Cracking behaviour of green lightweight concrete one-way slabs using medium K Basaltic Andesitic pumice and Scoria

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Abstract. This paper investigates experimentally the cracking behaviour of green lightweight concrete one-way slabs where coarse aggregates comprised medium K basaltic andesitic pumice and scoria. Three points bending test was performed on 24 one-way slabs of both lightweight concrete with three compressive strengths and four reinforcement ratios, and 1 one-way slab of normal concrete as control. Responses consisted of crack width, mid-span reinforcement strain and mid-span deflection that were measured for observation purposes. To show the cracking behavior, their low tensile strengths were evaluated by representing their compressive strengths. Load versus crack width and reinforcement strain diagrams are simultaneously used to evaluate their cracking behaviors. Effects of reinforcement ratio, reinforcement stress, type of lightweight concrete and compressive strength to the maximum crack width are also investigated. Similarly, cracking patterns as well as failure modes are observed to show their appropriate performances. The results show that the reinforcement ratio and reinforcement stress are the main factors that affect significantly the cracking behavior and maximum crack width. However, the type of lightweight concrete and compressive strength affect them but less significantly. All one-way slabs exhibited a typical flexural crack, at the first time the reinforcement yields and then the concrete compressive zone crushes.

1. Introduction
One of the problems in a structural lightweight concrete is the use of artificial lightweight coarse aggregates that require high thermal energy to produce them [1] so that it does not support energy saving programs. In addition, during manufacturing it releases air pollution so that these products are less environmentally friendly. The utilization of volcanic lightweight coarse aggregates such as pumice and scoria are considered as one of the solutions to overcome the disadvantages of this lightweight concrete [2]. These natural aggregates are abundant and spread evenly in the existing check dams so it is easy to explore them. Several studies on pumice and scoria lightweight concretes were conducted previously [3-7] and the results fulfilled the requirements of structural lightweight concrete with the reduction of density is approximately 20 %. Thus, this typical lightweight concrete can be considered as green lightweight concretes that save energy, are more environmentally friendly and can be used for structural elements of the building.

Kelud Volcano is located in East Java Indonesia, it ejects simultaneously medium K basaltic andesitic pumice and scoria in certain period as part of the explosive eruption products. These vesicular rocks differ only in color however their chemical composition, mineralogy and texture are practically similar. Furthermore, their specific gravities are greater than one [8] so that they are directly submerged in water.
The study of these volcanic rocks as coarse aggregates on structural lightweight concrete was conducted by [9, 10] and the results showed that these aggregates were categorized as the lightweight coarse aggregates and had unique properties that differed from existing pumice and scoria. The production of these pumice and scoria structural lightweight concrete used PPC, without admixture and coarse aggregates were presoaked for 18 hours. They yielded a maximum compressive strength of 30 MPa with approximately 20% reduction of density. Their chord modulus of elasticity were approximately (73-76) % of normal concrete as control. However, their splitting tensile strength and modulus of rupture were relatively low where their magnitudes ranged (81-84) % of control.

The use of dolomite limestone as coarse lightweight aggregates on reinforced concrete beams indicated a similar behavior in flexure compared with reinforced normal concrete beams [11]. Meanwhile, the utilization of scoria lightweight aggregate on reinforced concrete beams also showed that similarity as structural elements [12]. The application of medium K basaltic andesitic pumice and scoria as coarse aggregates on reinforced concrete one-way slabs was carried out by [10, 13]. The results showed that these lightweight coarse aggregates can be utilized practically on reinforced concrete one-way slabs with sufficient performance. These kind one-way slabs also showed the typical flexural behavior on the reinforced concrete structures with initial cracking loads, ultimate loads and stiffness were lower than those of normal concrete one-way slab as control. By considering their reduction of density mentioned previously, the tall building self-weight, for example, may be significantly reduced. The building dimensions can be reduced and overall costs may also be significantly reduced, then the building mass decreases, the horizontal and inertial forces decrease so that the risk of damage due to the earthquake also decreases [2]. Furthermore, these typical one-way slabs may support a green building program and it can be produced as a precast slab element that can reduce their self-weight because the slab is a structural element that dominates the total volume of building.

