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EFFECTIVENESS AND STRENGTH OF AUTOCLAVED AERATED CONCRETE (AAC) IN THE COMPOSITE SECTION R.C. BEAMS AND SLABS

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Abstract

An ideal situation for material saving in structural design is to reduce the structure's weight without compromising its strength and serviceability. The objective of this study is to use autoclaved aerated concrete (AAC) for the composite section. The reinforced concrete section in AAC blocks is used as infill material. This research aims to develop the composite section, a reinforced concrete sandwich with a filling of autoclaved aerated concrete blocks used in beams and slabs. The present study was conducted to investigate the structural behavior of beam and slab infill AAC. A Finite element model based on the computer program (ANSYS WORKBENCH 20 R1) has been developed to predict the behavior and strength of lightweight Composite section reinforced concrete element beams and slabs. This study contains two parts, the first part presented seven models of beams, and the second part presented five models of slabs. The results show that the difference between that solid beam and beam infill AAC at failure load is 12.7 %. This study aims to reduce weight without compromising the composite section's resistance and efficiency.

KEYWORDS: composite section; autoclave aerated concrete (AAC); ANSYS; void chambers; reinforced concrete

فعالية وقوة الخرسانة الخلوية المعالجه في القطاع المركب من الخرسانة المسلحة فى الكمرات و البلاطات

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الملخص

يهدف البحث الى استخدام الخرسانه الخلويه المعالجه فى القطاع المركب من الخرسانه المسلحه لتقييم مدى كفاءتها و قوتها. ومن خلال برنامج الانسيز للعناصر المحدده تم دراسة سبعة نماذج من الكمرات و خمسة نماذج من البلاطات. وتم دراسه حمل الانهيار والترخيم لكل النماذج و اثبتت الخرسانه الخلويه المعقمه كفاءتها و قوتها.

1. Introduction

Autoclaved aerated concrete (AAC), as a form of cellular concrete, is a low-density cementitious product of calcium silicate hydrates. The lowest density is obtained by forming microscopic air bubbles, mainly by chemical reactions within the mass during the liquid or plastic phase. The air bubbles are uniformly distributed and retained in the matrix on the setting, hardening, and subsequent curing with high-pressure steam in an autoclave to produce a homogeneous structure of microscopic voids cells [1]. Jaime Fernando [2] said available data for AAC's critical mechanical properties are evaluated and synthesized. The objective of this thesis was to evaluate and synthesize data from various sources regarding the mechanical behavior of autoclaved aerated concrete (AAC) and to integrate those data consistently and coherently for use by others to refine previously developed design formulas for AAC shear walls and for use by the author to develop design provisions and their technical justification for reinforced AAC floor panels. Ibrahim Shaaban et al. [3], this study focuses on the structural behavior of studied beams, including first crack, ultimate load, deflection, ductility index, strain characteristics, and crack pattern failure mode were investigated. Experimental work showed that ferrocement beams exhibited higher ductility indices than the control standard and lightweight test beams to different degrees. As Ibrahim Shaaban [3] has not investigated the R.C. beam with infill AAC, the researcher will tackle it. Ali M Memari et al. [4], this study focus on evaluating the feasibility of FRP application to retrofit existing structures or components made of AAC. The specimens used in this study include AAC lintels without FRP and two alternative FRP schemes applied to the external lintel surfaces for flexural and shear strengthening. V. Vimonsatit et al. [5], this paper presents a novel use of lightweight concrete to create a lightweight sandwich reinforced concrete (LSRC) section. The developed LSRC section can be used as beams or slabs in concrete structures. As V. Vimonsatit [5] has not investigated the R.C. beam and slab effect without infill AAC, the researcher will tackle it. Ezzat H. Fahmy et al. [6], this paper presents the results of an investigation to develop reinforced concrete beams consisting of precast permanent U-shaped reinforced mortar forms filled with different types of core materials to be used as a viable alternative to the conventional reinforced concrete beam. As Ezzat H. Fahmy et al. [6] have not investigated the R.C. beam effect to infill AAC. Rutvik. R. Patel [7], this paper presents the outcome of an investigation into the experimental and theoretical flexural behavior and strength of doubly-reinforced concrete Beams without hollow R.C. beams with infill AAC. Researchers are going to tackle it. Yavuz Yardim et al. [8] this study use Autoclaved Aerated Concrete (AAC) as an infill material for semi-precast panels is investigated experimentally. Nahor Radi Husein et al. [9] examination of lightweight web sandwich panels (LWSP) was determined. Ten specimens are LWSP with aerated concrete as a core and three LWSP with thermocouple as a core encased by ferrocement with different water-cement ratios (w/c) and different waterproofing admixture.

