1769 kg/m^3 respectively. Therefore, cube concrete with 0.38 and 0.40 w/c ratios are no longer considered as lightweight concrete. Therefore, the optimum w/c ratio of foamed concrete with 0% PP is 0.36.

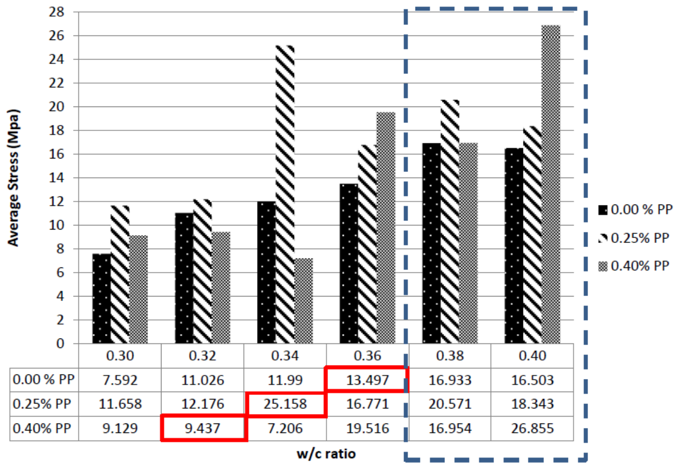


Fig. 3 Average compressive stresses vs. w/c ratio

The result of 0.25% PP shows that the highest stress is 25.185 MPa with the w/c ratio of 0.34. Based on the density and flow table measurement result, cubes concrete with w/c ratio of 0.38 and 0.40 can no longer be considered as lightweight foamed concrete. Therefore, by considering the density and the compressive strength of the concrete, 0.34 with the compressive strength of 25.26 MPa is taken as the optimum w/c ratio for foamed concrete with 0.25% PP.

It also can be observed that the compressive strength of the lightweight foamed concrete increase at 16.77 MPa at 0.36 w/c ratio to 20.57 MPa at 0.38 w/c ratio. This is because the lightweight foamed concrete with 0.38 w/c segregated and no longer acting as a foamed concrete but mortar concrete instead.

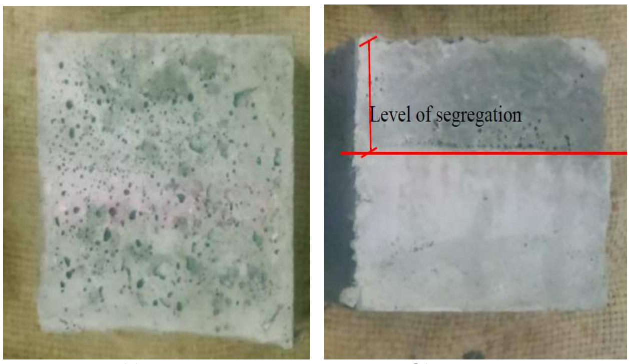
Fig. 4 shows the mode of failure of the segregated foamed concrete and normal foamed concrete. As shown in Fig. 4(a), the segregated layer break easily when compressive stress is applied to the cube while the failure mode of normal LFC (Fig.4(b)) is distributed uniformly.

Due to this, the compressive load is applied to the mortar surface, and only the mortar cross-sectional area was taken into account when calculating the compressive strength of the concrete. However, considering the characteristic of the lightweight foamed concrete itself, the cubes are no longer considered as a lightweight foamed concrete.

From the result of 0.40% PP, compression test of cubes with 0.40% PP. The highest average stress on the cube concrete is 26.86 MPa with the w/c ratio of 0.40. However, based on the result, the cube with 0.40% PP starts to segregate at w/c ratio of 0.36. As compression test applied, cubes with w/c ratios of 0.36, 0.38 and 0.40 resist the compression stress as a mortar with the strength range of 19.52 to 26.86 MPa.

