Behavior Studies of Columns with Transverse Steel Reinforcement Made from Lightweight Aggregate

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ABSTRACT

With transverse steel reinforcement, this research investigates how lightweight aggregate concrete columns behave. Tests were performed on 12 reinforced specimens with an axial compressive load that increased monotonically over time. Transverse steel and tie configurations are two factors that were examined in the research. Compared to normal weight concrete specimens, the fracture patterns of constrained lightweight aggregate concrete columns showed substantial differences, Some researchers have suggested that coarse aggregate-cement paste contact is where failure planes may have travelled or evolved. In order to make lightweight aggregate concrete very flexible and strong, this may be accomplished by carefully choosing the tie pattern and appropriately supplying steel reinforcement. It is found that the axial load-carrying ability and the ductility of specimens housed in rectangular hoops with cross ties are adequate throughout the test. In order to accurately estimate peak stress and strain, an analytical model has been suggested that integrates both the confinement efficiency factor (lt) and a coefficient (k). When compared to other models, the model has a high level of accuracy in predicting the future.

“**Keywords:** Columns, confinement, ductility, lightweight aggregate concrete, stress–strain relationships, tie configuration”

1.INTRODUCTION

Many recognized benefits of LWAC include greater fire-resistance capacity and reduced permeability, as well as a reduction in dead weight and the dimensions of components and an increase in the seismic resistance capacity of building structures. 1,2 Consequently, bridge and high-rise structure employ it extensively, and its future applications seem bright. Although LWAC's lower elastic modulus and substantial shear brittleness limit its use in major vertical bearing components like columns, it is nonetheless widely used in other applications. As a result, the vertical bearing components serve a crucial role in preventing building structures from collapsing at any given moment. In order to successfully increase column toughness, it is generally advised that a reasonable lateral confinement be provided.

There have been a number of investigations on the behavior of NWC columns exposed to concentric loads during the last four decades. “Many parameters, As an example, Richard et al.3, Sheikh and Uzumi4 and Mender et al.5 studied concrete compressive strength (fc0), tie yield strength (fyt), the kind of tie used (s), the length of tie utilised (rg), and the amount of concrete used (cov) in-depth. 6 Stress–strain models for lateral-constrained NWC specimens have been suggested by Park et al.7, Valens et al.8, and Fajitas and Shah, as well. 9 On the basis of genuine NWC data, these models may not accurately depict LWAC columns that include transverse steel reinforcing beams. Several studies have examined the stress-strain behaviour of passive or active restricted concrete columns in the recent past. 10 In order to assess the deformability, ductility, and strength of reinforced concrete structural components, it is necessary to investigate the whole stress–strain curve of the confined material. Only a small number of experiments have examined the axial compressive behaviour of LWAC columns under confinement. It has not yet been thoroughly investigated how limited LWAC behaves under stress and strain. There were correlations observed between the maximum stress, maximum strain, and ductility ratio when Martinez et al. studied 27 LWAC columns enclosed in circular spirals under concentric loading. Restricted high-strength LWAC in full-size columns was studied by Basset and Suzumori using various parameters.” Research by Berkley and colleagues found that confined LWAC columns had considerably different properties than unconfined specimens when subjected to long-term loading. Kahlo and Bozorgzadeh15 developed a stress–strain model based on peak stress and peak strain calculation formulas utilising an experiment using eight high-strength LWAC columns encased by composite elliptical spirals. Lower tie spacing and widening stirrups have been found by Haling et al. to greatly boost the deformation ability of specimens when they are confined. Calculating LWAC's elastic modulus has finally been solved. According to a thorough review of existing research, the axial compression of constrained LWAC columns has received less attention. It has been widely accepted that prior research have relied on the NWC specimens for their theoretical analysis but have not provided enough experimental support or a clear theoretical foundation.

