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Sustainable Use of Autoclaved Aerated Concrete (AAC) Block Waste in Concrete

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Abstract*— The construction industry has a major impact on the environment and on resources. Autoclaved aerated concrete is an incredibly green, eco-friendly, and sustainable building material (AAC). The use of AAC is now highly necessary because to India's growing urbanization. It is consequently expected that post-demolition garbage will increase in the future. However, post-demolition AAC is mostly disposed of in landfills because to declining landfill capacities. This study looks into the idea of employing waste from autoclaved aerated concrete (AAC) blocks to replace coarse and fine aggregate in concrete separately at varied replacement levels of 4%, 8%, and 12%. The study aims to assess the impact of adding discarded AAC material on concrete's mechanical qualities. Through experimental investigation, the split tensile and compressive strengths were evaluated. The results demonstrate that increasing the proportion of AAC waste substitution typically leads to gains in compressive and split tensile strengths when compared to conventional aggregates. These findings suggest that residual AAC block material might be substituted for aggregate in concrete mixtures, potentially strengthening and improving the material's sustainability for use in construction. The main objective of this work is to employ locally available AAC trash as a lightweight aggregate in concrete production, potentially allowing industrial wastes to be transformed into higher-value products. The results of this study can aid in the growth of a circular economy in the construction industry by promoting the use of environmentally friendly alternatives in upcoming projects.

Keywords*— *Autoclaved aerated concrete (AAC), Waste, Replacement, Mechanical properties. Autoclaved aerated concrete (AAC), Waste, Replacement, Mechanical properties.

1. INTRODUCTION

The blocks known as AAC (Autoclaved AeratedConcrete) are a ground-breaking development in the building materials industry. Since their development in the early 20th century, AAC blocks have beenwell-known for their exceptional qualities and diverse range of uses in a variety of construction projects across the globe. An innovative procedure that involves aerating and curing a mixture of sand, cement, lime, gypsum, and an expansion agent like aluminium powder is used to make AAC blocks. The mixture is formed into lightweight, cellular concrete blocks with a unique porosity structure by pouring it into moulds and then exposing them to high-pressure steam curing.

As urbanization continues to grow in emerging nations, enormous volumes of construction and demolition (C&D) waste are produced. Usually, the demolition of heat-conservation wall material produces AAC waste. AAC blocks are in high demand on the market, and the construction process will produce a significant amount of autoclaved aerated concrete waste (AACW) [11] However, the majority of this kind of construction waste is disposedof in an easy manner, like stacking, which contaminates the soil and water in addition to occupying land resources [12]. Therefore, recycling of AAC waste in building materials has garnered a lot of attention because it is a traditional construction and demolition waste. A possible strategy including the substitution of AAC waste for cement in sustainable construction materials was suggested by certain researchers [13]. The AAC waste's fineness was enhanced and disposed of using the wet-milling procedure. According to [1]. (2014), the majority of the research employed AAC waste as a lightweight aggregate for building materials.

According to research, aggregate consumption was projected to be approximately 37,400 metric tons annually in 2010 and may potentially reach 51.7 billion metric tons by 2019. The over use of natural aggregates could harm ecosystems, but if waste and residues are correctly handled, they can end up somewhere far more sustainable. The purpose of this study is to examine the viability and effects of using AAC block waste in place of conventional aggregates in concrete mixes at different replacement percentages of 4%, 8%, and 12%.Overall, there are a number of ways to improve strength and performance when using AAC block waste as fine and coarse aggregates in concrete. This study aims to compare the mechanical characteristics such as compressive strength, split tensile and also workability of concrete using AAC with conventional concrete by an extensive examination of the literature and experimental investigation. Through the investigation of the impact of AAC block waste replacement on concrete performance, this study advances the use of sustainable building practices. The use of AAC block waste in place of aggregate could ultimately transform concrete construction techniques and open the door to a more sustainable and environmentally friendly built environment.