Fig. 4 Modes of failure (a) segregated LFC (b) normal LFC

Therefore, to obtain the optimum w/c ratio of the lightweight foamed concrete, only 0.30 to 0.34 is taken into consideration. The highest stress is 9.44 MPa with w/c ratio of 0.32. So, 0.32 is taken as the optimum w/c compared to the 9.13 MPa and 7.21 MPa value of compressive strength. The condition of hardened foamed concrete with a water-cement ratio of 0.34 and 0.36 are shown in Fig. 5.



(a) w/c 0.34 (b) w/c 0.36

Fig. 5 The hardened concrete condition

B. *Optimum Water-Cement Ratio*

The optimum water-cement (w/c) ratio obtained is plotted on a graph as shown in Fig. 6. The Figure shows the relationship between the optimum water-cement ratio and the percentage of PP in lightweight foamed concrete. Based on the graph, the optimum w/c ratio decreases as the percentage of PP increase. This result is compared with another trial mix with cement/sand ratio of 3:1. The comparison is shown in Fig. 7.

Based on the result, the optimum w/c ratio obtained with 3:1 cement-sand ratio is slightly lower than the optimum water-cement ratio of 2:1. This proves that the amount of solid ratio affects the amount of water needed in maximizing the compressive strength of the foamed concrete. As seen in the graph, the range of the optimum w/c ratio which is 0.32 to 0.36. It also can be concluded that higher c/s ratio needs lower w/c ratio to produce the maximum strength, at the same time providing a workable concrete mix.

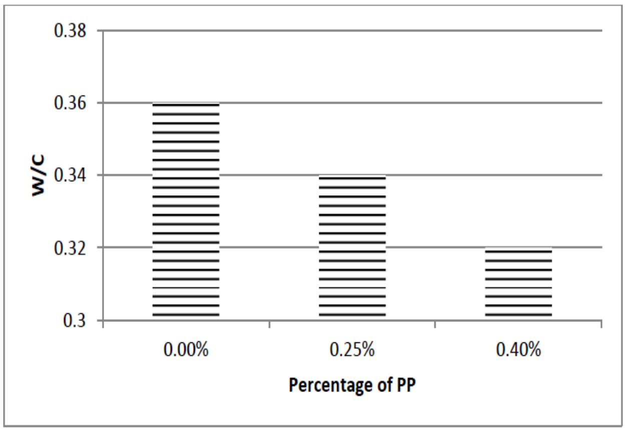


Fig. 6 Optimum w/c ratio vs. percentage of PP

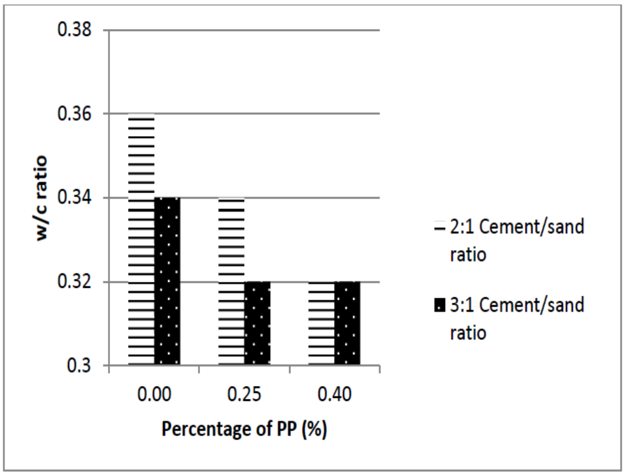


Fig. 7 Comparison of optimum w/c for LFC with 2:1 and 3:1 c/s ratio

C. Splitting Tensile Result

Table 3 show the result of the average density of cylinder foam concrete before and after curing. All the density of the specimens was controlled to 1500 kg/m^3. Based on the table shown, the density of cylinder concrete is increasing after several days of curing. It has also been observed that the increment in the average density of cylinder concrete is increasing as the period of curing increasing. This is because the concrete tends to absorb more water when it is immersed longer in water.

