# A STUDY ON THE EFFICACY OF RHA AS A FULL REPLACEMENT FOR CLAY IN BRICK-BLOCKS

**Bandaru Sri Sai Shanmukh[1], Bagadi Saikumar[2]**

*[1]Student (B. Tech 4th year), Dept. of Civil Engineering, Gayatri Vidya Parishad College of Engineering (Autonomous), Visakhapatnam, A.P., India*
*[2]Student (B. Tech 4th year), Dept. of Civil Engineering, Gayatri Vidya Parishad College of Engineering (Autonomous), Visakhapatnam, A.P., India*

---***---

**Abstract -** *Clay bricks are the earliest known building blocks which have adverse effects on environment due to their large-energy-consuming manufacturing process. The ease of manufacturing and handling of fly ash bricks and Aerated Autoclaved Concrete (AAC) blocks, and a need to conserve traditional clay which is facing depletion, has resulted in replacement of clay bricks with these modern materials. The wide acceptance in the construction field led to the search of new and alternative materials which are energy-saving and environment-friendly. Firstly, the properties of Rice Husk Ash (RHA) were found and then design of mixes for various proportions of RHA were carried out. Later moulding of the specimens were done, followed by curing and testing of specimens. In the study brick-blocks were prepared using more than 50% RHA in all the mixes, which is much higher than the percentages reported by earlier researchers. Engineering properties like compressive strength, water absorption, size and shape have been studied. The results showed that clay when replaced with RHA in blocks showed a lesser value of compressive strength to those used in major construction as per IS 3495 and IS 12894, and have a higher water absorption value than the prescribed limits. From the results obtained it can be concluded that the bricks (with 50:20:30, RHA: M-sand: Cement proportion) can be used for unimportant works as they belong to Class C as per (Indian Standards) IS code. UPV tests revealed that the brick-blocks are very porous, as their wave velocities were about 1km/s.*

***Key Words*: Rice Husk Ash (RHA), Brick-block, sustainability, UPV**

## 1. INTRODUCTION

Paddy is a monocot plant and rice obtained from it is the staple food for a large portion of population leading to a large amount of paddy production and resulting in generation of large quantities of waste, most of which is not adequately managed. Rice husk wastes are used as animal feed [1], fertilizer and fuel for small-scale energy production, but little work has been reported on the use of RHA in the production of brick-blocks. For every 1000kg (980.7kN) of paddy milled, about 220kg (2.16kN) (22%) of husk is produced, and when this husk is burnt in the boilers, about 55kg (540N) of ash (i.e., RHA) is generated of the 220kg (2.16kN) (25%) of rice husk, resulting in an annual production of 120 million tons of RHA worldwide [29]. Based on the burning technique adopted the type of ash obtained varies considerably. At $550^0C$–$800^0C$ amorphous ash is formed and at higher temperatures, crystalline ash is formed. In this study RHA has been utilized for the preparation of brick-blocks with complete replacement of clay. Properties such as compressive strength, water absorption, and size and shape have been studied. Different proportions of RHA ranging from 50-70% by mass were mixed to the raw brick-clay. Higher RHA content required a higher water content to ensure the right dry density. All test specimens were hand moulded and cured by covering these with a wet gunny bag. The samples were tested according to the Indian Standards. All the specimens were made with mixes having RHA more than 50% by mass, in order to reduce the carbon footprint [2].

### 1.1 Literature Review

Bricks using clay-sand mixes with different percentages of RHA were prepared [3]. Burning in a furnace at 10000C for different firing times (2 hours, 4 hours and 6 hours) was done and it was found that at a firing duration of 4 hours (at 1000°C) highest compressive strength of the bricks (mixed with RHA contents) was obtained.

Utilization of lime and rice husk ash for soil stabilization produced considerable strength gain and other geotechnical properties of the stabilized soils [4]. The use of lime and rice husk for unfired brick or compressed stabilized earth was studied. The compressive and three-point flexural strength tests including compressive strength after water submersion were carried out and the compressive and flexural strength of clay brick improved by addition of lime and RHA.