2.METHODOLOGY

A. Materials and Methods

The five components of concrete make up the materials used in this experiment are:

Fine aggregate: Locally available sand was used with specific gravity and fineness modulus of 2.68 and 10.35.Particles in fine aggregate range in size from 75 microns (μm) to 4.75 mm. The strength, longevity, and workability of concrete are all strongly impacted by the particle size distribution, which is frequently represented by gradation curves. IS 383: 1970 specifies four grading zones for fine aggregates. The given sample belongs to Zone II.

TABLE 1: SIEVE ANALYSIS OF FINE AGGREGATE

Sieve size in mm	Weight of soil retained in g	% Retained	Cumulative % retained	% Finer
4.75	-	-	-	100
2.36	149	14.90	14.90	85.10
1.18	276.50	42.55	42.55	57.45
0.600	121	54.65	54.65	45.35
0.425	127.50	67.40	67.40	32.60
0.300	92.50	76.65	76.65	23.35
0.150	155	92.15	92.15	7.85
0.075	15.50	93.70	93.70	6.30
Pan	6	100	100	0

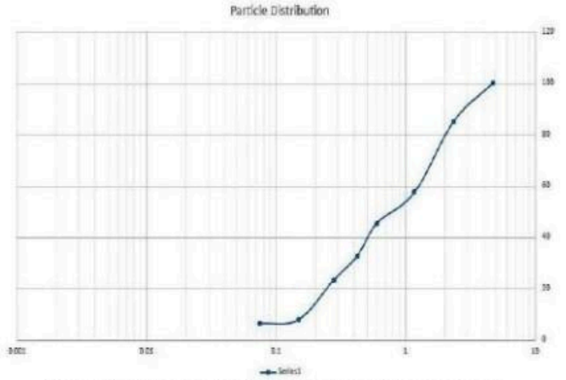

Fig 1. Particle size distribution curve of fine aggregate

Coarse aggregate: Coarse aggregate is obtained from locally available source with specific gravity and fineness modulus of 2.60 and 4.42.Water absorption value is found to be 0.91%.

TABLE 2: SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve size in mm	Weight of soil retained in g	% Retained	Cumulative % retained	% Finer
50	-	-	-	100
40	-	-	-	100
31.5	-	-	-	100
25	218	4.36	4.36	95.64
20	2106.5	42.13	46.49	53.51
16	2108.5	42.17	88.66	11.34
12.5	499	9.98	98.64	1.36
10	25	0.5	99.14	0.86
6.3	9	0.18	99.32	0.68
4.75	-	-	99.32	0.68
Pan	34	0.68	100	0
		Total = 535.93g		

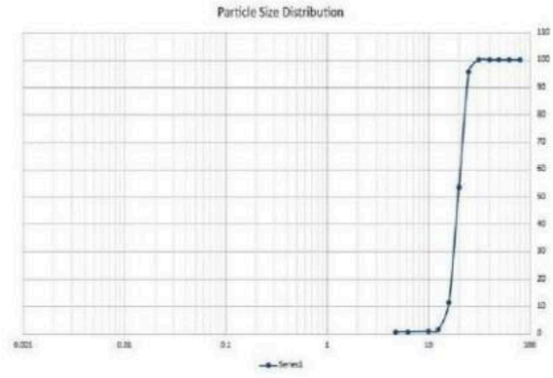

Fig 2 : Particle Size Distribution of Coarse Aggregate

Cement and Water: OPC grade 53 cement is used in this study. Properties of cement are tabulated in table 3. Vicat apparatus is used to determine the initial and final setting time of cement. Water as per IS 456: 2000 is used for the making of all concrete.

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TABLE 3: PROPERTIES OF CEMENT

Properties	Result	Permissible Limit
Specific Gravity	3.15	3.0-3.15
Fineness	2%	<10%
Normal Consistency	31%	<34%
Initial Setting Time	190 minutes	>30 minutes
Final Setting Time	435 minutes	<10 hours

AAC Waste: Damaged AAC goods are collected from local shops as AAC waste. First AAC is crushed into smaller pieces and then is made into fine aggregate in Los Angeles Abrasion machine. AAC are sieved through 4.75mm sieve to get fine aggregates. To get coarse aggregate AAC is passed through 16mm sieve and retained on 12mm sieve. Properties of AAC are labelled in a table below.