2. Section and materials properties of beams

In the first part of the study, seven models were analyzed model (1) was reinforcement concrete solid beam (R.C.), model (2) was R.C. beam infilled with fourteen AAC blocks, model (3) was R.C. beam void chambers same as the model (2), model (4) was R.C. beam half infilled with seven AAC block, model (5) R.C. beam half void chambers same as a model (4), model (6) was R.C. beam infilled with AAC and have two ribs only, while model (7) R.C. beam infilled fourteen AAC blocks of dimension 240 x 75 x 150 mm shown in figure (1). The beams had a rectangular section with a constant width and depth of 200 mm and 300 mm. The beam length was 3000 mm, with a 2800 mm clear span, and the block was 180 mm x 75 mm x150 mm. In order to consider the ability and capability of concrete and infill beam modeling by applying the said techniques, an experimental test by Ade Sri Wahyuni [5] has been modeled as a sample.

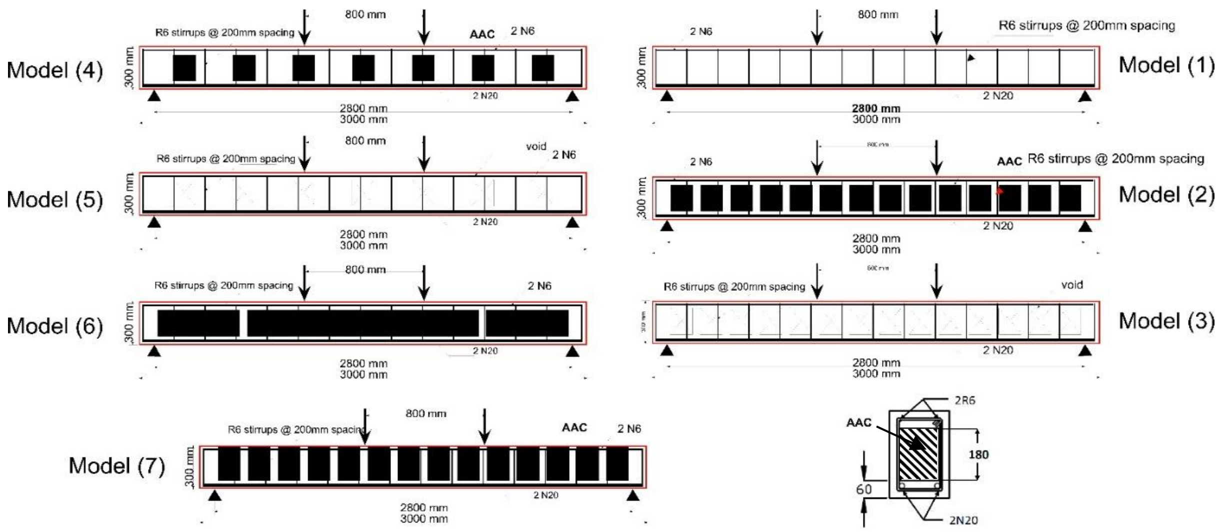


Figure 1: Beam details for section models 1,2,3,4,5,6,7

Table 1: Details of the Model Beams

model	No of blocks	No of Void	Weight reduction %
1	---	---	---
2	14	---	27.7
3	---	14	36
4	7	---	14
5	--	7	18
6	14	---	27.7
7	14	---	47

Table 2: Properties of Materials [5]

Properties	Concrete	Steel reinforcement	AAC
Compressive strength (*fc*) Mpa	43		3.5
Modulus of elasticity (*Ec*) Mpa	32000	200000	8000
Poisson’s ratio	0.2	0.3	0.2
Density kN/m^3	25	78	5.3

Concrete Properties: *fc* = 43 MPa, *Ec* = 32,000 MPa, Poisson’s ratio = 0.2, density concrete = 25 kN/m3; Steel Reinforcement properties: The tensile strength at yield was 560 MPa for the N-bars and 300 MPa for the R-bars, Poisson’s ratio = 0.3, *Es* = 200,000 MPa. AAC

Properties: *fc* AAC = 3.5 MPa, *E*AAC = 8000 MPa, Poisson's ratio = 0.2, Density AAC = 5.3 kN/m3 [5], where *Ec* Modulus of elasticity of concrete, *E*AAC Modulus of elasticity of AAC, *Es* Modulus of elasticity of steel.

2.1 Beams Modeling by ANSYS

ANSYS program provides simulations of solid concrete elements with eight-node (solid65), steel elements (186 link elements), and AAC solid elements with eight-node (solid65). The finite element analysis models (1,2,3,4,5,6,7) are plotted compared to the results in figure 2. there are significant differences in failure load capacities and deflection. The results by ANSYS workbench 2020 R1 are shown in **Table 3**.