Incinerated RHA as brick clay was used to produce a high quality brick. A mixture of up to 50% RHA additives by weight can be used in building fired brick production, particularly for lightweight brick [5]. RHA can be used as an organic kind of pore-forming additive in the clay body without any harmful effect on the other brick manufacturing parameters.

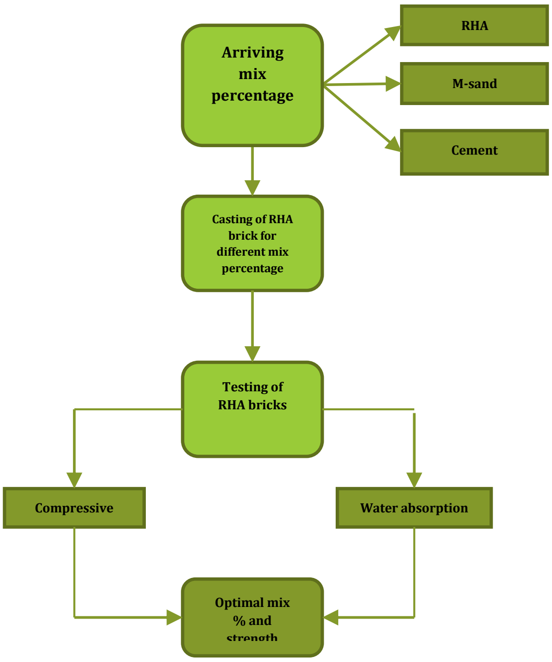



Fig. 1 Schematic diagram of brick manufacturing

Rice Husk Ash was utilized for the preparation of bricks in partial and full replacement of clay [6]. Studies revealed that the optimum proportion for the bricks is 30% RHA and 70% Clay and the bricks exhibited high compressive strength and low brick weight.

For a given mix, the water requirement increases as the rice husk ash content increases, during the preparation of sandcrete blocks. As the ash content the setting times also increased. The compressive strength increases with age of curing and decreases with RHA content, the optimum being 20% RHA [7].

The preparation of lightweight aggregate (LWA) from rice husk ash (RHA) obtained from a biomass power plant was studied [8]. As-received and ground RHAs were mixed with sodium hydroxide solution (NaOH) and cured to obtain the hardened sodium silicate paste. Ground RHA–LWA mixes resulted in better performances in terms of expansion, solubility, and disintegration than the as-received RHA–LWA.

Concrete and mortars containing 25% RHA as a replacement of cement, exhibited same or better results compared to conventional concrete leading to substantial cost savings and benefits to the environment [9].

Eco-friendly fired-clay bricks produced using oat husk and barley husk and middlings resulted in density in the range of 1300–1800kg/m3 (12.75-17.65kN/m3), compressive strength in the range of 3.30–9.50MPa, porosity in the range of 34-49%, and water absorption in the range of 14–28% [10].

The compressive strength of the bricks made using different percentages of Rice Husk, Wood Ash, clay, Fly Ash & Cement were compared. The wood ash admixture, in line with its pozzolanic nature, was able to contribute in attaining denser products with higher compressive strengths, higher softening coefficients, lower water absorption rates, lower saturation [11].

Clay containing illite was mixed with RHA & FA in various percentages and it is observed that water absorption and porosity increased with increasing percentage of ashes [12].

Rice husk in two forms as ground rice husk and coarse rice husk were substituted by volume (5%, 10% and 15%) of the brick raw material [13]. The observations revealed that bricks with the 5% and 10% addition of rice husk to brick clay exhibited a compressive strength of 7–10MPa which is less than that of the reference clay bricks. It was found that samples containing coarse rice husk possessed lower thermal conductivity than ground rice husk added samples.

Samples containing rice husk up to 20% by weight were sintered with dried water-treatment-sludge. They were fired using a heating schedule that allowed effective organic burnout. Materials containing rice husk 15% by weight which were sintered at 11000C produced low bulk density less than 1.80g/cm3 and relatively high strength materials of about 10MPa that were compliant with relevant Taiwan standards for use as lightweight bricks [14]. Further, it was observed that the addition of rice husk increased the porosity of sintered samples and higher sintering temperatures increased compressive strength.