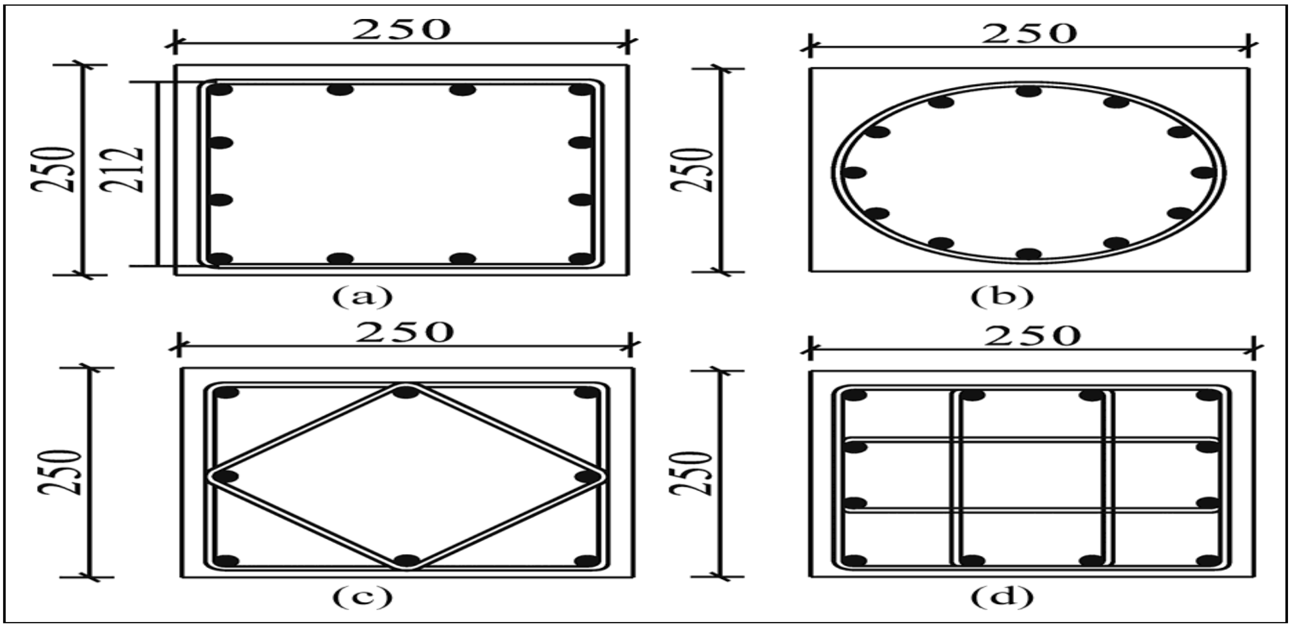

Figure 1. Cross-sectional dimensions for specimens:
series A, (b) series B, (c) series C; (d) series D."

2.Experimentalprogram

Testspecimens

It was separated into four series A to D to differentiate between the four different column configurations, which featured 12 constrained columns with square cross sections ranging from 250mm3250mm3750mm to 250mm3750mm3750mm, respectively (Figure 1). It was decided that each specimen would have a concrete cover of 15 mm in thickness. One may find all of this information and more in Table 1 and Figure 2 of this study. A–D indicate the cross-sectional tie configurations in Table 1, H or S signify the hoop or spiral lateral reinforcement, respectively, which follows those letters. Number types in this equation include 1.97 and 2.80, which represent lateral reinforcement ratio, and 1.97 and 1.80, which represent tie spacing, respectively.

Materials

According to the results of the investigation, As for oven-dried densities, the LWAC varied from 1800 to 1827 kg/m3 for wet densities. According to the manufacturer, the coarse material used was expanded shale with a cylinder compressive strength of 10.5 MPa. The river provided the fine aggregate. The size of each aggregate was restricted to 16 and 5 microns, respectively. Besides fly ash and HRWRA (high-range water-reducing additive), the mix also included standard Portland cement 42.5R and normal tap water."Table 2 displays the correct proportions of the concrete mix, according to the information provided Pre-wetting expanded shale aggregates prior to mixing is required in order to minimise the influence of water absorption and desorption on the mechanical characteristics of the concrete. Six 100 mm 3100 mm 3300 mm prisms and three 100 mm cubes were kept from the same batch of specimens in order to fabricate tubes with the requisite diameter."