Table 3: Results of failure load and deflection of all different models.

Model	1	2	3	4	5	6	7
Failure load, P kN	77.5	67.6	54.7	73.5	60.1	69	27
Precanteag of failure load compared to a solid beam	100%	87.2%	70.5%	94.8%	77.5%	89%	35%
Deflection, D mm	12	11.4	10	11.8	10	10.23	8.2
Precanteag of deflection compared to a solid beam	100%	95 %	83.3%	98.3%	83.3%	85.2%	68.3%

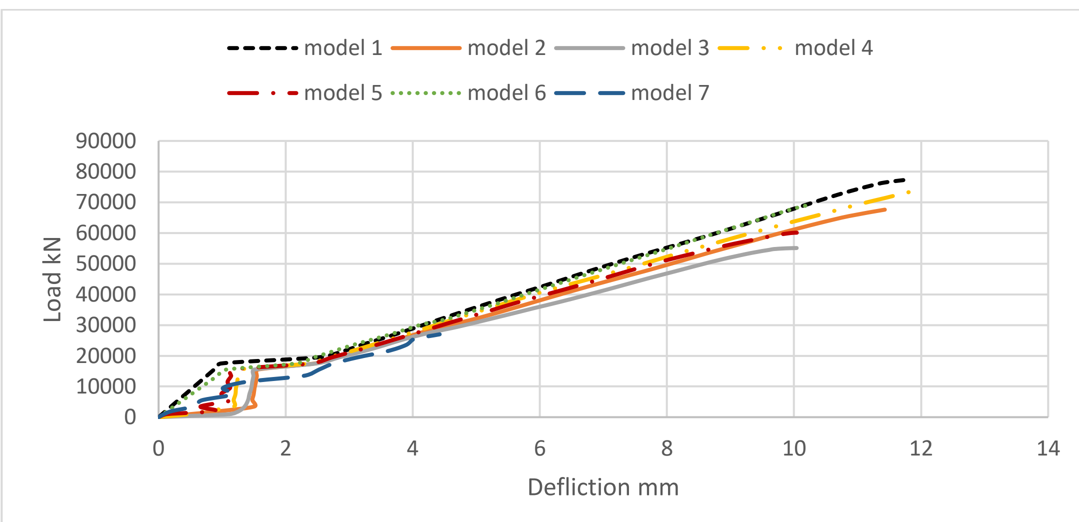


Figure 2: Load and deflection for all models by ANSYS 2020R 1

Based on these results, AAC blocks concrete replacement reduces weight on the model (2). The failure loads of the solid and LSCRC (A Lightweight Composite Section Reinforced Concrete) beams at ANSYS were found to be 12.7 %. It was found that model (2), which had the maximum AAC blocks, failed at 67.6 kN, model (1) and model (4) failed at 77.5 kN and 73.5 kN, respectively, and reduced weight at the model (2) and model (4) 27.7%, 14%, respectively. The comparison between model (2) and model (3) shows AAC's effect when the concrete replaces fourteen AAC blocks versus fourteen void chambers at the failure load of 67.6 kN and 54.7 kN, respectively. The comparison between model (4) and model (5) shows AAC's effect when the concrete is replaced by seven AAC blocks versus seven void chambers at the failure load of 73.5 kN and 60.1 kN, respectively. Model (2) and model (7) showed the compered zone's effect when the concrete replacement by fourteen AAC blocks and the concrete compression zone by replacement by fourteen AAC blocks in the model (2), the failure load was 67.6 kN and 27 kN, respectively.

3. Section and Materials Properties of Slabs

The second part studies five slabs, one solid model (a), two LCSRC (A Lightweight Composite Section Reinforced Concrete) sections, the model (b) reinforcement concrete slab had thirty-two AAC blocks placed within the slab, and the model (d) reinforcement concrete slab had sixteen AAC blocks placed within the slab. The model (c) reinforcement concrete slab had thirty-two voids placed within the slab in two void sections, and the reinforced concrete slab had sixteen voids placed within the slab (e). All slabs had the exact dimensions and reinforcement details. Slabs were 3000 mm long, 1000 mm wide, and a depth of 250 mm. The AAC block dimension was 300 mm long, 180 mm wide, and 150 mm thick.[5]. In order to consider the ability and capability of concrete and infill wall modeling by applying the said techniques, an experimental test by Ade Sri Wahyuni [5] has been modeled as a sample. The minimum gaps between the blocks in model (b) were 50 mm in the cross-section and the slab's longitudinal directions.