Researchers [1] evaluated the effects of addition of RH and RHA to clay for the manufacture of clay bricks. The addition of Rice Husk (RH) by 10%, resulting in the best piece of brick and the properties of Thailand industry standard lightweight brick of C12 (Thailand industry standard of lightweight concrete grade) and when adding RHA to 10% by weight resulted in the best piece of brick and the properties of Thailand industry standard lightweight brick of C12. Because the amount of RH ash with a more resolution causes a more porosity which also affects the density of the piece.

The compressive strength of bricks with 5% of Sugarcase Bagasse Ash (SBA) and 5% RHA satisfied the Pakistan Building Code requirements (i.e. >5 MPa) [15]. The study concluded that brick specimens incorporating lower dosage of SBA and RHA (i.e. 5% by clay weight) will not only relieve the environmental burden but also result into a more sustainable and economical construction.

Clay was treated with controlled burning rice husk ash (CBRHA), uncontrolled burning rice husk ash (UCBRHA), ground rice husk (GRH) [1]. Thermogravimetric analysis showed that the clay when heated started losing water when heated up to 2500C and big changes were seen between 5000C to 5700C where the dehydroxylation of clay minerals occurred.

Five batches of different compositions of rice husk ash, lime, sand, binder were used [16] to prepare bricks. Experiments revealed that the compressive strengths of the five batches are 1.18MPa, 1.60MPa, 1.90MPa, 2MPa and 2.10MPa respectively. The peak loads are 3126N, 6280N, 9722N, 10850N and 12883N respectively. Strain at brick of five batches of experiment is 1.18 %, 2%, 2.4%, 3%, 3.6% respectively.

Lightweight concrete brick properties under full water curing and air-dry curing made using RHA as partial cement replacement and Expanded Polystyrene (EPS) as partial aggregate replacement in the mixes respectively were studied [17]. In the study, the control sample with a Cement: Sand: EPS ratio of 1.0: 1.5: 1.5 was first produced. The cement in the sample was then replaced by 5%, 10%, 15% and 20% of RHA while w/c ratio of 0.50 was used throughout this investigation. Full water curing and air-dry curing conditions were employed. It was observed that EPS-RHA-concrete brick gave promising results in the form of slump, fresh concrete density, air content, compressive strength, water absorption, sorptivity and thermal conductivity for the above mixes.

It was observed that waste materials used for making bricks have the potential for contamination [18]. It is also suggested that standardization and proper government policies and public education can be helpful in recycling waste for sustainable development.

Researchers [19] developed the densified mixture design algorithm (DMDA) method and studied unground rice husk ash (URHA) geopolymer brick. Solid bricks were prepared in accordance with official Vietnamese product standards in steel mould under 35 MPa forming pressure. After casting, the brick samples were stored at 350C and at a relative humidity of 50% until the age required for testing. The compressive strength and flexural strength ranged, respectively, between 20.9–31.5MPa and 5.7–6.7MPa.

Researchers [20,21] studied the effect between rice husk and rice husk ash to properties of bricks and inferred that by adding 2% of rice husk ash by weight is the best resulting in brick properties with 6.20-13.50MPa as compressive strength, 1.68-1.69g/cm3 (16.48-16.57kN/m3) as density, and 11.50-15.20% as water absorption.

Increase in RHA replacement percentage reduced the compressive strength and linear shrinkage of fired-clay bricks while the porosity and water absorption value increased [22].

Farm economy can be improved indirectly if high-quality RHA is produced. Prices of rice husk ash are competitive in the world market and farmers fetch more prices [2].

Effects of rice husk ash and fly ash on properties of red clay were investigated [23]. Different percentages of rice husk ash (RHA) and fly ash (5%, 10% and 15%) were thoroughly mixed with clay to analyse various physical and chemical properties of clay followed by heat treatment of 8000C to 11000C. Water absorption and porosity increased with increasing percentage of ashes. The percentage of water absorption was within 6 to 10% for different mixtures. Both fly ash and RHA of 15% could be used to improve some properties of clay. The optimum firing temperature for all the samples was 10500C.