TABLE 4 : PROPERTIES OF AAC

Properties	Value
Dry Density	500 – 730 kg/m^3
Working Density	650 – 910 kg/m^3
Compressive Strength	3.0 – 5.5MPa
Thermal Conductivity, K	0.24 W/ mK

Fig 3 : : AAC Waste being prepared

Mix Design:
Grade of concrete = M30
Cement type = OPC Grade 53
Maximum nominal size of aggregate= 20mm
Specific gravity of cement = 3.15
Specific gravity of coarse aggregate= 2.680
Specific gravity of fine aggregate = 2.683
Adopted water – cement ratio from table 5 of IS 456 = 0.45
Estimated water content for 100mm slump= 186 + 6/100 x 186 = 197 Ltr

Cement content= 197/0.45 = 437.77kg/m^3
Target strength = fck + 1.65s
= 30 + (1.65x5)
= 38.25 N/mm^2

Mix proportioning, For 1 m^3

TABLE 5 : MIX PROPORTIONING

Item	Quantity in Volume
Volume of Cement	0.139
Volume of Water	0.197
Volume of all in aggregate	0.664

The study uses Indian Standard IS 10262: 2019 to test and evaluate the properties of the materials used. This research uses M30 Grade concrete and it was designed for load bearing structures. Water cement ratio was found to be 0.45. As per IS 10262: 2019 , the mix proportion for the desired concrete is obtained as 1 : 1.504 : 2.559 :0.45Fine aggregate and coarse aggregate are replaced at 4,8 and 12%. For each replacement 9 cubes and 3 cylinders are made so a total of 9 cubes and 3 cylinders for control group, 27 cubes and 9 cylinders for fine aggregate replacement and 27 cubes and 9 cylinders are required for coarse aggregate replacement are required. Cube mould is constant dimension of 150mm × 150mm × 150mm. Before filling, the slump of concrete was conducted. The compressive strength of concrete will be tested by using a compressive strength machine after cured for 7, 14 and 28 days. The cube specimens will be put under pressure of load 140kg/m^3 per minute until it fails to determine the compressive strength. The formula for compressive strength, N/mm^2 is express by Force, N per Area, mm^2 is in Eq.1:

$$Compressive\ strength, \sigma = \frac{\text{Force}}{\text{Volume}}$$

. 1

The tensile strength of the concrete is found with the formula:

$$Tensile\ Strength = \frac{2}{\ }$$

Eq. 2

Where: P is the maximum applied load (in N), D is diameter of the specimen (in millimetres), and L is the length of specimen (in mm).

3.RESULT AND DISCUSSIONS

A. Slump test of Concrete

The slump cone test provides valuable insights into the workability of fresh concrete, The measured slump value reflects the ability of concrete to flow and deform under its own weight, indicating its

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suitability for various construction applications. Table 6 provided the concrete slump test results, and the graph displayed the height of slump for concrete withfive distinct AAC percentages.

TABLE 6: SLUMP VALUE OF CONCRETE WITH FINE AGGREGATE REPLACEMENT

% of Replacement of AAC in Concrete	Value of Slump Test cm	Degree of Workability
0% replacement of AAC	75	Normal Slump
4% replacement of Fine aggregate with AAC	80	Low slump
8% replacement of Fine aggregate with AAC	87	Low slump
12% replacement of Fine aggregate with AAC	95	Low slump
4% replacement of Coarse aggregate with AAC	79	Low slump
8% replacement of Coarse aggregate with AAC	84	Low slump
12% replacement of Coarse aggregate with AAC	87	Low slump

[16] Reported that the percentage of foamed concrete waste used as partial fine sand replacement increases,so does the slump read of the concrete. Table 3 shows that when the quantity of AAC aggregates in concrete increases, so does the height of slump. This experiment had proven that [16] research had achieved. During the removal of the slump cone, the concrete shows a true slump in form. As the percentage of AAC aggregate used as fine aggregate and coarse aggregate in the concrete mixture increased, so did the degree of workability. The larger quantity of porosity was the cause of slump height was getting higher that allows more water to be absorbed. This happened because of the physical properties of AAC has a numerous of voids present init. If there was no slump occurs during the slump testing, it was recommended to add a small amount ofwater consequently to avoid dry mixes