Table2.MixproportionofLWAC.

Materials	Cement	Naturalsand	Expandedshale	Water	HRWRA	Fly ash
Designmixproportion	1	1.75	1.54	0.375	0.01	0.25
Unitconsumption(kg)	400	700	616	150	4.0	100

LWAC:lightweightaggregateconcrete;HRWRA:high-rangewater-reducingadmixture.

Table 3. Material properties of LWAC.

Specimen	f_{cu}(MPa)	f_t(MPa)	E_c(MPa)	Specimen	f_{cu}(MPa)	f_t(MPa)	E_c(MPa)
AH-1.97-50	51.1	3.34	19,300	CH-1.97-55	51.2	3.58	20,300

AH-2.80-35	58.2	3.62	20,500	CH-2.80-39	58.1	3.64	20,500
AS-1.97-50	50.9	3.51	20,000	CS-1.97-55	58.5	3.33	19,200
AS-2.80-35	52.7	3.46	19,800	CS-2.80-39	57.0	3.41	19,600
BS-1.97-50	53.9	3.34	19,300	DH-1.97-76	57.3	3.60	20,400
BS-2.80-35	55.2	3.62	20,500	DH-2.80-53	57.5	3.59	20,300

LWAC:lightweightaggregateconcrete.

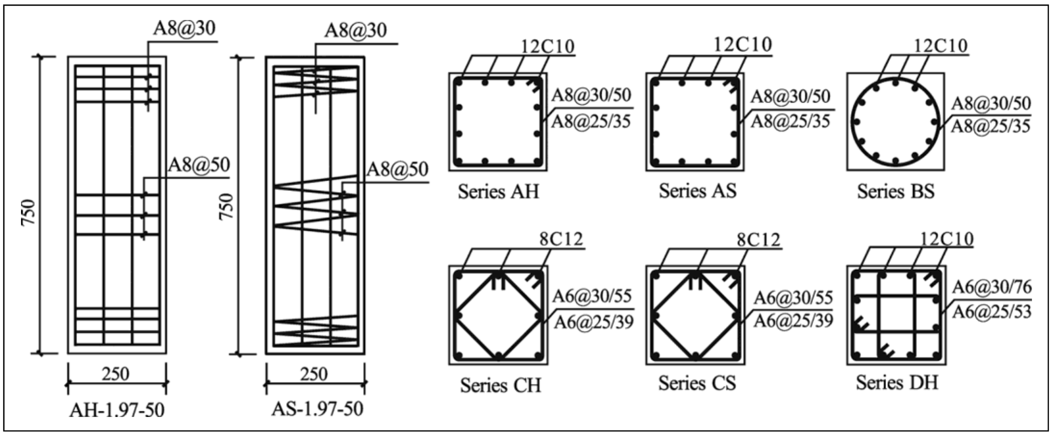

Figure 3. Specimen dimensions and reinforcement details."

Instrumentation and measurements

Figure 4 shows the test setup, On a universal testing machine, all specimens were tested in displacement-controlled mode and at a loading rate of 0.01 millimetres per second (0.012 inches per second). To achieve a consistent weight distribution over the column's cross section, a 3 mm thick coating of fine sand was applied to the column's ends on both ends to cap them. In order to improve local confinement and avoid early concrete crushing, This week, an upper column capping device with a 20-mm steel plate thickness and a 150-mm steel plate height was put in place (as seen in Figure 4). Another measure used to maintain uniform compression pressure was the inclusion of a spherical hinge at the column's lower end as an extra safety. Axial load–carrying capacity declined to 60% of the maximum load or the specimen collapsed into failure mode, the test was declared terminated and the results were recorded.