Researchers [24] observed that the total embodied energy of load bearing masonry buildings can be reduced by 50% when energy efficient/alternative building materials are used.

## 1.2 Preparation of brick-block samples:

The RHA was collected from East Godavari district of Andhra Pradesh State (India). The RHA collected was first dried, to remove the excess moisture and large foreign matter. The dry RHA thus obtained is sieved using a 600 micron IS sieve. The RHA passing through the sieve is collected and mixed with M-sand (manufactured sand pertaining to Zone – II as per IS 383 - 2016) and cement after finding their specific gravities. The percentages of RHA in the mix combinations are varied from 50% to 70% by volume. Then the mixtures were hand-moulded. The mould was slightly large having a frog as per Indian Standards. The mixture was tempered and made into a ball which was thrown forcefully into a 230mm x 115mm x 70mm mould. The excess material on top of the mould was trimmed and removed using a thin wire.

**Fig.** 1a Sieving of RHA **Fig.**1b Prepared brick-block

**Fig.** 1c Air-dried brick-block

Before filling the mould with the mixture, a butter paper was placed in the mould to prevent the mix from sticking on to the inner faces of the mould. Bricks were demoulded and then air-cured in a damp atmosphere for five days. During and after curing no cracks were visible. Different tests were carried out to determine the properties of blocks. These are specific gravity for materials and compressive strength (Table 2), water absorption (Table 3) and efflorescence for bricks. The average values of the test results of three specimens were used in each test. The product is examined by IS Codes [25-28]. The quantity (by weight) of water added to mix is same as that of the RHA.

## 2. Materials Used:

**Rice Husk Ash:** It is obtained by burning rice husk, which is whitish grey in colour. It was passed through 600 micron sieve and then the specific gravity and bulk density were found to be 2.14 and 105kg/m3 respectively.

**M-sand:** It is an eco-friendly material which made from rock pieces by artificial processes. The specific gravity and bulk density were found to be 2.70 and 1736kg/m3 respectively.

**Cement:** Ordinary Portland cement of 53 Grade conforming to IS 8112 -1989 was used, and the specific gravity and bulk density of cement are 3.15 and 1440 kg/m3 respectively.

**Table 1:** Various Mixes used for preparation in % by weight

| Mix Designation | RHA | M-sand | Cement |
|---|---|---|---|
| 1 | 50 | 30 | 20 |
| 2 | 50 | 25 | 25 |
| 3 | 50 | 20 | 30 |
| 4 | 60 | 20 | 20 |
| 5 | 60 | 15 | 25 |
| 6 | 60 | 10 | 30 |
| 7 | 70 | 10 | 20 |

## 3. Test results and discussions

**3.1 Compressive Strength:** The results of compressive strength are shown in Table 2 when brick-blocks are tested in accordance with the procedure laid down in IS 3495 (Part 1).

**Table 2:** Compressive Strength

| Mix Designation | Load (kN) | Compressive Strength ($kN/mm^2$) |
|---|---|---|
| 1 | 198.375 | 7.5 |
| 2 | 233.81 | 8.84 |
| 3 | 257.35 | 9.73 |
| 4 | 231.9 | 8.76 |
| 5 | 213.9 | 8.76 |
| 6 | 201.28 | 7.61 |
| 7 | 188.32 | 7.12 |

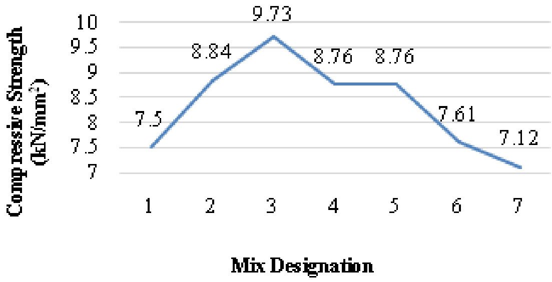



**Chart -1**: Variation of compressive strength with mix

**Fig. 2:** Compressive Strength test on RHA-Brick block

### 3.2 Water absorption:

The water absorption values of the brick-blocks when tested in accordance with the procedure laid down in IS 3495 (Part 2), after immersion in water for 24 hours are shown in Table 3.