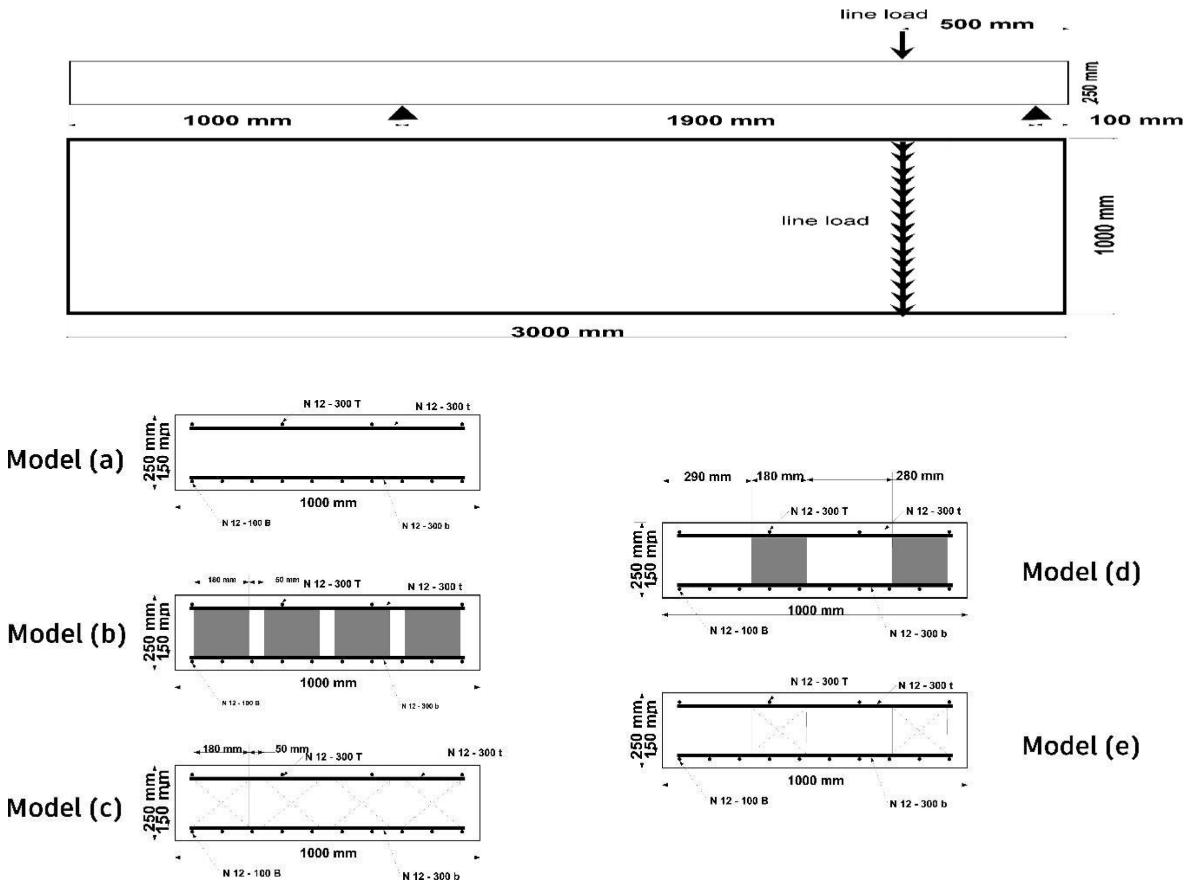


Figure 3: Slabs details for section model a, b, c, d and e

Table 4. Details of model slabs

Model	No of blocks	No of Void	Weight reduction %
a	---	---	---
b	32	---	26.7
c	---	32	35
d	16	---	13.4
e	--	16	17.8

3.1 Slabs modeling by ANSYS

ANSYS program provides simulations of the solid concrete element with eight-node (solid65), steel element (186 link element), and AAC solid element with eight-node (solid65). The finite element analysis models (a, b, c, d, e) are plotted in figure 4. As shown in Figure 4, there are significant differences in failure load capacities and deflection in five model slabs. The results by ANSYS workbench 2020 R1 are shown in **Table 5**.

Table 5. Results of failure load and deflection all different models.

