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Experimental Study on the Structural Performance of Lightweight Precast Concrete Slabs Incorporating AAC Block Aggregate

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Abstract: ***Precast concrete slabs offer advantages in quality control, construction speed and installation efficiency; however, their self-weight increases the loads transferred to supporting structural members and complicates transportation and handling. This study investigates the preliminary development of lightweight precast concrete slabs incorporating waste Autoclaved Aerated Concrete (AAC) block aggregate as a partial replacement for natural coarse aggregate. The Phase I work comprised a review of 19 research studies, identification of the research gap, preliminary M40 concrete mix proportioning, manual design of a two-way slab, aggregate testing and an initial finite-element analysis using ANSYS. Five mixtures were proportioned with 0%, 5%, 10%, 15% and 20% AAC replacement by volume of coarse aggregate, at a preliminary water–cement ratio of 0.40. The cement content was 437.1 kg/m³ and the AAC aggregate specific gravity was measured as 0.60, with 15% water absorption. The aggregate impact value was 37%. A 700 mm × 600 mm × 100 mm two-way slab was designed using the procedure stated in IS 456:2000 and provided with 8 mm diameter reinforcement at 150 mm centres in both directions. Preliminary calculations indicated adequate flexural, shear and deflection checks under the adopted design assumptions. The initial ANSYS model produced deformation, strain and stress contours; however, the reported peak values are unusually high and require verification of units, material properties, loading, boundary conditions and mesh before engineering interpretation. The results presented are therefore limited to Phase I preparation and preliminary assessment. Cube and slab testing, durability assessment and experimental validation are planned for Phase II.***

Keywords: AAC aggregate; lightweight concrete; precast slab; structural behaviour; mix proportioning; ANSYS; recycled construction material

1. Introduction

Concrete remains a principal construction material, while precast concrete components are increasingly used because they can be manufactured under controlled conditions and rapidly erected at site. Precast slabs are applied in floors, roofs and similar structural systems. Their comparatively high self-weight, however, increases dead load on beams, columns and foundations and can increase lifting, transport and handling requirements.

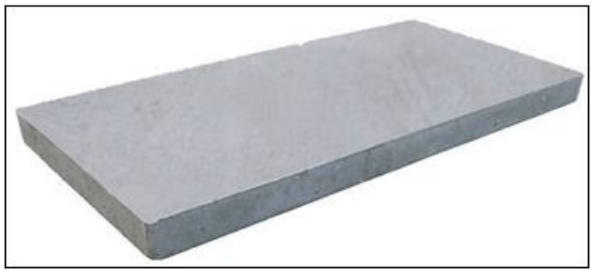


Figure 1: Typical precast concrete slab element

Lightweight concrete can reduce the mass of structural elements by incorporating low-density aggregates. Waste AAC blocks generated during cutting, handling and construction represent a potential secondary resource. Their use as aggregate may reduce dependence on natural aggregate and divert waste from disposal. The porous nature and water absorption of AAC, nevertheless, require careful control of aggregate condition and mix water.

Prior studies reviewed in the project report have considered lightweight precast, sandwich, hollow-core and composite slabs, together with lightweight aggregates such as AAC, pumice, scoria and expanded clay. Reported weight reductions in various slab systems are encouraging, but the report identifies limited slab-level experimental evidence specifically for precast concrete slabs incorporating crushed AAC block aggregate. The present Phase I work establishes the preliminary mix, specimen design and analysis framework for addressing this gap.

2. Objectives and Scope

The objectives are: (i) to develop lightweight precast slab concrete mixes using AAC block aggregate as a partial replacement for natural coarse aggregate; (ii) to evaluate structural behaviour through load–deflection response, cracking pattern and failure mode; (iii) to compare AAC-based slabs with conventional precast slabs; and (iv) to identify a mix balancing reduced weight, structural performance and durability.



Figure 2: Summary of the objectives of the study

This manuscript reports Phase I only: literature review, material selection, preliminary M40 mix proportioning, manual design of a two-way slab, preliminary aggregate tests and an initial ANSYS analysis. Casting and curing of cubes and slabs, strength testing, water absorption/permeability testing, slab loading and selection of the optimum mix remain Phase II activities and are not reported as completed results.