One of the characteristics of the serviceability of reinforced concrete structures is the maximum crack width that must be evaluated due to the low tensile strength [14, 15]. The cracking behavior can be investigated from load versus crack width diagrams obtained by bending test of reinforced concrete structures while the maximum crack width determined at the specified service load. Steel reinforcement stress and reinforcement ratio are the main factors that affect significantly the cracking behavior and maximum crack width [16]. However, the mechanical characteristics of concrete, i.e. the compressive strength, tensile strength as well as modulus of elasticity also influence them but less significantly. The maximum crack width depends on the maximum crack spacing which is influenced by the bond strength between the steel reinforcement and the concrete surrounding it [17]. To simplify the calculation, usually the bond strength is expressed proportionally by the concrete tensile strength [18-20], when the tensile strength decreases the bond strength also decreases. Meanwhile, for increasing bond strength, the maximum crack spacing decreases and the maximum crack width also decreases.

As mentioned previously, the tensile strength of these typical pumice and scoria lightweight concrete are relatively low, this was due to their high porosities and amorphous glass microstructures [9, 10]. The Splitting tensile strength and modulus of rupture were approximately 9% and 12% of their compressive strength and lower than normal concrete as control. Furthermore, both tensile strengths correlated with their compressive strength and were expressed precisely in power function of the compressive strength [21]. The failure mode of lightweight concrete also differs from normal concrete, initial cracks will occur in coarse aggregates because they are weaker than cement paste and transition zone [10, 22]. The proportion of these coarse aggregates occupied a large part of their total volume, then if they are used as the material of structural elements, these disadvantages should be considered. The cracking behavior as well as the maximum crack width of one-way slabs using both lightweight concretes, may be affected similarly by the weaknesses of the pumice and scoria coarse aggregates.

The objective of this study is to investigated experimentally the effect of pumice and scoria concrete disadvantages on cracking behavior and maximum crack width of one-way slabs. These disadvantages are only emphasized on the tensile strengths which will be represented by their compressive strengths. For comparison, the cracking behavior and maximum crack width are also evaluated by varied reinforcement ratio of one-way slabs and measured tensile strain on the steel reinforcement level. In this
study, other factors such as steel bar diameter, concrete cover and reinforcement spacing are not considered and specified for all testing specimens.

2. Experimental investigation

2.1. Construction materials
The lightweight coarse aggregates were produced from medium K basaltic andesitic pumice and scoria that obtained from lava catchment area or check dams of Kelud volcano. They consisted of 4 fractions with maximum particle size was 19 mm, their grading was designed according to the requirements of ASTM C330-04 [23] and the fineness modulus were 6.69 [9]. The photograph of these typical pumice and scoria is presented in Figure 1, while the grading of both lightweight coarse aggregates is presented in Figure 2. The local crushed stones were used as control of normal aggregate with similar previous grading. The light river sand was used as fine aggregates with its grading was according to ASTM C330-04 [23] and the fineness modulus was 2.61 [9]. The binders consisted of Portland Pozzolana Cement (PPC) and clean water for drinking, while admixtures were not used in all concrete mixtures. The steel deformed bars D13 were utilized as the longitudinal reinforcement while the transversal reinforcements were plain bars $\phi 6$. The mixed proportion of structural lightweight concrete using these typical pumice and scoria were designed in accordance with ACI 211.2-98 (R2004) [24]. Pumice and scoria lightweight concrete comprised three mixed proportions with determined compressive strengths of 20 MPa, 25 MPa and 30 MPa, respectively. Meanwhile, the control of normal concrete with local crushed stone as coarse aggregate, and its mixed proportion was designed according to ACI 211.1-91 (R2002) [25] with specified compressive strength of 25 MPa. The slump value for all fresh concrete was determined approximately (60-70) mm with 3 % estimated air content.

![Figure 1. Medium K basaltic andesitic pumice and scoria.](image1)

![Figure 2. The grading of both lightweight coarse aggregates.](image2)

2.2. Fabrication of one-way slab specimens
Specimens comprised three groups, group A (PLCS) consisted of 12 one-way slabs made with pumice lightweight concrete, group B (SLCS) consisted of 12 one-way slabs made with scoria lightweight concrete and group C (NCS) was one one-way slab made with normal concrete as control. Groups A and B included three variations of previous compressive strength and each consisted of four variations of reinforcement ratios. The reinforcement ratios were designed between $\rho_{\text{min}}$ and $\rho_{\text{max}}$, such that they comprised 3, 4, 5 and 6 steel deformed bars. The detail of the experimental design is presented in Table 1, whereas the detail of one-way slab dimensions is presented in Figure 3 [13]. Five transversal reinforcements bounded the longitudinal reinforcements that assembled according to the previous amount of deformed steel bar. The tensile strain in steel bar level were measured by a strain gauge pasted at mid-span of the one of longitudinal reinforcement.
Table 1. Detail of experimental design.

