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# Comparative Study of AAC Block and Brick Fully Infill Buildings and Buildings having Soft Storey at Different Floor Subjected to Earthquake: A Review

Hrituraj Singh Rathore[1], Dr.Savita Maru[2]
[1]*M. E Student - Department of Civil Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh*
[2]*Professor - Department of Civil Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh*

***Abstract: Autoclaved Aerated Concrete is a Low cost, Lightweight, Load- bearing, High-insulating, Durable building product, which is produced in a wide range of sizes and strength and used widely due to its low cost in earthquake prone area. In this study a 3D numerical model of AAC and Brick fully infill building and buildings having soft storey is constructed and performed the analysis by using software SAP 2000 (ver.16.0) using static nonlinear method. This paper highlights the comparing and investigating the changes in structural behaviour of AAC and Brick fully infill and building having soft storey subjected to seismic load. The result of the analysis for displacement base shear and storey drift have been studied and compared for all the structure models.***
***Keywords: AAC Block, Brick Infill, SAP2000, Nonlinear static Analysis, Soft storey.***

## I. INTRODUCTION

The Autoclaved Aerated Concrete (AAC) material was developed in 1924 in Sweden. It has become one of the most used building materials in Europe and is rapidly growing in many other countries around the world. AAC is produced from the common materials lime, sand, cement and water, and a small amount of rising agent. After mixing and moulding, it is then autoclaved under heat and pressure to create its unique properties. AAC has excellent thermal insulation and acoustic absorption properties. AAC is fire and pest resistant and is economically and environmentally superior to the more traditional structural building materials such as concrete, wood, brick and stone.

Earthquakes present one of civil engineering's most complex challenges. They typically strike without forewarning and impact every aspect of a civilization's infrastructure. Approximately 20% of the world population lives in or near earthquake zones, more than 70% of that percentage (a staggering one billion people) is represented by low income or poverty level socio-economic classes. The statistics show that countries with high population density and lower standards of living also happen to be countries situated in seismically active regions. Indonesia, India, China, Asia, and portions of the South Americas are examples. A large majority of the population in these areas, in turn, live in low income housing constructed of earth, stone, thatch, hollow block, and other types of low cost materials.

AAC blocks manufacturing projects exist in more than 40 countries and used across more than 70 countries. Cumulative manufacturing capacity of AAC blocks manufacturing projects stands at over 75 million m3/year. Biltech Building Elements Limited is India's largest AAC manufacturer.

Now a day's large number of building are constructed using AAC block due to its lower cost than brick masonry, Easy to construct, light in weight, high thermal insulation, high fire protection, high sound insulation, lower water absorption, eco-friendly.

Therefore, it is essential to analysis the AAC block and brick fully infill building and building having soft storey subjected to earthquake using SAP 2000 (ver. 16.0) and compare the response of structure in terms of base shear, displacement and storey drift.

## II. LITERATURE REVIEW

Robert G. Mathey and Walter J. Rossiter, Jr. (1988) the review addressed the overview of the manufacturing process uses of the autoclaved aerated concrete block use in building construction, properties, energy consideration, the availability of code-related documents, and standards. Uses include block and panels construction floor, and roof. Many properties are reviewed including density, fire resistance, moisture expansion, shrinkage, strength, structure, thermal conductivity.

Costa, A. Penna, G. Magenes and A. Galasco (2008) In order to assess the seismic behavior of entire AAC masonry buildings, a calibration of the nonlinear macro-element included in the TREMURI analysis program was carried out based on the experimental cyclic response of masonry piers observed. The results obtained from adaptive pushover analyses (Actual Displacement-Based Adaptive Pushover) of the different prototypes have been compared with the results of incremental dynamic analyses.

Ayudhya (2011) discussed Compressive and splitting tensile strength of autoclaved aerated concrete (AAC) containing perlite aggregate and polypropylene fibre subjected to high temperatures. Experimental tests are performed on Cylinder specimens which is subjected to various temperature ranges of 100, 200, 400, 800, and 1,000°C. The mixtures were prepared with AAC cementitious materials containing perlite at 15%, 20%, and 30% sand replacement. The polypropylene fibre content of 0, 0.5%, 1%, 1.5%, and 2% by volume was also added to the mixture. The results showed that the unheated compressive and splitting tensile strength of AACs containing PP fibre were not significantly higher than those containing no PP fibre. Furthermore, the presence of PP fibre was not more effective for residual compressive strength than splitting tensile strength. The 30% perlite replacement of sand gave the highest strength.