**Table 3:** Water absorption of brick-blocks

| Mix Designation | % increase in weight |
|---|---|
| 1 | 23.4 |
| 2 | 24.8 |
| 3 | 26.1 |
| 4 | 25.2 |
| 5 | 26.7 |
| 6 | 27.2 |
| **7** | 28 |

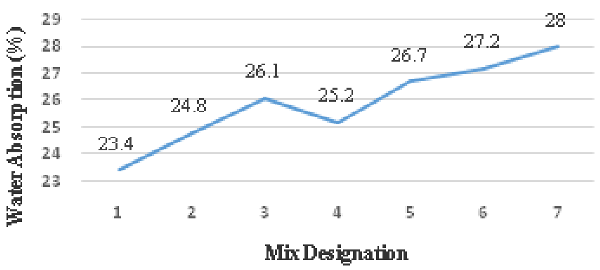
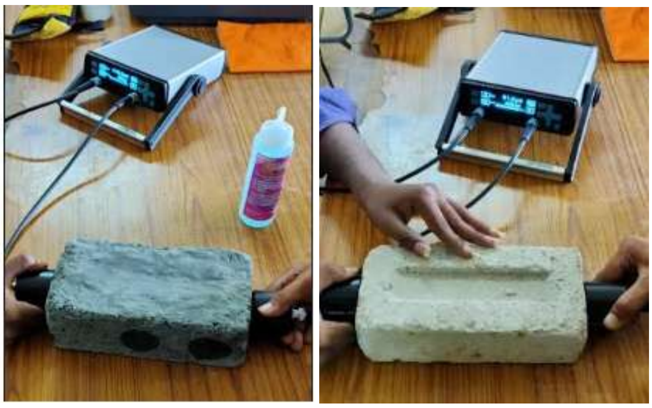



**Chart -2**: Variation of water absorption with mix

**3.3 Efflorescence:** As per IS 3495 (Part 3) the efflorescence of all the bricks was found to be Moderate.

**3.4 Ultrasonic Pulse Velocity (UPV) Test:** The UPV test on the brick-blocks were tested in accordance with the procedure laid down in IS 13311 (Part 1) 1992.

The following values of UPV are obtained for various test specimens:
RHA-brick-block : 1km/s
Red clay brick: 1.33-1.75km/s
Fly ash brick: 2.83-3.18km/s



**UPV Test on RHA-Brick-block and Fly ash-Brick-block**

**Fig -3**: UPV test in progress on brick-blocks

## 4. ENVIRONMENT IMPACT:

The eco-friendly-building-materials industry is growing rapidly as these materials are gaining a lot of popularity. The four main factors influencing the growing popularity of eco-friendly building materials are:

- environmental regulations,
- impact on the environment and human health,
- decarbonization objectives and
- Utilization of materials at the end of the lifecycle.

The conventional bricks are made with a mixture of clay and water, molded into standardized dimensions which are air-dried or fired in a kiln as per the required strength for the brick. The key ingredient in conventional bricks is clay and to get high strength, the bricks have to be fired in kiln. Clay which is considered a non-renewable natural resource is mined excessively to meet the demand of the market, which is a threat to the environment. Conventional kiln burning of clay bricks pollutes the air by emitting a huge quantity of toxic elements, containing suspended particulate matter rich in carbon particles and high concentration of carbon monoxides and oxides of Sulphur (SOx) that are harmful to eye, lungs and throat [18].

The production of OPC and its release is around 7% of total annual global $CO_2$ emissions. It is estimated that producing 1.0kg (9.80N) of OPC reportedly consumes around 1.50kWh of energy and releases about 1.0kg (9.80N) of $CO_2$ into the atmosphere. Each fired-clay-brick approximately consumes 2.0kWh of energy and releases about 0.41kg (4.02N) of $CO_2$ into the environment during its production. Globally $CO_2$ is a major contributor to man-made greenhouse gas emissions, which is a key contributing factor to global warming and climate change [17, 24].
In India the building industry consumes about 20000 million bricks and 27% of the total natural energy consumption for their production [15].