Fig 4: Slump cone test

A. Compressive Strength

After water curing for 7, 14, and 28 days, the compressive strength of concrete containing sevendifferent percentages of AAC as a partial replacement of fine and coarse aggregate was measured. The compressive strength of concrete for 7 and 28 days following curing is shown in Tables 6 and 7. The average compressive strength graph for the 7th, 14th, and 28th days of curing is shown in Figure 3. This finding indicates that as the percentage of AAC waste grew, compressive strength also increased. The control group's compressive strength on the seventh day of curing was determined to be 24.58 N/mm2, while the maximum compressive strength recorded on the seventh day of curing was 27.40 N/mm2, obtained when 12% of the fine aggregate was replaced with AAC trash.

Table 6: Compressive strength after 7 days of curing

% of Aggregate Replaced with AAC Waste	Compressive Strength N/mm^2
0% Replacement of Aggregate	24.58
4% Replacement of Fine Aggregate	25.18
8% Replacement of Fine Aggregate	26.07
12% Replacement of Fine Aggregate	27.40
4% Replacement of Coarse Aggregate	25.77
8% Replacement of Coarse Aggregate	25.77
12% Replacement of Coarse Aggregate	27.01

Table 7: Compressive strength after 14 days of curing

% of Aggregate Replaced with AAC Waste	Compressive Strength N/mm^2
0% Replacement of Aggregate	31.26
4% Replacement of Fine Aggregate	35.10
8% Replacement of Fine Aggregate	35.90
12% Replacement of Fine Aggregate	36.70
4% Replacement of Coarse Aggregate	32.88
8% Replacement of Coarse Aggregate	37.77
12% Replacement of Coarse Aggregate	39.11

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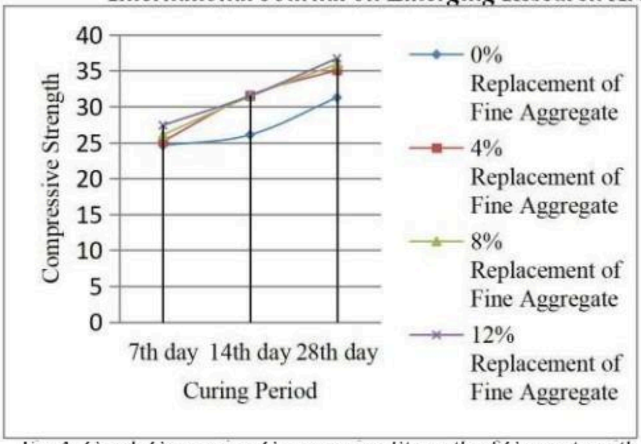

Fig 4: Graph Comparing Compressive Strength of Concrete with Partial Fine Aggregate Replacement

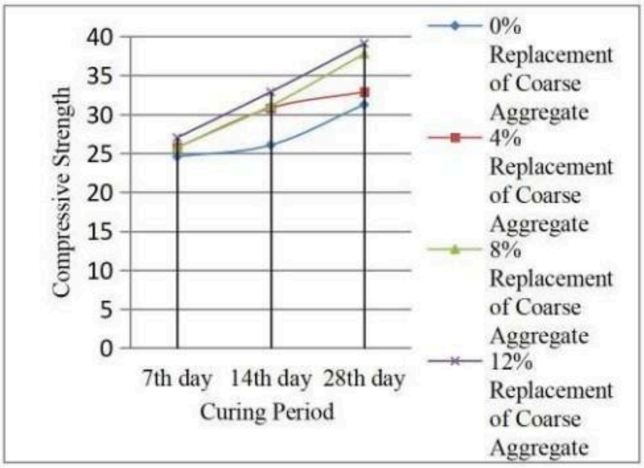

Fig 5: Graph Comparing Compressive Strength of Concrete with Partial Coarse Aggregate Replacement

The intended target strength design was achieved in this concrete strength testing. On the 28th day of testing, the concrete's compressive strength test readings for every group of specimens are greater than 30 N/mm2. The water reserve of recycled AAC aggregate provides moisture for the cement hydration process. In real-world applications, internal curing will expand the positive curing regime from inside the concrete structure, as the effectiveness of external curing may be limited due to an unsatisfactory penetration of curing water into the samples (4). The addition of AAC silt may have also increased compressive strength since it increases the interfacial bonding between AAC and other materials.