Rivera and Baqueiro (2012) evaluate system over strength factors (R) for AAC structures. The R factors are calculated as the product of independent over strength factors associated with the amount of flexural steel reinforcement, the actual yielding strength in this reinforcement, the rate of loading, the use of load and strength-reduction factors and the simplifications assumed in the design. These independent factors are evaluated for AAC wall structures designed in different soil types according to the current Mexico City Seismic Code (MCSC). Based on the results obtained in their work it is concluded the system overstrength factor depends mainly on the factors RAS, RFD and RVMIN. The system overstrength factor decreases as the natural period of the structure increases. The system overstrength factors for soil type I are smaller than those obtained for soil type IIIa. At the same time, the system overstrength factors obtained for soil type IIIa are smaller than those obtained for soil type IIIb. The system overstrength factors are greater than those specified in the MCSC in soil types IIIa and IIIb. An equation is proposed to determine the system overstrength factor as a function of the natural period of the structure and the soil parameters.

Penna et al. (2012) studied Enhancement of the seismic performance of AAC masonry by means of flat-truss bed-joint reinforcement. Their study presents the results of an experimental campaign including in-plane cyclic tests on autoclaved aerated concrete (AAC) masonry panels with thin bed- and head-joints filled with glue-mortar. Some of the specimens are made of unreinforced masonry, whilst in other the masonry walls are reinforced by means of bed-joint flat-truss reinforcement only. Based on the results of tests, complemented by specific tests performed on Wallette's realized with the two different construction techniques, a possible strength criterion is proposed. The results indicate that the inclusion of bed-joint reinforcement has the double effect of improving masonry resistance and displacement capacity, hence reducing damage.

Samoila (2012) focuses on determining the width of compressed strut by means of different equations available, but recommends the use of Paulay and Priestley relation. The infill influence on frame members is studied on several models, as the single-strut model, the three-strut model and finite element models. By analyzing the resulting forces in the beam and columns both as values and distribution, it has been observed that the three-strut model can estimate local effects more precisely due to frame infill interaction.

Akpınar and Binici (2013) discussed the failure mechanisms of the infill walls were numerically simulated by integrating an element removal algorithm to the traditional diagonal strut models. The possible unfavourable effects of infill walls on the reinforced concrete structures were investigated under the earthquake loads. For this purpose, a 4-story 3-bay deficient reinforced concrete frame with infill walls was examined and the results were compared with those of the bare frame. 7.4 magnitudes 1999 Duzce earthquake was used as the ground motion record in the nonlinear time history analyses. The analysis results indicated that including infill wall collapse in analyses resulted in large deformation demands, sudden stiffness degradations and formation of a soft story. These detrimental damage events were not observed when the presence of infill walls was neglected.

Catherin et al. (2013) discussed the different modelling aspects of masonry infills given by various researchers. They conclude that the masonry infills, although do not interfere in the vertical load resisting system for the RC frame structures, they significantly affect the lateral load-resisting system of the same. Formulation given by FEMA 356, Turkish Seismic Code-2007 for equivalent diagonal strut is the simplest of all the methods. Indian code does not consider the position or amount of infill present in the structure, whereas Euro code gives importance to the masonry in the first storey but the results of the Indian code are better compared to Euro code.

Hassan and Vidyadhara (2013) carried out seismic analysis of earthquake resistance multi-storey multi bay RC frame. They studied the seismic behaviour of bare frame model, building with first soft storey (infill wall in upper storeys) with presence of both infill and shear wall at corner position for which they used 4 bays twelve storey building situated at a slope of 1:1/3 located in seismic zone V. These buildings have been analyzed using Equivalent static, Response spectrum and Pushover analysis. Based on Equivalent analysis results they noted that there is reduction in displacement of models with infill and shear wall at corners with respect to bare frame model by almost 79.15% and 89.27% respectively in longitudinal direction and from Response spectrum analysis which are almost 50.95% and 73.97% respectively. Hence, they conclude that the presence of Brick infill and shear wall reduces lateral displacement considerably.). From pushover analysis, it is observed that the spectral displacement and Roof displacement of bare frame is higher than building with shear wall at corner. Thus, they conclude that the presence of infill wall and shear wall influences the overall behaviour of structures when subjected to lateral forces by effectively reducing large joint displacements found in bare frame.