| Group | Lightweight coarse aggregates | Concrete compressive strength (MPa) | Label of one-way slab | Number of reinforcement | Reinforcement ratio $\rho$ |
|-------|--------------------------------|-----------------------------------|-----------------------|-------------------------|--------------------------|
| A     | Pumice                         | 20                                | PLCS11                | 3                       | 0.00671                  |
|       |                                 |                                   | PLCS12                | 4                       | 0.00895                  |
|       |                                 |                                   | PLCS13                | 5                       | 0.01119                  |
|       |                                 |                                   | PLCS14                | 6                       | 0.01342                  |
|       |                                 | 25                                | PLCS21                | 3                       | 0.00671                  |
|       |                                 |                                   | PLCS22                | 4                       | 0.00895                  |
|       |                                 |                                   | PLCS23                | 5                       | 0.01119                  |
|       |                                 |                                   | PLCS24                | 6                       | 0.01342                  |
|       |                                 | 30                                | PLCS31                | 3                       | 0.00671                  |
|       |                                 |                                   | PLCS32                | 4                       | 0.00895                  |
|       |                                 |                                   | PLCS33                | 5                       | 0.01119                  |
|       |                                 |                                   | PLCS34                | 6                       | 0.01342                  |
| B     | Scoria                         | 20                                | SLCS11                | 3                       | 0.00671                  |
|       |                                 |                                   | SLCS12                | 4                       | 0.00895                  |
|       |                                 |                                   | SLCS13                | 5                       | 0.01119                  |
|       |                                 |                                   | SLCS14                | 6                       | 0.01342                  |
|       |                                 | 25                                | SLCS21                | 3                       | 0.00671                  |
|       |                                 |                                   | SLCS22                | 4                       | 0.00895                  |
|       |                                 |                                   | SLCS23                | 5                       | 0.01119                  |
|       |                                 |                                   | SLCS24                | 6                       | 0.01342                  |
|       |                                 | 30                                | SLCS31                | 3                       | 0.00671                  |
|       |                                 |                                   | SLCS32                | 4                       | 0.00895                  |
|       |                                 |                                   | SLCS33                | 5                       | 0.01119                  |
|       |                                 |                                   | SLCS34                | 6                       | 0.01342                  |
| C     | Local crushed stone            | 25                                | NCS22                 | 4                       | 0.00895                  |

Before concrete mixing, a presoaking treatment on pumice and scoria coarse aggregates were performed during 18 hours in order to reduce high absorption as well as high rate absorption. All one-way slabs were casted in two layers on plywood moulds and compacted carefully by a vibrator. Four 150x300 mm cylinders were casted simultaneously for each casting of half one-way slab in order to measure their compressive strength and equilibrium density. Demolding of concrete cylinder were performed after 24 hours casting. All specimens were cured by covering them within wet burlaps during 7 days and then placed in a dry room until 28 days, whereas demolding of one-way slabs were carried out after 21 days. The curing of equilibrium density as well as its testing were conducted in according to ASTM C567-00 [23].

2.3. Instrumentation and testing procedure

Three points bending test diagram is presented in Figure 4, where all one-way slabs were assumed as a simple beam with 2000 mm span. The testing was carried out at 28 days by a point load at mid-span. The vertical loading was generated by a manual handy pump to load cell through hydraulic jack, then a rigid lateral loading spreader transferred it to slab surface. The strain gauges pasted previously measured tensile reinforcement strains, whereas LVDT measured the mid-span deflections that was installed at
the central bottom side. To remove anything slack on the supports, all one-way slabs were subjected to an initial loaded approximately 0.5 kN and then all instruments were initialized. A USB digital microscope photographed the maximum crack widths and then a complementary software incorporated on the equipment was used to measure them precisely. During testing, the load indicator recorded loading data outputs, the strain-meter recorded the mid-span reinforcement strains whereas the data logger measured the mid-span deflections. All responses were simultaneously recorded at 2 kN interval of the monotonic loading until failure. After failure, the total number of cracks were appropriately counted on the two side slabs. Compressive tests were also carried out on concrete cylinders at the similar day to determine their compressive strengths as well as their chord modulus of elasticity. The testing instrumentation set up is presented in Figure 5.

Figure 3. Reinforcement of one-way slab sections.

