 MPa. Compressive strength of Polystyrene concrete can be seen in Table 4, Diagram of Polystyrene concrete stress and strain can be observed in Fig. 1.

From Table 4, it can be explained that elastic modulus on specimens of KB-1, KB-2 and KB-3 are 194 MPa, 385 MPa and 250 MPa as well as 276 MPa, consecutively. From the test, it is resulted that elastic modulus of Polystyrene is varied due to differences on compression and densities.

From Fig. 3, it can be seen that the diagram of stress-strain Styrofoam concrete is different with normal concrete. Polystyrene concrete is pliant (ductile), so it absorbs more energy. Graph on result of flexural test on polystyrene concrete panel is demonstrated in Fig. 2. While maximum flexural test is presented in Table 5. The result of maximum load and deflection are demonstrated in Table 6. Furthermore, the result of comparison with previous researches is illustrated in Table 7.

Table 4: Elastic modulus of polystyrene concrete

Code	L (m)	W (m)	H (m)	Fcr (Mpa)	Cr (Mpa)	Ecr (Mpa)	Aecr (Mpa)
KB-1	0.0738	0.0734	0.0734	1.144	0.0059	194	276
KB-2	0.0730	0.0730	0.0767	0.896	0.0023	385	
KB-3	0.0739	0.0737	0.0725	1.224	0.005	250	

Table 5: Load and deflection of specimens on the first crack

Code	L (mm)	W (mm)	H (mm)	Ld (N)	Flt-eqv (Mpa)	A-Flt-eqv (Mpa)
PL-1	500	300	40.5	A/N	A/N	2.69
PL-2	500	300	41.0	1800*	2.68**	
PL-3	500	300	40.8	1700*	2.70**	

Table 6: Data of maximum elastic load and deflection of specimens

Code	L	W	H	Pcr (N)	α (mm)	K (N mm^{-1})	Ak (Nmm^{-1})
KB-1	0.8	0.3	0.0405	A/N	A/N	A/N	897.37
KB-2	0.8	0.3	0.0410	1800*	2.00	900	
KB-3	0.8	0.3	0.0408	1700*	1.90	895	

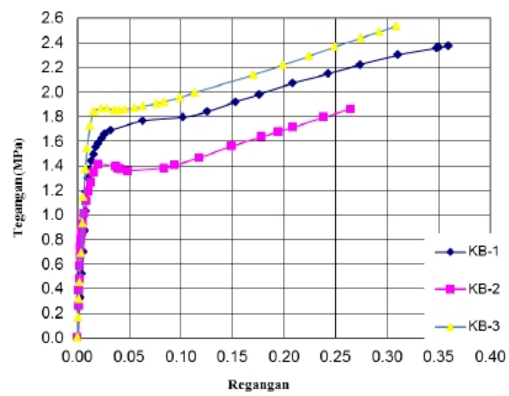

Fig. 3: Stress-strain of polystyrene concrete

From Table 5, it can be seen that flexural strength of specimens PL-1, PL-2 and PL-3 are A/N, 2.68 MPa and 2.70 MPa, consecutively. Average flexural strength of Styrofoam panel is 2.69 MPa, >SNI 03-3122-19921 which is 1.37 MPa. From Table 6 and Fig. 4 can be seen that flexural rigidity of the specimens PL-1, PL-2 and PL-3 are A/N; 900 MPa and 895 MPa, consecutively. Average polystyrene concrete panel is 897.37 MPa. Flexural rigidity of PL-1 is way below PL-2 and PL-3. It is caused by manual testing by using Hydraulic Jack, so the weighing speed of each test becomes unstable.

From Table 7, it can be described that compressive strength on lightweight polystyrene concrete 100% with compression of 2 MPa could enhance compressive strength to 2.26 MPa. It demonstrated bigger result than previous research that was conducted by Utomo that yielded 0.72 MPa that performed without compression. Recent research also accomplished grater result if it is compared with research from Sulistyorini

Table 7: Comparison result of lightweight concrete wall panel

Reseacher	Wide (cm)	Skin wide (mm)	Ø wire (mm)	Polystyrene (%)	Cement (kg m^{-3})	WCR	Fc' (cube MPa)	Flexural strenghtpanel (Mpa)	Weight panel (kg m^{-3})
Utomo9	8	5	3	100	300	0.48	0.72	3.01	1045.7
		10						4.08	
		15						4.15	
Sulistyorini10	6	10	4	80	350	0.43	1.583	10.85	1549.9
		15						8.78	
	8	10						12.06	
		15						8.68	
Wibowo11	7	15	3	60	350	0.5	3.348	5.84	1658.9
								5.10	
								5.78	
Our study	4		0.6	100	250	0.4	2.72	2.69	1483