Jadhao and Pajgade (2013) studied the behaviour of RC frames with both AAC block and conventional clay bricks infill when subjected to seismic loads. They conclude that the base shear experienced by models with AAC blocks was significantly smaller than with conventional clay bricks which results in reduction in member forces which leading to reduction in required amount of Ast to resist member forces. So, economy in construction can be achieved by using AAC blocks instead of conventional clay bricks.

Md. Anisur Rahman and Md. Masum, Syeda Zehan Farzana and Dr. Md. Jahir Bin Alam (2014) study is to analysis of drift or displacement of highrise building. Lateral loads are mainly responsible for drift. After completion it is found that seismic load is more critical than wind load, for this basis here seismic load is considered as well as wind load. A theoretical study has been made finding of drift value for high rise building due to lateral loads.

Cerny and Drochytka (2014) studied Utilization of FBC ash in autoclaved aerated concrete technology. Their study deals about the possibility of fluidized fly ashes utilization in the technology of autoclaved aerated concrete, rheological properties of the mixture, the plastic strength, compressive strength and density of aerated concrete. in this they also determined current state of use and legislative background of use of CCPs in the Czech Republic. they also verify the autoclaving time influence on tobermoritic phase developments and to this related compressive strength of the fly ash aerated concrete.

Shukla (2014) discussed an effort towards comparing two main construction materials and providing comprehensive analysis which will help Engineers and Architects determining their material choices. Comparative Analysis indicates that in almost all the parameters, the AAC blocks have a superior edge over burnt clay bricks. The use of AAC blocks leads to savings in overall project cost; enables to speed up the construction process reduced environmental and social impact. Therefore, she concluded that use of ACC blocks over burnt clay bricks is recommended. It is advisable to developers, contractors, and individuals to encourage this product as its use is in national interest.

Niruba (2014) performed analysis by assigning different Partial Safety Factors (PSF) to the mechanical parameters of infill walls, in order to investigate their effect on the overall structural response of the building. A number of non-linear static (pushover) analyses were performed on proper structural models of the building, considering both bare framed structure and the infilled one, in order to appraise the influence of infill walls on the failure mechanisms. Itis observed that frames with infill produce much smaller deflections as compared to frames without infill. The results reflect the significance of infill in increasing the strength, stiffness and frequency, of the entire system depending on the position and amount of infilling. Lower infilling is noted to provide more stiffness for the system as compared with upper locations.

T. Sandeep (2015) a 3d analytical model of multistory building have been generating for different building models and analysing using structural analysis tool ETABS, to study the effect of ground soil, infill and models with ground soft during earthquake, seismic analysis both linear static, linear dynamic as well as non linear static(pushover) procedure have to be perform. It shows that the Infills having no irregularity in elevation having beneficial effects on buildings. In infilled frames with irregularities, such as ground soft storey, damage was found to concentrate in the level where the discontinuity occurs.

Elhamed and Mahmoud (2015**)** investigate the seismic response of reinforced concrete frame building considering the effect of modelling masonry infill walls. The seismic behaviour of a residential 6-storey RC frame building, considering and ignoring the effect of masonry, is numerically investigated using response spectrum analysis. The considered here in building is designed as a moment resisting frame (MRF) system following the Egyptian code (EC) requirements. Two developed models in terms of bare frame and infill walls frame are used in the study. Equivalent diagonal strut methodology is used to represent the behaviour of infill walls, whilst the well-known software package ETABS is used for implementing all frame models and performing the analysis. The results of the study indicate that the interaction between infill walls and frames significantly change the responses of buildings during earthquakes compared to the results of bare frame building model. Specifically, the seismic analysis of RC bare frame structure leads to under estimation of base shear and consequently damage or even collapse of buildings may occur under strong shakings. On the other hand, considering infill walls significantly decrease the peak floor displacements and drifts in both X and Y-directions.