3. Materials and Methods

3.1 Materials

Ordinary Portland Cement (OPC) 53 Grade was adopted, with a specific gravity of 3.15. Fine aggregate conforming to Zone II was considered, with a specific gravity of 2.60. Natural coarse aggregate of 20 mm nominal size was used as the reference aggregate, with a specific gravity of 2.70. Crushed waste AAC block was selected as the lightweight aggregate. Its specific gravity was measured as 0.60 and water absorption was reported as 15%. Because of its porosity, the AAC aggregate was proposed to be pre-soaked and brought to saturated surface-dry (SSD) condition before mixing. Clean potable water and a superplasticizer dosage of 1% of cement mass were adopted. The superplasticizer specific gravity was taken as 1.10.

3.2 Experimental programme and methodology

The planned programme consists of literature review, material selection, mix proportioning, casting, curing, mechanical testing, water durability testing, comparison with a conventional control slab, optimum-mix selection and conclusions. The Phase I aggregate tests completed were aggregate impact value and specific gravity. The Phase II programme proposes 150 mm cube compressive-strength tests at 7, 14 and 28 days for each AAC replacement level, water absorption and permeability tests, and structural testing of slab specimens to record load–deflection behaviour, cracking and failure mode.

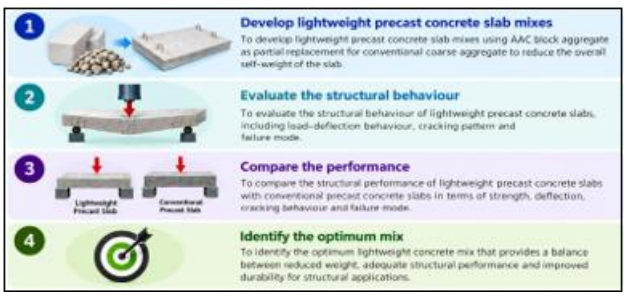


Figure 3: Research methodology adopted for the study

3.3 Preliminary aggregate testing

The aggregate impact value was calculated as the percentage ratio of the mass of fines passing the specified sieve (W_2) to the original sample mass (W_1): $AIV = (W_2/W_1) \times 100$. Two trials were reported. AAC aggregate specific gravity was calculated using the pycnometer readings and the expression $G = D/[A - (B - C)]$, where A is SSD aggregate mass, B is pycnometer plus aggregate plus water, C is pycnometer plus water, and D is oven-dry aggregate mass.



Figure 5: AAC aggregate sample and laboratory test apparatus

4. Preliminary Mix Proportioning

A preliminary M40 mix was proportioned following IS 10262:2019. The characteristic compressive strength was 40 MPa and the assumed standard deviation was 5 MPa. The target mean strength was calculated as $f'ck = fck + 1.65S = 40 + 1.65(5) = 48.25$ MPa. A preliminary water–cement ratio of 0.40 and water content of 174.84 L/m³ were adopted. The resulting cement content was 174.84/0.40 = 437.1 kg/m³. Superplasticizer was taken as 1% of cement content (4.37 kg/m³).

The aggregate volume was estimated by the absolute-volume method as 0.6624 m³. The preliminary coarse-aggregate fraction was 0.64 and fine-aggregate fraction was 0.36. The corresponding fine aggregate and total coarse aggregate quantities were 620.0 kg/m³ and 1144.7 kg/m³, respectively. AAC replacement was specified by volume of coarse aggregate; the quantities below reproduce the preliminary values reported in the project report.

Table 1: Preliminary M40 mix proportions for AAC aggregate replacement

Mixture	Cement (kg/m³)	Water (L/m³)	Fine aggregate (kg/m³)	Natural CA (kg/m³)	AAC (kg/m³)	SP (kg/m³)
Control (0%)	437.1	174.84	620.0	1144.7	0	4.37
AAC 5%	437.1	174.84	620.0	1087.4	12.72	4.37
AAC 10%	437.1	174.84	620.0	1030.2	25.44	4.37
AAC 15%	437.1	174.84	620.0	973.0	38.16	4.37
AAC 20%	437.1	174.84	620.0	915.7	50.87	4.37

The reported AAC water absorption was 15%. The report estimates water uptake of 1.91, 3.82, 5.72 and 7.63 L/m³ for the 5%, 10%, 15% and 20% replacement mixtures, respectively, if dry AAC is used. The proposed procedure is to pre-soak the AAC and use it in SSD condition; these absorption estimates should not be added automatically to the mixing water.

For three 150 mm cubes, the batch volume including a 10% allowance was taken as approximately 0.01114 m³. The batch quantities are shown below.