TABLE IIIII
AVERAGE DENSITY OF CYLINDER BEFORE AND AFTER CURING

Amount of PP	Average density of cylinder (kg/m^3)					
	7-day curing		28-day curing		90-day curing	
	Before curing	After curing	Before curing	After curing	Before curing	After curing
0.00%	1506	1549	1487	1593	1483	1602
0.25%	1494	1547	1492	1589	1489	1608
0.40%	1513	1547	1354	1422	1453	1576

Table 4 shows the summary result of the average tensile stress of three different percentage of PP with 7 days, 28 days and 90 days curing age applied to 3:1 cement-sand ratio. Note that, the cement-sand ratio of 3:1 is taken based on the consideration of the amount of sand to the mix. Based on the result obtained, few observations can be made. Firstly, based on the average splitting tensile strength of the control sample which with 0.0% PP, the average stress of splitting tensile test is increasing as the period of curing increase. The average stress is increasing from 1.63 MPa to 7 days to 2.14 MPa at 90 days of curing. This simply shows that the curing period of the concrete does affect the tensile strength of the lightweight foamed concrete.

However, when the polypropylene fiber was added to the mix, there is a slight change compared to the usual pattern of lightweight foamed concrete without the addition of any polypropylene fiber. At a normal curing period (7 days) the result of splitting tensile test is increasing as the amount polypropylene fiber added increase. This shows that polypropylene fiber does enhance the tensile strength of the lightweight foamed concrete. The interfacial adhesion between the matrix of the concrete and fibers improved. The Higher amount of polypropylene fiber may be permits higher stress transfer. Thus, increases the tensile splitting strength of the foamed concrete. This pattern of the result is the same as with the pattern of a previous study [13] where the splitting tensile strength is increasing until at the addition of 1.5% PP.

TABLE IVV
AVERAGE STRESSED FROM SPLITTING TENSILE TEST

Amount of PP	Average splitting tensile stress (MPa)		
	7-day	28-day	90-day
0.00%	1.613	1.935	2.138
0.25%	1.715	1.649	1.743
0.40%	1.815	0.991	1.647

However, by comparing the average stress withstand by the lightweight foamed concrete with 0.25% PP and 0.40% PP for 28 days and 90 days, the stress is decreasing from 1.65 MPa to 0.99 MPa and 1.74 to 1.65 MPa respectively. This is opposing to the result of 7 days curing. The possible reason is the characteristic of the foamed concrete which is porous. This is because the non-uniform distribution and orientation of PP cause some cracks in the concrete hence lowering the strength.

Next, by looking at the result of 0.40% PP at the curing of 28 days, the average stresses are the slightly off compared to other values. This may be because of the poor dispersion and orientation of PP fibers in the foamed concrete mixed that consequently increase the pore volume of cement matrix and creates more micro defects in cement matrix thus decreasing the tensile strength of the concrete. Another reason for 0.40% PP at 28 days to have a very low stress is due to the improper placing during the moulding process as was mentioned before. This can be seen with the changes of its density to a very low density during the hardening process, which changes from its controlled density 1500 kg/m^3 to 1354 kg/m^3.

IV. CONCLUSIONS

From the data results discussion, several conclusions of the study are stated in order to answer the objectives of the study:

- The density achieved in this experiment is in the range of 1940 kg/m^3 to 1540 kg/m^3 with the achieved compression strength range 7.21 MPa to 25.16 MPa.

- The optimum obtained from the compressive strength results with c/s ratio of 2:1 is 0.36, 0.34 and 0.32 for addition of polypropylene fiber of 0.00%, 0.25% and 0.40% respectively. For cement/sand ratio of 3:1, the optimum w/c is 0.34, 0.32 and 0.32 respectively. It can be concluded that the optimum w/c ratio needed to achieve the maximum compressive strength is decreased as the amount of polypropylene fiber increases.
- The addition of polypropylene fiber enhances the tensile strength of the lightweight foamed concrete. By looking the result of splitting tensile strength for 7 days, the tensile strength increase from 1.61 MPa to 1.82 MPa.

Overall, it can be concluded that polypropylene does enhance the tensile strength of the foamed concrete but not with significant increment. However, the split tensile strength results do not give the perfect estimation about the tensile strength of concrete because of the mixed stress field and fiber orientation. Although the result gives the good pattern about the mechanical strength of the material.

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