Different types of solid waste materials such as fly ash (FA), bottom ash, slag, and RHA are waste materials and their management is a huge challenge. They were simply dumped in heaps. These waste materials can be used as backfill for retaining walls. These materials contain fine particles and are light in weight and with wind breeze fly in the air and pollute the surrounding environment and remain as suspended particulate matter.

The abundant production of paddy and the pozzolanic properties of RHA make it important to assess the efficacy of using RHA in the production of construction brick-blocks in terms of environmental benefits and cost advantages. Under optimized incineration temperature conditions, the RHA so obtained may contain up to 95% reactive silica in amorphous form.

Keeping all these issues in view, in the present paper the study of geopolymerization technology to produce brick-blocks from RHA, M-sand and cement. Brick-blocks produced using this technique consume significantly less energy and release much lower amounts of greenhouse gases in comparison to conventional brick making techniques.

Therefore, the effective disposal of these wastes, a sustainable way to produce building materials and a less carbon footprint structures can be built when these type of brick-blocks are used in construction. Many previous studies considered the use of RHA as a raw material in bricks manufacturing. Recent research suggested that RHA may improve the mechanical properties of brick sand enhance frost resistance.

## 5. Cost analysis:

Clay in brick-blocks was replaced by 50% of RHA, 20% of M-sand and 30% cement for optimum results. It is noted that by substituting clay with above mix, cost of brick increased by 8% that of a ordinary clay brick without sacrificing the strength. However the cost per brick-block can be reduced by production plant automation. Hence, replacement of clay by RHA: M-sand: Cement (50:20:30) can result in cost savings with added benefits of alleviating environmental problems related to clay bricks production and RHA dumping

## 6. CONCLUSIONS

- This study involved preparation of brick-blocks using RHA, M-sand and Cement, thereby 100% replacement of natural clay is achieved.
- In the current study, brick-blocks were prepared using more than 50% RHA in all the mixes, which is much higher than the percentages reported by earlier researchers.
- Of all the mixes investigated, brick-block with 50:20:30 (RHA: M-sand: Cement) proportions is considered better of all, as it resulted in the highest compressive strength. However, this mix resulted in a higher water absorption value, more than the permissible value of 20%. Hence, these brick-blocks may be used for unimportant works, such as compound walls, parapet walls, gardening blocks etc., as they belong to Class 3 as per IS 12894:2002.
- The brick-block leaves a lot of residue (fine powder) after the curing period, and hence the strength reduces.
- The velocity of the wave in the brick-block is about 1km/s (tested using a UPV meter), which indicates that the brick-block is highly porous.

## ACKNOWLEDGEMENT

We express our deep gratitude to our **S. V. S. L. Manisri Gayathri**, **E.O. (Team SVAS, CFI-GVPCoE(A))** for her support throughout project. We thank, **Dr. Ravi Saripalle Director, CFI-GVPCoE(A)** for providing us with space at CFI, GVPCoE(A). We also thank, **Prof. Dr. Srinivas Manchikanti**, **Smt. MEGHANA Assistant Professor** and **Mr. G. L. Ravi Raj Assistant Professor** of **Civil Engineering Department, Gayatri Vidya Parishad College of Engineering (Autonomous)** for helping in our project and verifying results and methods. We are deeply obliged to our friends **M. V. M. Sai Chowdary**, **K. B. S. Sri Pranathi**, **V. R. Sai Sampath**, **T. N. Manikanta Reddy**, **S. Udaykumar** and **M. N. Sai Sundeep** for their constant help and support throughout the project work.

## REFERENCES

[1] Janbuala, S., Wasanapiarnpong, T. (2015). Effect of Rice Husk and Rice Husk Ash on Properties of Lightweight Clay Bricks. Key Engineering Materials, 659, 74–79. https://doi.org/10.4028/www.scientific.net/kem.659.74.