Fig 6: Compression Testing

B. Split Tensile Strength

One popular technique for determining the tensile strength of concrete specimens is the split tensile test. The split tensile test results for concrete are shown in this section. Table 8 shows split tensile result at various replacement.

Table 8: Tensile Strength of concrete

% of Aggregate Replaced with AAC Waste	Tensile Strength N/mm^2
0% Replacement of Aggregate	2.01
4% Replacement of Fine Aggregate	2.16
8% Replacement of Fine Aggregate	2.21
12% Replacement of Fine Aggregate	2.22
4% Replacement of Coarse Aggregate	2.12
8% Replacement of Coarse Aggregate	2.68
12% Replacement of Coarse Aggregate	2.40

We saw a small improvement in split tensile strength from this test, which indicates that we can use AAC waste for aggregate without sacrificing its mechanical qualities. The highest tensile force is seen when 8% of the fine aggregate is replaced with AAC waste (2.68 N/mm^2).The measured values of tensile strength were compared with the concrete mix's design specifications. The findings show that the concrete specimens satisfied the design specifications defined tensile strength requirements. Figure 7 shows split end tensile test and Figure 8 represents the comparison of split tensile strength at different percentage of replacement.

Fig 7: Split Tensile Testing

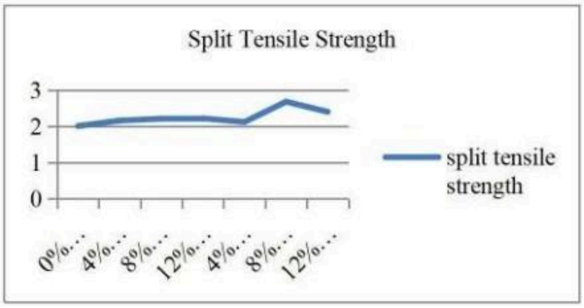

Fig 8: Comparison of Split Tensile Strength after 28 days of curing

4.Conclusion

To conclude the current research, replacing fine aggregate and coarse aggregate in concrete has improved the compressive strength and split tensile. The optimum percentage of 12% replacement of fine aggregate and coarse aggregate has highest compressive strength of 36.60 N/mm2 and 39.11 N/mm2. The experiment's outcomes demonstrate that the study's goals were effectively met. Every piece of information gathered in the anticipated outcomes demonstrates that the AAC block waste produced during concrete building and demolition can be recycled or utilized again for the creation of new concrete. In this instance, utilizing less aggregate in concrete mixtures can support both construction and the environment. The primary goals of this study are to identify the physical characteristics of concrete, such as compressive strength, split tensile and workability. The concrete's level of workability is found to be low when AAC was added. Building trash can be sustainably managed and circular economy concepts can be promoted in the construction industry by utilizing AAC block waste. By keeping AAC waste out of landfills and using it for recycling as aggregate, the building industry helps reduce waste and conserve resources, which lessens its negative effects on the environment and promotes the development of more sustainable built environments.

References

[1] Shankar, A. N., et al. "Physical and mechanical properties of foamed concrete, a literature review." Materials Today: Proceedings (2023).

[2] Zou, Dujian, et al. "Sustainable use of recycled autoclaved aerated concrete waste as internal curing materials in ultra- high performance concrete." Journal of Cleaner Production 373 (2022): 133910

[3] Gyurkó, Zoltán, et al. "Sustainable applications for utilizationthe construction waste of aerated concrete." Journal of cleaner production 230 (2019): 430-444.

[4] Shukla, Mr Ashutosh, Satyendra Dubey, and Anubhav Rai. "investigating the impact of partial cement replacement with waste from aac and clc block production on cement mortar."Yang, Jin, et al. "Utilization of submicron autoclaved aerated concrete waste to prepare eco-friendly ultra-high performance concrete by replacing silica fume." Journal of Cleaner Production 376 (2022): 134252.