Deshmukh and Pajgade (2015) determined the behaviour of RC frames with both AAC block and conventional clay bricks infill with varying percentage of opening subjected to seismic loads on ETABS v 9.6.0. they concluded that the bare frame for all models showed lower strength, initial stiffness and ductility, as compared to fully infilled models. In column, considering AAC infill wall effect, the value of axial force, bending moment, Ast is less compared to brick infill frame. Because of infill wall effect, there is drastic decrease in the value of axial force in column. Maximum Axial Force is at the foundation level. The deflection and drift of structure with AAC block in all cases was less as compared with the corresponding cases of structure with brick masonry. The Axial force in columns is significantly reduced for structure with AAC block masonry as compared with the structure with brick masonry. The bending moments for members of structure with AAC block in all cases were less as compared with corresponding cases of structure with brick masonry.

Rathi and Khandve (2015) replaced the red bricks with eco – friendly AAC blocks. on the basis of their study they concluded that the usage of AAC block reduces the cost of construction upto 20% as reduction of dead load of wall on beam makes it a comparatively lighter member. The use of AAC block also reduces the requirement of materials such as cement and sand upto 50%.

Miao et al. (2015) carried out Research on Self-Thermal Insulation Wall Construction Technology of Autoclaved Aerated Concrete Block. Their study proposes the construction of self-thermal insulation wall, shear wall insulation treatment measures and the detail construction of beam column thermal bridge. According to design standard for energy efficiency of residential building, their study analyzes the thermal performance of self-thermal insulation wall of AAC block, and focuses on the inner surface condensation trouble by illustrating the example of 200mm-thick reinforce concrete shear wall in Jinan region. The research results show that, AAC block of different levels with different thickness can meet the requirements of residential building energy conservation design standard in the cold and severe cold zones. The construction treatment of pasting heat-thermal plates outside concrete shear wall and smearing thermal-insulating mortar can avoid the inner surface condensation trouble of AAC block self-thermal insulation.

Aminudin et al. (2015) studied properties of industrial boiler ash as sand replacement and thermal improvement in aerated concrete. The Industrial Boiler Ash from Tanjung Bin Power Plant, Malaysia was used in their study. It is believed beneficial as by adding this precious material, it may improve properties of aerated concrete mechanically and thermally especially in the effect on improving the thermal conductivity. Their study presents the effects of using different character of mixing constituent such as various amount of foaming agent and range of superplasticizer content on the compressive strength. Besides that, determination on the final product properties in microstructure were also investigates. The results of their study show that using the IBA have a lower density compared to normal sand with a dry density of 1.408kg/m3 which a compressive strength of 5.258 MPa but also observed beneficial as it might improve the thermal conductivity behaviour with 0.52 W/mk compared to normal mortar concrete having 2.52 W/mk. This indicate that the use of Industrial Boiler Ash aerated concrete give a less impact of heat due to low thermal conductivity created.

Khandve (2016) discussed various new application of AAC product in construction industry are elaborated in order to utilize most advantages of AAC. Different AAC manufacturing industries should take initiative to make these new applications more popular so as to increase the share of AAC in construction industry contributing to green initiatives for sustainable development of nation as well. on the basis of his study he concluded that building with AAC panels makes it possible to reduce the total cost of ownership for the final consumer. Offering buildings made of solely prefab AAC elements results in a fast, easy construction and no on-site waste.

Desani et al. (2016) determined a sustainable alternate of clay brick masonry in form of light weight concrete. They concluded that 10 % and 20 % of the water treatment sludge ratio in mixture to make a hollow load bearing concrete block can reduce the cost at 0.64 baht and 1.05 baht per block, 50 % of water treatment sludge ratio in mixture to make a hollow non-load bearing concrete block can reduce the maximum cost at 2.35 baht per block, Dewatered water treatment sludge can be used for construction works such as hollow non- loading concrete blocks and hollow load bearing concrete blocks, Production of various mixed ratio of hollow concrete blocks from dewatered water treatment sludge used as a fine aggregate in hollow concrete blocks, could be a profitable disposal alternative in the future and will be of the highest value possible for the foreseeable future.

Rathi and Khandve (2016) discussed cost effectiveness of using AAC blocks for building construction in residential building and public buildings. The 6” and 9” thick wall building were designed using Staad pro software and the cost calculation for different component parts of the building were carried out. From the experimental results, it is observed that the compressive strength of AAC block is comparatively more than traditional bricks and the density of AAC block is comparatively less which helps in reducing the dead load of structure. It is found that upto 15 to 20%, the cost of construction can be reduced by using AAC blocks.