Figure 4. Three points bending test diagram.
3. Results and discussion

3.1. Construction materials
The equilibrium density of pumice and scoria lightweight concretes ranged (1867-1878) kg/m³ and (1891-1919) kg/m³, respectively. These are lower than 1920 kg/m³ and then satisfy to requirements of structural lightweight concrete [2]. The density measured at 28 days of normal concrete as control is 2385 kg/m³, this means that the reduction of density of both lightweight concretes is approximately 20%. The compressive strength of these lightweight concrete ranged (22-30.50) MPa and (23-31) MPa, respectively, these mean that the measured compressive strengths satisfy those determined in their mix designs. The chord modulus of elasticity of this lightweight concrete ranged (12293-14942) MPa and (12367-15159) MPa, these are approximately 73% of normal concrete as control, i.e. 18630 MPa. The yield tensile strength of steel reinforcement was 458 MPa whereas ultimate tensile strength was 648 MPa, modulus of elasticity was 205 GPa and yield tensile strain was 0.00224.

3.2. Load versus crack width diagrams
Figure 6 shows an example of load versus crack width diagrams for the second compressive strength of both lightweight concretes. Increasing the crack width due to the given load yield a different slope of the curve referenced from the initial cracking point. When the reinforcement ratios increase, the maximum crack widths decrease significantly and the curve becomes nonlinear. The type of lightweight concrete, i.e. pumice and scoria lightweight concretes may be said to affect the crack widths less significantly. Furthermore, the magnitude of initial cracking loads differ less significantly. Similarly, for the first and third compressive strengths also indicate a similar trend.

3.3. Load versus mid-span reinforcement strain diagrams
Figure 7 constitutes an example of load versus mid-span reinforcement strain diagrams for the second compressive strength of both lightweight concretes. The diagrams are characterized by three different curve segments, namely the linear curve from the origin to the initial crack point, linear curve with a lower slope to yield reinforcement point and third curve until its failure. When the reinforcement ratios increase, the mid-span reinforcement strains decrease significantly, the slope of the curve also increases so that the one-way slab stiffness increases. The magnitude of the reinforcement strain at the initial cracking load differ less significantly, while the type of lightweight concrete also does not affect them. The tensile strain correlates proportionally with the tensile stress on this reinforcement so that their diagrams may also similar. Similarly, for the first and third compressive strengths also indicate the similar trend.
Figure 6. Load versus crack width diagrams.

Figure 7. Load versus mid-span reinforcement strain diagrams.

Figure 8. Comparison with control.
3.4. Comparison with control

Figure 8 shows a comparison with normal concrete one-way slab for two sample diagrams presented above. The trend of increasing crack width may not be significantly different between three types of one-way slabs, however the initial cracks of one-way slabs made with pumice and scoria lightweight concretes occur earlier than control. Similarly, the trend of increasing of mid-span reinforcement strain also indicates the similar trend.

3.5. Results of three points bending test

Table 2 shows the results of three points bending test for one-way slabs utilizing pumice and scoria lightweight concretes and control. The cracking loads were measured when the initial crack occurs, the ultimate loads were measured when the failure of one-way slab occurs and the numbers of crack were calculated on both sides. The service loads are determined based on the assumption that its magnitude is the ultimate load divided by 1.6 [24], while the maximum crack widths, mid-span reinforcement stresses and mid-span deflections are related to these service loads. The mid-span reinforcement stresses are calculated based on the elastic property before their yield points with modulus of elasticity presented previously. The mid-span deflections are determined from the load versus mid-span deflection diagram which were also measured simultaneously in the three points bending test. The comparison of load versus mid-span deflection diagram of both lightweight concretes with control is presented in Figure 13. It can be seen that the mid-span deflections of one-way slabs using both lightweight concretes are lower than the control so that their stiffness are also lower. This may be due to their modulus of elasticity which are lower than the control as mentioned previously.

3.6. Effect of reinforcement ratio and compressive strength

Figure 9 shows the effect of reinforcement ratio on the maximum crack width for three variations compressive strength of both lightweight concretes. The maximum crack widths decrease significantly to the increase in the reinforcement ratios with the average decrease is approximately 18 %. When the reinforcement ratio increases, the number of reinforcement bars also increases and the distance of each longitudinal reinforcement decreases. The tensile force due to flexure may spread according to the amount of reinforcement so the tensile force on each reinforcement bar decreases. The capability of each reinforcement bar to bond with lightweight concrete increases and the tendency to slip decreases so that the maximum crack width is also significantly reduced. Meanwhile, when the compressive strength of both lightweight concretes increases, the maximum crack width decreases, but these effects are less significant.