[5] Tanash, Alaa Omar, et al. "Potential of recycled powder from clay Brick, sanitary Ware, and concrete waste as a cement substitute for Concrete: An overview." Construction and Building Materials 401 (2023): 132760.

[6] Bergmans, Jef, et al. "Recycling of autoclaved aerated concrete in screed and stabilized sand." Fifth International Conference on Construction Materials (CONMAT), Whistler,BC, Canada. 2015.

[7] Suwan, Teewara, and Pitiwat Wattanachai. "Properties and internal curing of concrete containing recycled autoclaved aerated lightweight concrete as aggregate." Advances in Materials Science and Engineering 2017 (2017).

[8] Volk, Rebekka, et al. "Life cycle assessment of post-demolition autoclaved aerated concrete (AAC) recycling options." Resources, Conservation and Recycling 188 (2023): 106716.

[9] Lam, Nguyen Ngoc. "Recycling of AAC waste in the manufacture of autoclaved aerated concrete in Vietnam." GEOMATE Journal 20.78 (2021): 128-134.

[10] Yang, J., Zeng, L.H., Su, Z.C., He, X.Y., Su, Y., Zhao, R.X., Gan, X.C., 2020. Wet-milling disposal of autoclaved aerated concrete demolition waste - a comparison with classical supplementary cementitious materials. Adv. Powder Technol.31 (9), 3736–3746.

[11] Yang, Jin, et al. "Potential usage of porous autoclaved aeratedconcrete waste as eco-friendly internal curing agent for hrinkage compensation." Journal of Cleaner Production 320 (2021): 128894

[12] Alik, Angelina Buhat Anak, and Masni A. Majid. "Physical and Mechanical Properties of Autoclaved Aerated Concrete (AAC) as Partial Fine Aggregate in Concrete." Recent Trends in Civil Engineering and Built Environment 4.1 (2023): 266-277. 119455.

[13] Bukhari, Syed Aqeel, et al. "Utilization of waste materials in non-autoclaved aerated concrete blocks: State of art review." Materials Today: Proceedings (2023).

[14] Tewar, Bhargav, Pramit M. Shah, and Parth B. Patel. "Effect of Partial Replacement of Sand with Wastage of Manufactured AAC Block in Concrete." Materials Today: Proceedings 4.9 (2017): 9817-9821

[15] Alik, Angelina Buhat Anak, and Masni A. Majid. "Physical and Mechanical Properties of Autoclaved Aerated Concrete (AAC) as Partial Fine Aggregate in Concrete." Recent Trends in Civil Engineering and Built Environment 4.1 (2023): 266-277. 119455.

[16] Bukhari, Syed Aqeel, et al. "Utilization of waste materials in non-autoclaved aerated concrete blocks: State of art review." Materials Today: Proceedings (2023).

[17] Tewar, Bhargav, Pramit M. Shah, and Parth B. Patel. "Effect of Partial Replacement of Sand with Wastage of Manufactured AAC Block in Concrete." Materials Today: Proceedings 4.9 (2017): 9817-9821.

[18] Affandy, Noor Edelah Mohd, and Masni A. Majid. "The Study of Crushed Autoclaved Aerated Concrete as Sand Replacement in Concrete." Recent Trends in Civil Engineering and Built Environment 4.3 (2023): 601-610.

[19] Lam, N. N. "Influence of fly ash and recycled AAC waste for replacement of natural sand in manufacture of Autoclaved Aerated Concrete." IOP Conference Series: Earth and Environmental Science. Vol. 505. No. 1. IOP Publishing, 2020.

[20] Paliwal, Mr Aditya, Mr Sooraj Jain, and Rajeev Jain. "Experimental Analysis on using Recycled CLC and AAC Block Dust As A Cementitious Material, in Rigid Pavement."

[21] Rafiza, A. R., et al. "An innovative autoclaved aerated concrete (AAC) with recycled AAC powder for low carbon construction." IOP Conference Series: Earth and Environmental Science. Vol. 268. No. 1. IOP Publishing,2019.

[22] He, Xingyang, et al. "Feasibility of incorporating autoclaved aerated concrete waste for cement replacement in sustainable building materials." Journal of Cleaner Production 250 (2020):