Pahade and Khare (2016) studied Comparison of Water analysis between AAC blocks-Gypsum plaster & Burnt red clay bricks-Sand cement plaster they found that AAC blocks are extremely resource efficient and environmental friendly material. As gypsum plaster does not require water curing a tremendous amount of water is saved. AAC block and gypsum plaster both only use 6-10 % water of conventional system. As there is no bigger disadvantage by using AAC block and gypsum plaster we can save lot water and it can be used for other activities. If wherever possible construction site makes this replacement of material it will contribute great saving of water in national interest.

Namboothiri (2016) discussed seismic evaluation of RC building with AAC block infill walls. A bare frame model and AAC block masonry infilled frame model with and without openings are modelled using the software ETABS. The infills in the structure are modelled as equivalent struts. The assumed structure is an apartment building of G+3storey in seismic zone III with medium soil strata. Seismic coefficient method of analysis is adopted. Influence of AAC blocks on various responses of RC framed structure is studied. Values of base shear, storey displacements and inter-storey drift are derived and compared to evaluate the effect of infill on the structure.

hote and Singh (2016) performed feasibility study for setting up a new autoclaved aerated concrete blocks manufacturing plant. their study is aimed at analyzing Technical, Economical and Financial viability of setting up an AAC Blocks Manufacturing Plant. they concluded that Fly ash is a major raw material source (65-70% of finished goods is fly ash) and by locating the plant almost adjacent to raw material source gives manifold advantage both logistically and commercially. The unit will be located in MIDC Butibori that is having direct access to all corners of the country through 4-laned national highways. The land is ideally located as it can cater to Nagpur (about 25 Km) and surrounding markets very conveniently. The current presumptions will be adequate and necessary for operation of 150,000 cu meter AAC unit. The plant design, OH cranes, rails have been planned in such a manner that the unit can double up its capacity simply by installing autoclaving chambers, with minimal changes in the infrastructure in the years to come.

Shivananda et al. (2016) performed investigation study on autoclave aerated concrete slab. in their study varying percentage of reinforcement are used in manufacturing of slab. In addition, the autoclaving process induces high thermal stress which can lead to cracking of slab due to thermal expansion of embedded steel reinforcement and larger spacing between the reinforcement. The slabs of live load 4 KN/m2 and 5KN/m2 are tested with 2-point loading system. The slabs are failed due to shear. The design of AAC slab is compared with RCC slab. The mass of AAC slab is considerably is less compared to equivalent RCC slab because of its less density.

Kurweti et al. (2017) performed Comparative analysis on AAC, CLC and flyash concrete blocks. In their study a deep discussion is carried out between the properties of AAC, CLC and fly ash. AAC (Autoclaved aerated concrete) is a light weight concrete material that was developed in many years ago, the main constituents used in making of this type of concrete is cement grade53, gypsum, class C lime (hydrated lime), aluminium powder (.05-.25% by wt of cement), fine aggregate or fly ash (class F) combining with definite proportions. CLC (Cellular light weight concrete) is another light weight concrete material which are widely used in making infrastructure and high-rise building, the main ingredients of making CLC is cement (OPC grade 53), Fly ash (class F), sand (passing 2mm sieve), foaming agent (either protein based or synthetic based). Fly ash is also taken in their study as a light weight concrete because it replaces partially fine aggregate and fully coarse aggregate the raw materials of this type of concrete is cement (grade53/grade43), Fly ash (class F), sand (passing 2mm sieve). On keeping density as a constant parameter their load carrying capacity in compression, thermal insulation and water absorption are to be tabulated and then conclusions are made by their best performance.

## III.CONCLUSIONS

From the above literature, it is seen that the researchers have been broadly carried out studies on the behaviour of AAC block. However, most of the studies have been analyzed with focus on AAC block building resting on plain ground with plan irregularity or performing experiments on AAC block for the static and dynamic loads. In other words, structural researchers are mostly concerned with the local compression effect, Physical properties, structure on plain ground, economic study, thermal comfort and block with opening but very few researchers concerned on effect of seismic loading on fully filled AAC block and Brick infill building and building having soft storey at different floor. Therefore, this topic requires further research and by the help of software we find a great result.

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