Table 2: Batch quantities for three 150 mm cubes

Material	0%	5%	10%	15%	20%
Cement (kg)	4.87	4.87	4.87	4.87	4.87
Water (L)	1.95	1.95	1.95	1.95	1.95
Fine aggregate (kg)	6.91	6.91	6.91	6.91	6.91
Natural CA (kg)	12.75	12.11	11.47	10.84	10.20
AAC (kg)	0	0.142	0.283	0.425	0.567
SP (g)	49	49	49	49	49

5. Manual Design of the Precast Two-Way SLAB

A simply supported two-way reinforced concrete slab of dimensions 700 mm × 600 mm × 100 mm was designed as the proposed test specimen using the procedure and assumptions reported with reference to IS 456:2000. The adopted concrete grade was M40, reinforcement grade Fe415, clear bottom cover 20 mm, and 8 mm diameter bars. The floor-finish load was 1.0 kN/m² and live load was 5.0 kN/m². The unit weight of concrete was taken as 25 kN/m³.

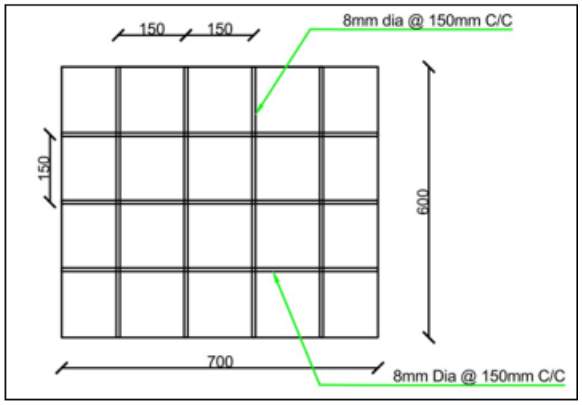


Figure 4: Preliminary reinforcement arrangement of the two-way slab (dimensions in mm).

Table 3: Adopted parameters for the preliminary two-way slab design

Parameter	Adopted value
Plan dimensions	700 mm × 600 mm
Overall thickness	100 mm
Concrete grade	M40 (fck = 40 N/mm²)
Reinforcement grade	Fe415 (fy = 415 N/mm²)
Clear cover	20 mm
Support condition	Simply supported on four sides
Reinforcement	8 mm diameter at 150 mm c/c both ways
Floor finish / live load	1.0 / 5.0 kN/m²

The aspect ratio based on plan dimensions was 700/600 = 1.17, indicating two-way action under the adopted criterion. Effective depths were calculated as 76 mm in the shorter-span direction and 68 mm in the longer-span direction. Effective spans were taken as 0.676 m and 0.768 m, giving an effective-span ratio of approximately 1.14.

The self-weight was 0.10 × 25 = 2.50 kN/m². Including floor finish and live load, the total service load was 8.50 kN/m² and the factored load was 1.5 × 8.50 = 12.75 kN/m². Using the moment coefficients reported from Table 27 of IS 456:2000, the design moments were 0.463 kN·m/m in the shorter direction and 0.351 kN·m/m in the longer direction.

Table 4: Summary of preliminary slab design checks.

Design check	Reported calculation/result	Reported assessment
Short-span moment	Mux = 0.463 kN·m/m; Mu, lim = 31.78 × 10⁶ Nmm/m	Safe in flexure
Long-span moment	Muy = 0.351 kN·m/m; Mu, lim = 25.50 × 10⁶ Nmm/m	Safe in flexure
Reinforcement	8 mm bars @ 150 mm c/c; Ast, prov = 335.1 mm²/m each way	Provided
Shear	τv = 0.0567 N/mm²; τc adopted = 0.62 N/mm²	Safe as reported
Deflection	Actual L/d = 8.89; basic allowable ratio = 20	Safe as reported

The report therefore adopts 8 mm diameter reinforcement at 150 mm centres in both directions. These checks are reproduced as preliminary design calculations and should be independently checked against the governing code provisions, actual support details, load assumptions and detailing requirements before fabrication or structural use.

6. Results and Discussion

6.1 Aggregate impact value

The two aggregate impact value trials used an initial sample mass W_1 of 500 g. The measured fines masses W_2 were 180 g and 190 g, giving impact values of 36% and 38%, respectively. The reported average was 37%.



Figure 6: Laboratory pycnometer arrangement used for aggregate specific-gravity testing.

Table 5: Aggregate impact value test results.

Trial	W_1 (g)	W_2 (g)	AIV (%)
1	500	180	36
2	500	190	38
Average			37

The value of 37% is the measured result reported for the AAC aggregate sample. Its implications for use in concrete should be judged alongside the applicable aggregate requirements and the complete mix and concrete test results; the value alone does not establish structural suitability.