"**Experimentalresultsanddiscussion**

General observation and failure modes"

During the first loading stage, a consistent pattern of behavior was seen for each specimen. Lateral confinement had minimal effect on the axial compressive load since it was mostly supported by the concrete and longitudinal bars at this point in time. Cracks could not be seen in the concrete cover. There were relatively low lateral reinforcement stresses and Poisson ratio values, which occurred during the linear elastic stage of the LWAC specimens' deformations. When the load grew, vertical fissures appeared along the corner longitudinal bars, and the concrete coating began to flake away from the foundation. The specimens then achieved their final condition. Three different loading stages were used to examine the fracture patterns and failure appearance of two typical specimens, the CH-1.97-55 and the BS-1.97-50 (see Fig. 6) shown.

On the specimen CH-1.97-55, It wasn't until a load of 1300 kN (or around 58% of the peak load, Ptest) was applied that an interesting phenomena emerged. Shortly after, the sound of concrete fracturing could be heard, indicating that fractures were beginning to form inside. The top ends of specimen surfaces B and C fractured at a width of 0.2 mm and a length of 1 cm at 1600 kN (about 72% Ptest). There were 5 cm-long vertical fractures on both surfaces A and B of a specimen when the load rose to 1850 and 2100 kN. (corresponding to 83 and 95 percent Ptest, respectively). A and B continued to increase in vertical and diagonal cracks, but the horizontal and vertical cracks on surface B continued to diminish, as seen in the figure. Shorting of the restricted column was followed by a loud cracking sound.

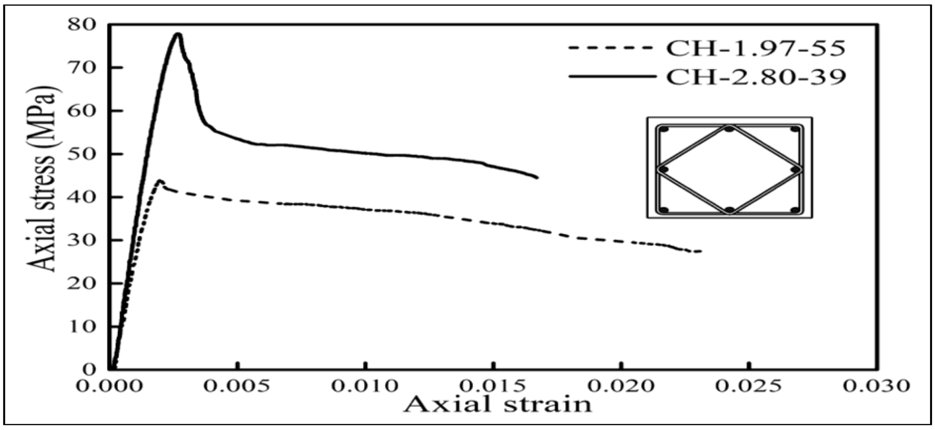

Figure 7. Stress–strain curves of the specimens.