Model	a	b	c	d	e
Failure load, P kN	190	165	135	184	148
Precanteag of failure load compared to a solid beam	100 %	86.8 %	71 %	96.8 %	77.8 %
Deflection, D mm	1	1.4	1.18	1.5	1.15
Precanteag of deflection compared to a solid beam	100 %	140 %	118%	150 %	115%

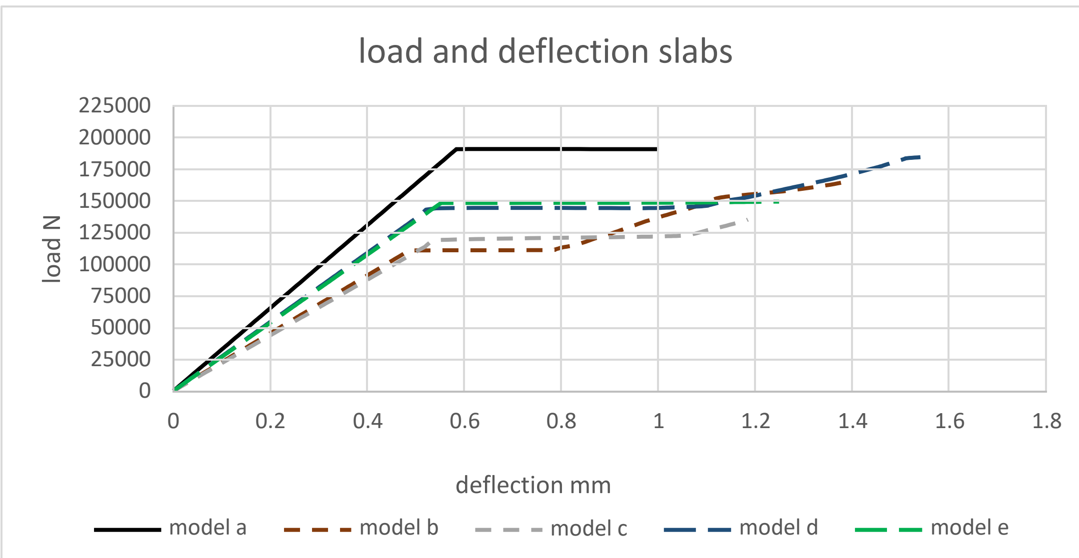


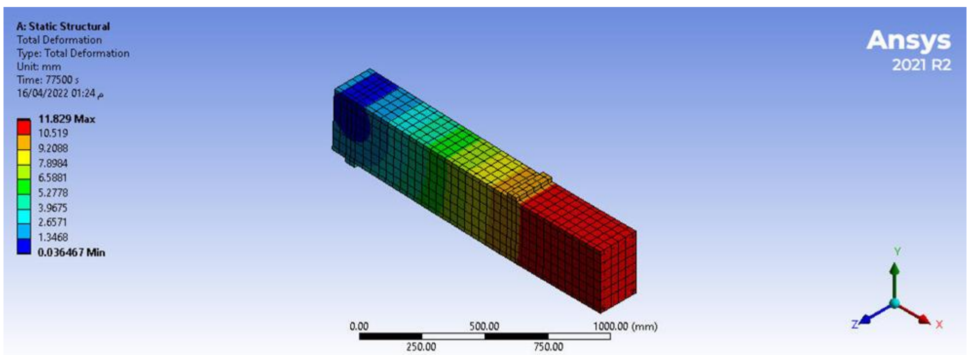
Figure 4. Load and deflection for all models by ANSYS 2020

Based on these results, the failure loads of the solid and LSCRC slabs at ANSYS

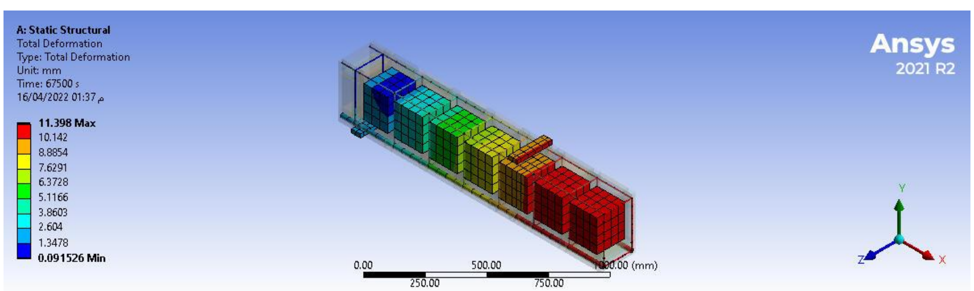
were found to be of slight difference. It was found that model (b), which had the maximum AAC blocks, failed at 165 kN, model (a) and model (d) failed at

190 kN and 184 kN, respectively, reduced the weight of models (b) and (d) by 26.7 % and 13.4 %, respectively. The comparison between model (b) and model (c) shows AAC's effect when the concrete replaces thirty-two AAC blocks versus thirty-two void chambers at the failure load of 165 kN and 135 kN, respectively. The comparison between model (d) and model (e) shows AAC's effect when the concrete replaces sixteen AAC blocks versus sixteen void chambers at the failure load of 184 kN and 148 kN, respectively.