6.2 Specific gravity and water absorption

The pycnometer readings were: SSD aggregate mass A = 600 g; pycnometer plus aggregate plus water B = 1700 g; pycnometer plus water C = 1400 g; and oven-dry aggregate mass D = 180 g. Thus, B − C = 300 g and A − (B − C) = 300 g. The calculated specific gravity was G = 180/300 = 0.60. The report also gives water absorption as 15%. These values indicate a highly porous, low-density aggregate and support the proposed pre-soaking/SSD handling procedure.

Table 6: Pycnometer readings for AAC aggregate specific gravity

Reading	Symbol	Mass (g)
SSD aggregate	A	600
Pycnometer + aggregate + water	B	1700
Pycnometer + water	C	1400
Oven-dry aggregate	D	180

6.3 Initial ANSYS analysis

An initial numerical analysis was performed using ANSYS to obtain contours for total deformation, X-directional deformation, equivalent elastic strain, equivalent (von Mises) stress and maximum principal elastic strain. The minimum, maximum and average values reproduced from the report are presented below.

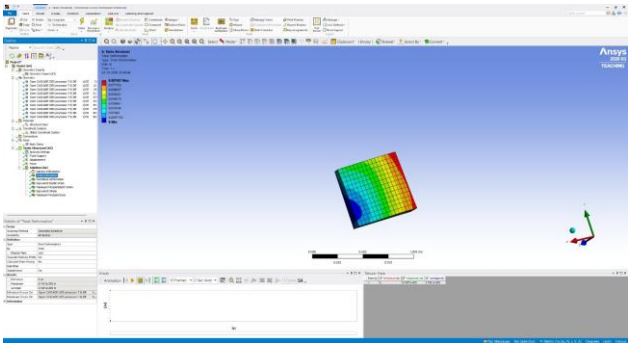


Figure 7: Initial ANSYS model and total deformation contour

Table 7: Initial ANSYS analysis results.

Output	Minimum	Maximum	Average	Unit
Total deformation	0	0.087437	0.0027401	m
Directional deformation (X)	−0.027243	0.04016	0.00051386	m
Equivalent elastic strain	0	0.72643	0.0023079	m/m
Equivalent stress	0	1.4529×10^{11}	4.3104×10^{8}	Pa
Maximum principal elastic strain	0	0.55994	0.0014225	m/m

The report notes that the peak values are substantially higher than expected for service-level concrete slab behaviour and may depend on material properties, boundary conditions, applied load and mesh size. Accordingly, these are treated as first-trial numerical outputs only, not validated performance values. Before comparison with experimental data, the model requires verification of unit consistency, geometry, material constitutive properties, reinforcement representation, load application, support constraints, contact assumptions and mesh convergence. The numerical model should then be calibrated against measured load–deflection response and observed cracking in Phase II.