Figure 10 shows an example of the effect of compressive strengths on the maximum crack width for the second reinforcement ratio. The maximum crack widths decrease less significantly to the increase in the compressive strengths with the average decrease is approximately 5.64 %. When the compressive strength increases, the tensile strength increases so that its bond strength also increases. The capability of each reinforcement to bond with lightweight concrete also increases and the tendency to slip decreases so that the maximum crack width decreases less significantly. Thus, the reinforcement ratio affects the maximum crack width more significant than the compressive strength. Similarly, the other reinforcement ratio also indicates similar trends.

| Label | Cracking load $P_c$ (kN) | Ultimate load $P_u$ (kN) | Number of crack | Service load $P_s$ (kN) | Maximum crack width $w_s$ (mm) | Mid-span reinforcement stress $f_s$ (MPa) | Mid-span deflection $\Delta_s$ (mm) |
|-------|--------------------------|--------------------------|----------------|--------------------------|-----------------------------------|--------------------------------------|-----------------------------------|
| PLCS11 | 7.85                     | 28.43                    | 13/13          | 17.77                    | 0.380                             | 337.46                               | 10.48                             |
| PLCS12 | 7.98                     | 37.32                    | 15/17          | 23.33                    | 0.335                             | 316.37                               | 10.87                             |
| PLCS13 | 8.34                     | 46.56                    | 18/18          | 29.10                    | 0.275                             | 301.83                               | 11.72                             |
| PLCS14 | 8.96                     | 50.63                    | 16/19          | 31.64                    | 0.225                             | 284.43                               | 11.84                             |
Table 2. Results of three points bending test (cont.)

| Label   | Cracking load $P_c$ (kN) | Ultimate load $P_u$ (kN) | Number of crack | Service load $P_s$ (kN) | Maximum crack width $w_s$ (mm) | Mid-span reinforcement stress $f_s$ (MPa) | Mid-span deflection $\Delta_s$ (mm) |
|---------|--------------------------|---------------------------|-----------------|-------------------------|---------------------------------|----------------------------------------|-------------------------------------|
| PLCS21  | 7.98                     | 29.32                     | 13/11           | 18.33                   | 0.343                           | 332.96                                 | 9.91                                |
| PLCS22  | 8.25                     | 38.84                     | 17/18           | 24.28                   | 0.308                           | 312.89                                 | 10.61                               |
| PLCS23  | 8.83                     | 48.22                     | 17/18           | 30.14                   | 0.252                           | 297.94                                 | 11.64                               |
| PLCS24  | 9.38                     | 51.76                     | 19/19           | 32.35                   | 0.213                           | 283.20                                 | 11.79                               |
| PLCS31  | 8.12                     | 30.72                     | 15/17           | 19.20                   | 0.328                           | 332.14                                 | 9.48                                |
| PLCS32  | 8.51                     | 39.78                     | 16/17           | 24.86                   | 0.287                           | 311.46                                 | 10.53                               |
| PLCS33  | 9.15                     | 50.13                     | 18/20           | 31.33                   | 0.238                           | 293.03                                 | 11.20                               |
| PLCS34  | 9.78                     | 52.72                     | 18/21           | 32.95                   | 0.205                           | 281.56                                 | 11.29                               |
| SLCS11  | 8.16                     | 29.14                     | 12/13           | 18.21                   | 0.373                           | 337.05                                 | 10.37                               |
| SLCS12  | 8.47                     | 39.82                     | 12/12           | 24.89                   | 0.332                           | 315.76                                 | 10.66                               |
| SLCS13  | 8.72                     | 47.61                     | 14/15           | 29.76                   | 0.268                           | 303.88                                 | 10.99                               |
| SLCS14  | 9.31                     | 51.33                     | 16/16           | 32.08                   | 0.223                           | 284.22                                 | 11.35                               |
| SLCS21  | 8.14                     | 31.26                     | 14/17           | 19.54                   | 0.341                           | 331.73                                 | 9.90                                |
| SLCS22  | 8.34                     | 40.34                     | 16/16           | 25.21                   | 0.304                           | 309.20                                 | 10.58                               |
| SLCS23  | 8.77                     | 50.00                     | 18/18           | 31.25                   | 0.245                           | 296.92                                 | 11.24                               |
| SLCS24  | 9.43                     | 53.37                     | 17/18           | 33.36                   | 0.206                           | 282.79                                 | 11.37                               |
| SLCS31  | 8.24                     | 32.68                     | 15/17           | 20.43                   | 0.316                           | 329.68                                 | 9.46                                |
| SLCS32  | 8.50                     | 41.88                     | 17/19           | 26.18                   | 0.281                           | 305.11                                 | 10.49                               |
| SLCS33  | 9.26                     | 51.41                     | 17/20           | 32.13                   | 0.237                           | 290.77                                 | 11.18                               |
| SLCS34  | 9.80                     | 54.44                     | 19/18           | 34.03                   | 0.204                           | 278.49                                 | 11.26                               |
| NCS22   | 9.98                     | 41.34                     | 16/16           | 25.84                   | 0.304                           | 307.97                                 | 8.96                                |