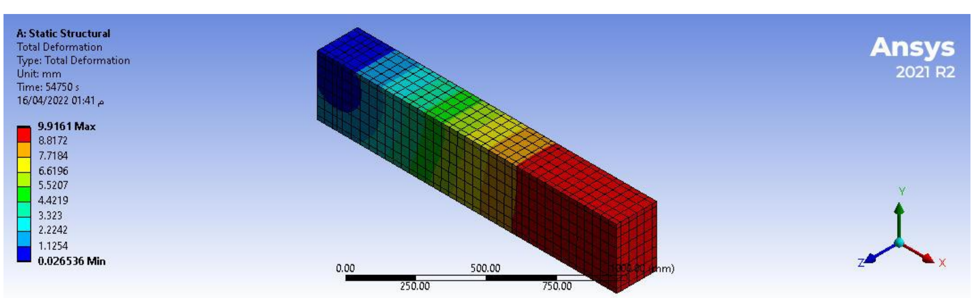
4. ANSYS WORKBENCH 20 R1 Graphical Output Beams



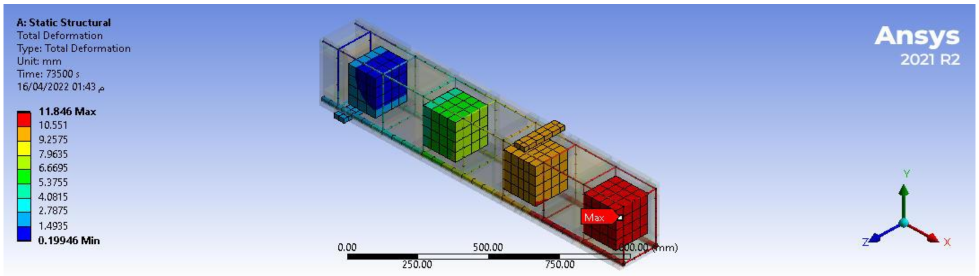
Model (1)



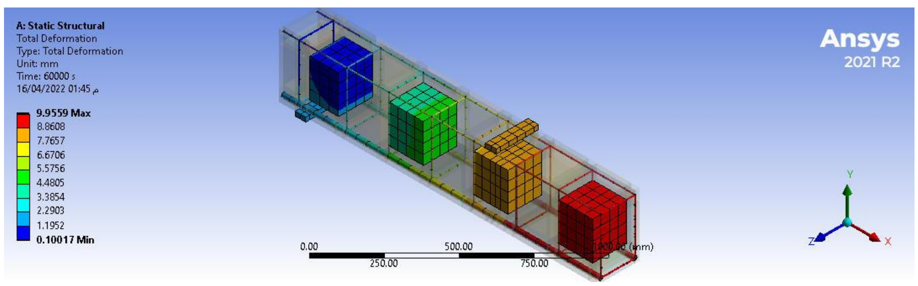
Model (2)



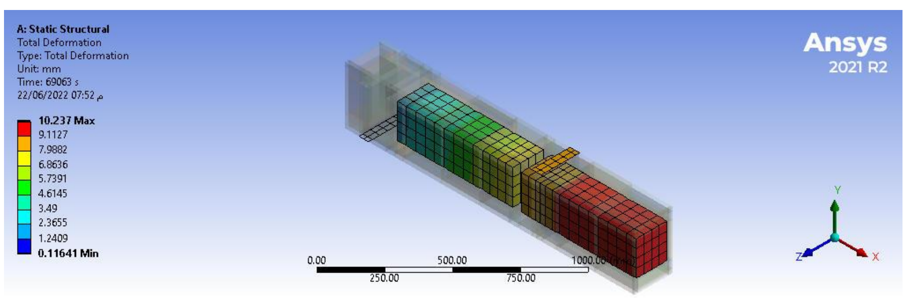
Model (3)

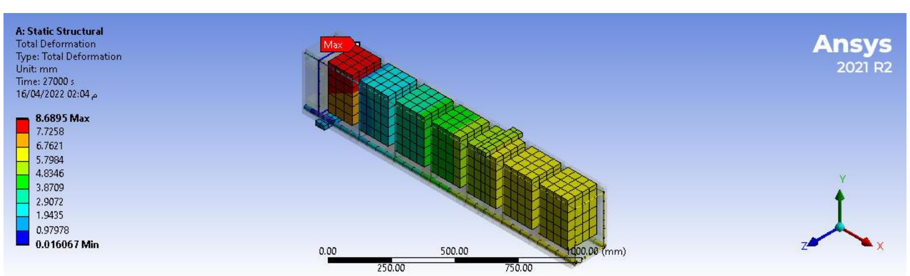


Model (4)



Model (5)