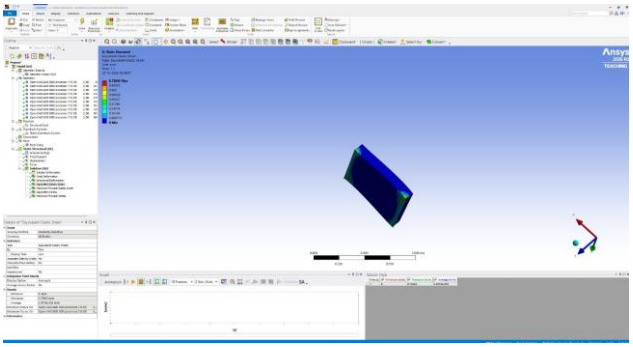


Figure 9: ANSYS equivalent elastic strain contour

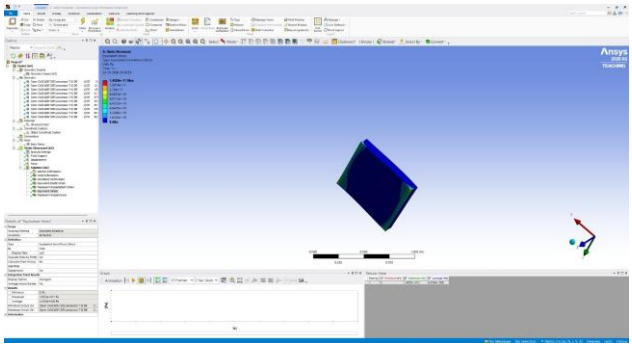


Figure 10: ANSYS equivalent stress contour

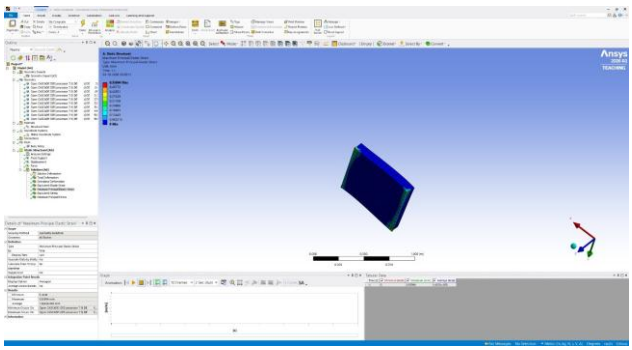


Figure 11: ANSYS maximum principal elastic strain contour

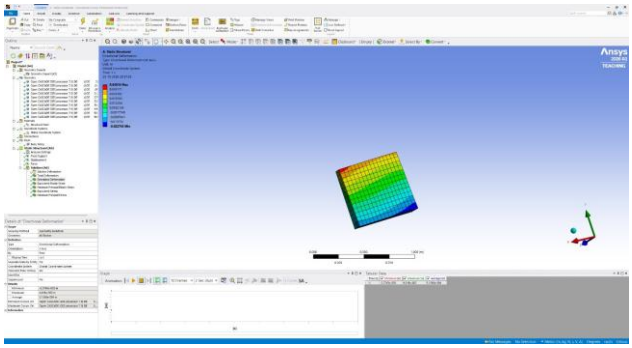


Figure 8: ANSYS directional deformation contour (X direction)

6.4 Overall discussion

The Phase I findings establish the preliminary material parameters and a test-slab design. The AAC aggregate specific gravity of 0.60 and reported water absorption of 15% are important mix-design considerations. The planned SSD conditioning is intended to reduce uncontrolled absorption of mixing water. The aggregate impact value of 37% requires consideration in conjunction with the concrete performance tests. Although the manual slab calculations indicate satisfactory checks under the stated assumptions, the structural response of AAC-containing concrete cannot be established from mix calculations or the initial ANSYS contours alone. Experimental cube, durability and slab tests are necessary to determine whether any replacement level provides an appropriate balance of weight reduction, strength and serviceability.

7. Conclusions and Future Work

The following conclusions are limited to the Phase I work reported:

1) Review of the literature identified a need for further slab-level investigation of precast concrete slabs incorporating AAC block aggregate, particularly with respect to load capacity, load–deflection response, cracking and failure mode.
2) A preliminary M40 mix was proportioned at a water–cement ratio of 0.40 for 0%, 5%, 10%, 15% and 20% AAC replacement by volume of coarse aggregate. The calculated cement content was 437.1 kg/m³.
3) The AAC aggregate had a reported specific gravity of 0.60 and water absorption of 15%. The aggregate impact value was 37%. Pre-soaking and SSD conditioning are proposed before mixing.
4) A 700 mm × 600 mm × 100 mm two-way slab was designed with 8 mm diameter bars at 150 mm centres in both directions. The preliminary manual calculations reported satisfactory flexure, shear and deflection checks under the adopted assumptions.
5) The initial ANSYS analysis generated deformation, strain and stress contours. The unusually high peak values require model and unit verification and experimental validation; they should not be interpreted as validated structural performance.

Phase II will include casting and water curing of 150 mm cubes and slab specimens, testing at 7, 14 and 28 days, compressive-strength evaluation, water absorption and permeability tests, and slab load testing to obtain load–deflection curves, crack patterns and failure modes. Results will be compared with the 0% AAC control mix to identify an optimum replacement level. The ANSYS model will be refined using the experimental response.

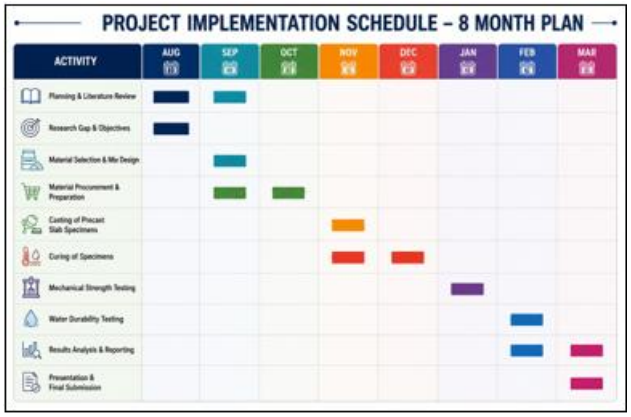


Figure 12: Project implementation schedule reported for the Phase II programme

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