Figure 9. Maximum crack width versus reinforcement ratio diagrams.

3.7. Effect of mid-span reinforcement stress
Figure 11 shows an example of the effect of mid-span reinforcement stress on the maximum crack width for the second compressive strength. The maximum crack widths increase significantly to the increase in the mid-span reinforcement stress with the average increase is approximately 20%. When the mid-span reinforcement stress increases, the given load increases and the maximum crack width also increases significantly. Meanwhile, the reinforcement ratio increases, the mid-span reinforcement stress decreases and the maximum crack width also decreases. It can be also seen that the type of lightweight
concrete does not affect significantly the maximum crack width. Similarly, the first and third compressive strengths also indicate the similar trend.

3.8. Effect of typical lightweight concrete
Figure 12 shows the effect of reinforcement ratio on the maximum crack width for the second compressive strength in considering the typical lightweight concrete. The maximum crack width for scoria lightweight concrete is lower than that for pumice lightweight concrete, but its difference is less significant, i.e. approximately 2%. This may be due to the difference of tensile strength that does not differ significantly so that the maximum crack width also does not vary significantly. Similarly, the first and third compressive strength also indicate the same trend. The results of this evaluation are precisely similar of those presented by previous researchers and literatures reviewed, that the reinforcement ratio and reinforcement stress are the main factors that affect the maximum crack width. However, the compressive strength or tensile strength of lightweight concrete and the type of lightweight concrete affect it less significantly.

Figure 10. Maximum crack width versus ccompressive strength diagram.

Figure 11. Maximum crack width versus mid-span reinforcement stress diagram.

Figure 12. Maximum crack width versus typical coarse aggregates.

Figure 13. Maximum crack width versus mid-span deflection diagram.
3.9. Cracking patterns and failure modes

Figure 14 shows the cracking patterns for one-way slabs made with pumice and scoria lightweight concretes, and control. All cracking patterns exhibited a typical flexural crack while the number of cracks on both sides of one-way slabs varies as presented in Table 2. It can be seen that for the second compressive strength as well as the second reinforcement ratio, the number of cracks for pumice lightweight concrete is greater than the control whereas for scoria lightweight concrete is similar. The failure modes of all one-way slabs were similar with previous design, i.e. at the first time the reinforcement yields and then the concrete compressive zone crushes.

![Figure 14. Three typical one-way slabs cracking patterns.](image)

4. Conclusions

This paper shows that the disadvantages of lightweight concrete made with medium K basaltic andesitic pumice and scoria, affect less significantly on the cracking behaviour and maximum crack width of one-way slabs. This is confirmed by the investigation of the compressive strength of lightweight concrete which is related analytically to their tensile and bond strength. In addition, the reinforcement ratio, steel reinforcement stress and the type of lightweight concrete were also investigated for observing its effect on cracking behavior and maximum crack width. From this evaluation reported on this study, five following conclusions are drawn:

- The compressive strength of both lightweight concretes may have a low effect on the cracking behavior and maximum crack width measured on one-way slabs. Therefore, the tensile and bond strengths may also have a less significant effect.
- The reinforcement ratio and steel reinforcement stress constitute the main factors that contribute more significant on the cracking behavior and maximum crack width measured on one-way slabs.
- The type of lightweight concrete may be said not affects the cracking behavior and maximum crack width measured on one-way slabs.
- The one-way slab cracking patterns are typical flexural cracks whereas the failure modes are similar with previous design, i.e. at the first time the reinforcement yields and then the concrete compressive zone crushes.
- As natural resources that are more environmentally friendly, both typical pumice and scoria can use practically for producing lightweight concrete of one-way slabs as precast elements of green building.

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