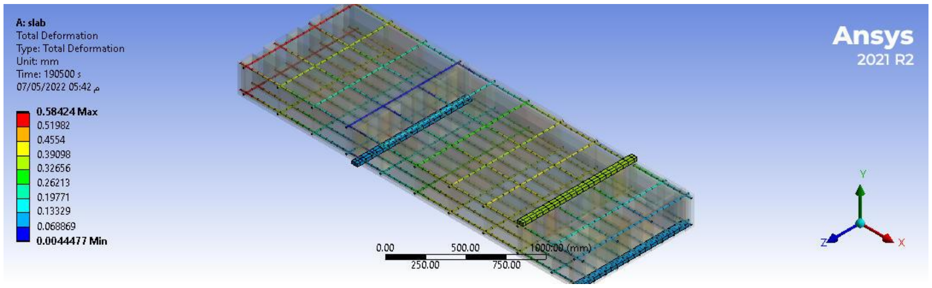




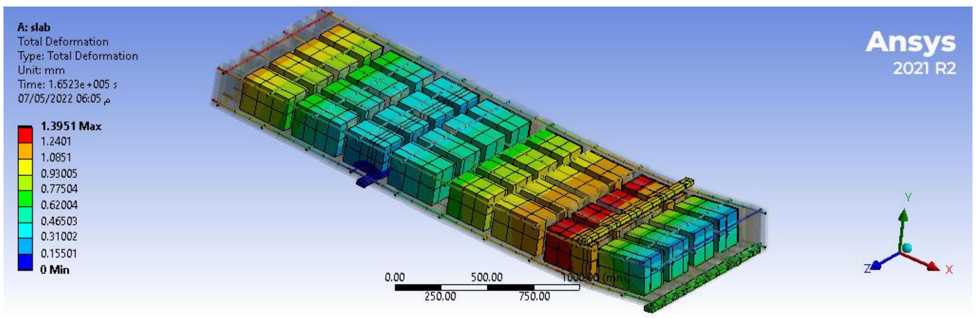
Model (7)

Figure 5. ANSYS Graphical Output for Beams

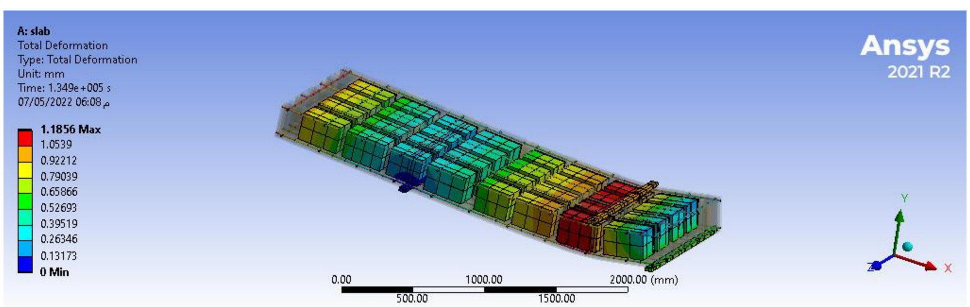
5. ANSYS WORKBENCH 20 R1 graphical output slabs



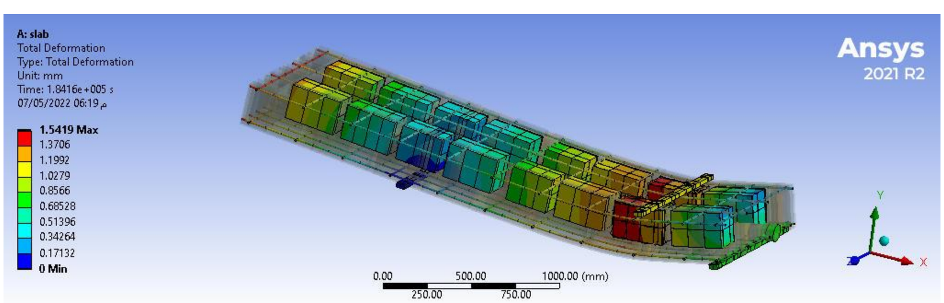
Model (a)



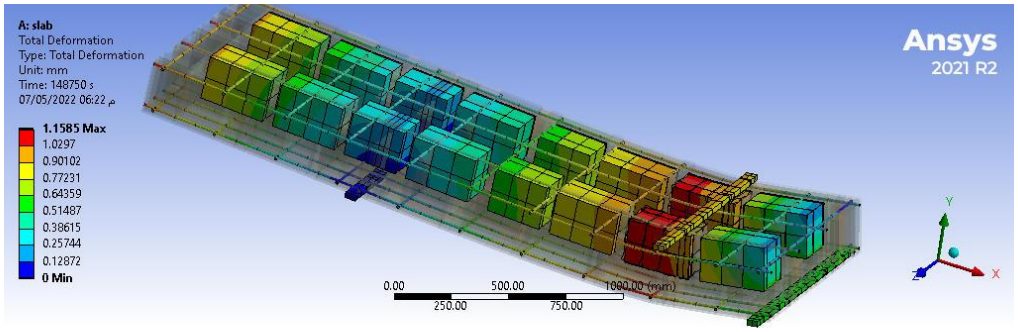
Model (b)