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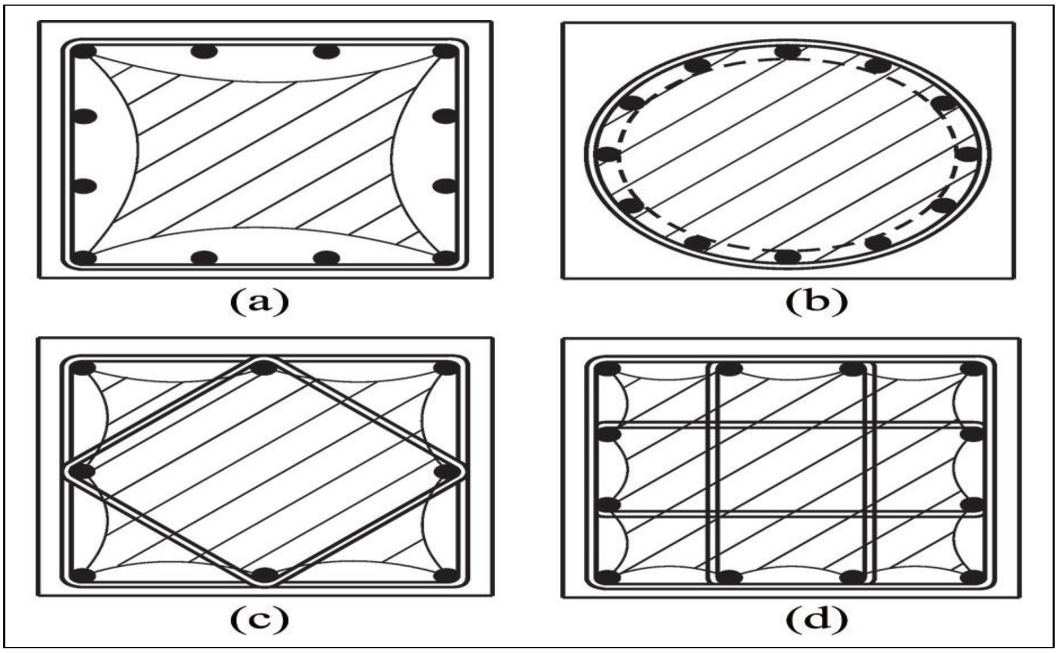

Figure 9. Effectively confined area of core concrete:(a)seriesA,(b)seriesB,(c)seriesC,and(d)seriesD.

Strains in lateral reinforcements

Figure 11 “The lateral reinforcing strain distribution along the column height is shown after the specimens have reached their maximum stresses and the peak stress has been decreased by 15%. Lower lateral steel strains were attributed to the decreased expansion of the core concrete during the initial loading stage. Ties in the column's structure become more apparent following concrete cracking.” A substantial difference was found between NWC and LWAC specimens in this investigation when it came to crack occurrence and development. Steel reinforcement and LWAC's higher interfacial strength are two of the primary causes of this occurrence. Consequently, the ties did not reach their yield point at full load in any of the examples, save BS-2.80-35. Stresses on the many steels in the failure zone quickly increased as a consequence of the concrete cover spalling across a vast area and the development of failure planes. At this point, the axial force should be lowered to 85% of its maximum value, the stirrups across the failure planes yielded. Crush damage occurred earlier in specimens with lower ratios of lateral reinforcements to core concrete, which was owing to inadequate confinement supplied by the lateral reinforcements.

Conclusion

This is what we can infer about specimen behavior based on 12 square short-confined LWAC columns of testing and analytical modelling:

1. Before the peak load point, NWC specimens and LWAC columns both fail in the same way when they are confined, according to the findings of this study. LWAC columns' concrete covers were chopped off

and spalled off after the peak load point, resulting in a loss of strength. Cracks appeared across aggregates or at the cement paste interface, which is a major difference when compared to NWC specimens in terms of performance. As a result, we noticed that 45-degree diagonal penetrating failure lines were created when diagonal penetrating failure lines intersected horizontal axes. LWAC and NWC specimens have the exact same stress–strain curve development law, despite their different materials.

2. Constrained specimens' ductility and strength may be greatly affected by the knot arrangement. Due to inadequate effective confined concrete area, It is possible to enhance specimen ductility even if the core concrete is not adequately contained and improve specimen load-carrying capacity by using rectangular spiral stirrups (section A) If you apply compound-diamond spiral reinforcement to the lateral side of the specimen (section C), the load-carrying capacity increases by around 60%. Internal and exterior layer spiral reinforcements are not working together effectively. The examples adopting the D-type construction show a considerable confinement of the core concrete and demonstrate higher strength and ductility increase when compared to other specimens.
3. Using the confinement efficacy factor (lt) in conjunction with a coefficient k, an analytical model is given, and it is shown to be more accurate and reasonable in forecasting the maximum stress and strain in confined LWAC columns.

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