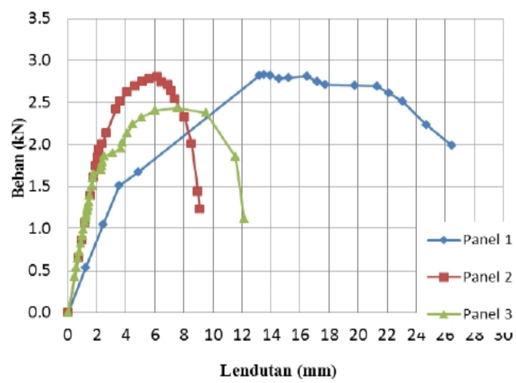

Fig. 4: Flexural test on wall panal

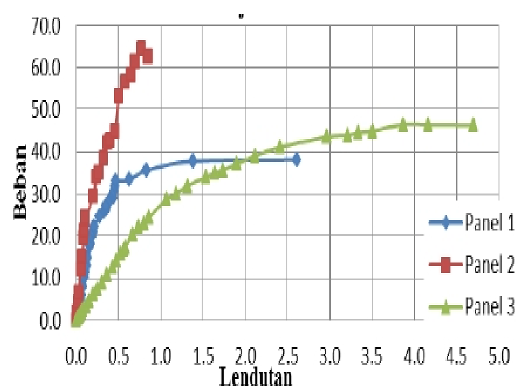

Fig. 5: Graph of compressive strength on polystyrene concrete panal

(2010) which was 1.583 Mpa with mixture composition of 80% polystyrene and 40% of sands. From Table 7, it can be resumed that flexural strength of polystyrene lightweight concrete 100% with compression of 2 MPa could enhance flexural strength to 4.0423 MPa. From the table, it can be seen the comparison of results towards previous research under different treatments.

From Fig. 5 and Table 8, it can be seen that compressive strength of specimen's PT-1, PT-2 and PT-3 are 31675, 5.3692 and 3.8733 Mpa

Table 8: Maximum compressive strength on polystyrene concrete panel

Sample code	L (mm)	W (mm)	H (mm)	MaxLoad (kN)	Ftk (Mpa)	A-Ftk (Mpa)
PL-1	800	30	40.2	38,2	3.1675	4.1367
PL-2	800	30	40	64.43	5.3692	
PL-3	800	30	40	46.48	3.8733	

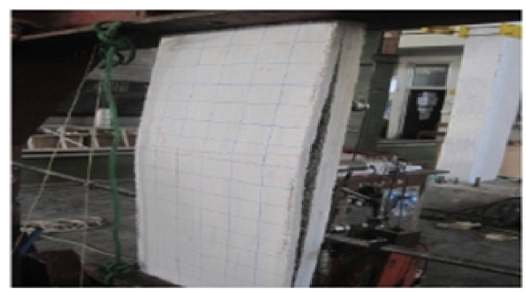

Fig. 6: Specimen of compressive test panal 1

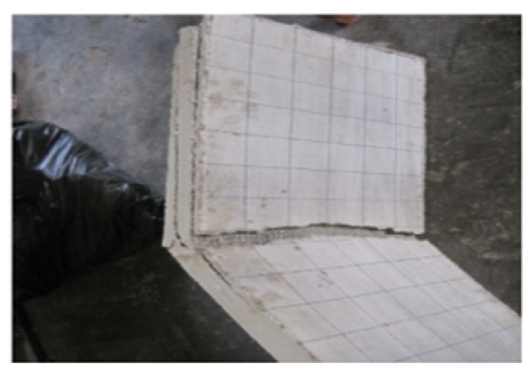

Fig. 7: Specimen of compressive test panel 2

Fig. 8: Specimen of compressive test panel 3

consecutively with average compressive strength of 4.1367 Mpa, >SNI 03-3122-19921 which is 3.45 MPa.

The difference of results on specimen PT-2 are experienced due to different weighing speed, the influence of polystyrene material, influence of coherency between cement, the influence of coherency between wire counters and cement. Type of specimens collapsing for PT-1, PT-2 and PT-3 can be seen in Fig 6-Fig. 8.

In Fig. 7 shows type of damage which is global buckling when whole wall is buckled as maximum load is exposed. Figure 8 demonstrates the panel separation when it is experiencing lack of adhesion between panels and Fig. 9 describes detached panel due to weak bonding between panels. Above three damaged panels are caused by furcation on the upper layer since the upper compression runs improperly if compared with the process in the lower layer which is so stable.

CONCLUSION

From this research, it can be further concluded that average compressive strength of polystyrene concrete is 2.72 MPa. Density of average polystyrene concrete is 1332 kgm^{-3}. Polystyrene concrete panel is categorized as lightweight concrete (density of 1483 kgm^{-2}) with middle level strength (flat equivalent = 2.69 MPa). Average modulus of elastic for polystyrene concrete is 276 MPa. Flexural strength of polystyrene concrete panel is calculated averagely 2.69 MPa. Average flexural rigidity of polystyrene concrete panel is 897.37 MPa. Average compressive strength of Polystyrene concrete panel is 4.1367 MPa. Flexural strength and compressive strength of the concrete wall panels with polystyrene processed with 2 Mpa compression is considered meets the SNI 03-3122-1992. Deflection of flexural test on Polystyrene for specimens of PL-1, PL-2 and PL-3 are A/N; 2.00 mm and 1.90 mm consecutively which is lower than maximum limit that required by SNI 03-2847-2002 which is (L/150) = 16.67 mm. Since, this research is carried out manually, future researches related to process of measurement, stirring and casting are highly recommended to achieve optimum results. Related to compression, it is also suggested to execute the compression with >2 MPa to enhance compressive and flexural strength on polystyrene wall panel. Furthermore, advance research on polystyrene partition panel reinforcement by the addition of other natural materials as coir fibers or coconut fibers is also advised.

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