Model (c)



Model (d)



Model (e)

Figure 6. ANSYS graphical output for slabs

6. Conclusion

The present study was conducted to investigate the structural behavior of beam and slab infill AAC. A finite element model based on the computer program (ANSYS WORKBENCH 20 R1) has been developed to predict the behavior and strength of lightweight Composite section reinforced concrete element beams and slabs. Based on the findings, the following conclusions can be drawn:

6.1 Beams

(1) The results show that fourteen AAC blocks replaced the concrete model (2), and seven AAC blocks replaced the concrete model (4) flexural strength differs from a solid beam. The self-weight reduction of the beam was about 14 – 27.7% of the equivalent solid beam. At failure load, compared to solid beam, fourteen AAC blocks replaced the concrete model (2), and seven AAC blocks replaced the concrete model (4) were 77.5 kN, 67.6 kN, and 73.5 kN, respectively.

(2) Effectiveness and strength of AAC infill beam; compared to solid beam, fourteen AAC blocks replaced the concrete model (2), and fourteen void chambers model (3) at the failure load were 67.6 kN and 54.7 kN, respectively.

(3) Effectiveness and strength of AAC half infill beam; compared to solid beam, the concrete is replaced by seven AAC blocks model (4) versus seven void chambers model (5), and the failure load was 77.5 kN, 73.5 kN, and 60.1 kN, respectively.

(4) Strength of compression zone at the beam, when AAC infill beam versus AAC top compression zone at the failure load was 67.6 kN and

27 kN, respectively. Hence AAC is not recommended to be used in the compression zone.

6.2 Slabs

(1) The results show that the flexural strength of solid slab, AAC infill slab, and AAC half infill slab is slightly different from a solid slab. The self-weight reduction of the slab was about 13.4 – 26.7% of the equivalent solid slab. At failure load, solid slab, AAC infill slab, and AAC half infill slab were 190 kN, 165 kN, and 184 kN, respectively.

(2) Effectiveness and strength of AAC infill slab; compared to solid slab, the concrete is replaced by thirty-two AAC blocks versus thirty-two void chambers, and the failure load was 190 kN, 165 kN, and 135 kN, respectively.

(3) Effectiveness and strength of AAC half infill slab; compared to solid slab, the concrete is replaced by sixteen AAC blocks versus sixteen void chambers at the failure load were 190 kN, 184 kN, and 148 kN, respectively.

References

1. Guide for Design and Construction with Autoclaved Aerated Concrete Panels (**ACI 523.4R-09**).
2. Jaime Fernando Argudo, P.E. "**Evaluation and Synthesis of Experimental Data for Autoclaved Aerated Concrete**" Degree of Master of Science in Engineering the University of Texas at Austin **August 2003**
3. Ibrahim G. Shaaban et al. "**Flexural characteristics of lightweight ferrocement beams with various types of core materials and mesh reinforcement**" Construction and Building Materials 171 (**2018**) 802–816.
4. Ali M. Memari, Andres Lepage "**An experimental study of autoclaved aerated concrete lintels strengthened with externally bonded glass FRP**." Journal of Reinforced Plastics and Composites · November **2010** https://www.researchgate.net/publication/240600380

5. Ade Sri Wahyuni **"Structural Characteristics of Reinforced Concrete Beams and Slabs with Lightweight Blocks Infill"** Degree of Doctor of Philosophy of Curtin University July **2012**

6. Ezzat H. Fahmy et al. "**Applying the Ferrocement Concept in Construction of Concrete Beams Incorporating Reinforced Mortar Permanent Forms**" International Journal of Concrete Structures and Materials Vol.8, No.1, pp.83–97, March **2014**

7. Rutvik. R. Patel "**flexural behavior and strength of doubly-reinforced concrete beams with hollow plastic spheres**" Degree of master of science (civil engineering) old dominion university May **2018**

8. Yavuz Yardim, et al. "**AAC-concrete lightweight precast composite floor slab**" Construction and Building Materials 40 (**2013**) 405–410

9. Nahro Radi Husein, et al. "**An Experimental Study on Using Lightweight Web Sandwich Panel as a Floor and a Wall**" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-7, December **2013**