[2] Gidde, M.R., Jivani, A.P. (2007). Waste to Wealth, Potential of Rice Husk in India a Literature Review. Proc. International Conference on Cleaner Technologies and Environmental Management, 586-590.

[3] Rahman, M. A. (1987). Properties of clay-sand-rice husk ash mixed bricks. International Journal of Cement Composites and Lightweight Concrete. 9(2). 105-108.

[4] Muntohar, A. S. (2011). Engineering characteristics of the compressed-stabilized earth brick. Construction and Building Materials. 25(11). 4215-4220.

[5] Tonnayopas, D., Tekasakul, P., Jaritgnam, S. (2008). Effects of rice husk ash on characteristics of lightweight clay brick. Technology and Innovation for Sustainable Development Conference, 36-39. https://www.researchgate.net/publication/266280427_Effects_of_Rice_Husk_Ash_on_Characteristics_of_Lightweight_Clay_Brick

[6] Mohan, N. V., Satyanarayana, P. V. V., Rao, K. S. (2012). Performance of rice husk ash bricks. International Journal of Engineering Research and Applications. 2(5). 1906-1910

[7] Oyetola, E. B., Abdullahi, M. (2006). The use of rice husk ash in low-cost sandcrete block production. Leonardo Electronic Journal of Practices and Technologies. 8. 58-70.

[8] Chindaprasirt, P., Jaturapitakkul, C., Rattanasak, U. (2009). Influence of fineness of rice husk ash and additives on the properties of lightweight aggregate. Fuel, 88(1), 158-162.

[9] Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A. N., Mirza, J. (2012). Reduction in environmental problems using rice-husk ash in concrete. Construction and Building Materials, 30, 360-365.

[10] Kizinievič, O., Kizinievič, V., Pundiene, I., Molotokas, D. (2018). Eco-friendly fired clay brick manufactured with agricultural solid waste. Archives of Civil and Mechanical Engineering, 18(4), 1156-1165.

[11] Parashar, A. K., Parashar, R. (2012). Comparative study of compressive strength of bricks made with various materials to clay bricks. International Journal of Scientific and Research Publications. 2(7). 1-4.

[12] Sultana, M. S., Hossain, M. I., Rahman, M. A., Khan, M. H. (2014). Influence of rice husk ash and fly ash on properties of red clay. Journal of Scientific Research, 6(3), 421-430.

[13] Görhan, G., Şimşek, O. (2013). Porous clay bricks manufactured with rice husks. Construction and Building Materials, 40, 390-396. https://doi.org/10.1016/j.conbuildmat.2012.09.110

[14] Chiang, K. Y., Chou, P. H., Hua, C. R., Chien, K. L., Cheeseman, C. (2009). Lightweight bricks manufactured from water treatment sludge and rice husks. Journal of hazardous materials, 171(1-3), 76-82.

[15] Kazmi, S. M., Abbas, S., Saleem, M. A., Munir, M. J., Khitab, A. (2016). Manufacturing of sustainable clay bricks: Utilization of waste sugarcane bagasse and rice husk ashes. Construction and building materials, 120, 29-41. https://doi.org/10.1016/j.conbuildmat.2016.05.084

[16] Khabir, M. L., Huda, M. M., Amin, D. R., Kamruzzaman, S. (2013). Energy Saving Brick from Rice Husk Ash. Proc. International Conference on Mechanical, Industrial and Materials Engineering. 222-226. http://icmime-ruet.ac.bd/2013/Contents/Technical%20Papers/Energy%20Technology/ET-07.pdf

[17] Ling, I. H., & Teo, D. C. L. (2012). Compressive strength and durability properties of lightweight concrete bricks under full water curing and air-dry curing. International Journal of Sustainable Energy Development, 1(1). 14-20. http://infonomics-society.org/wp-content/uploads/ijsed/published-papers/volume-1-2012/Compressive-Strength-and-Durability-Properties-of-Lightweight-Concrete-Bricks-under-Full-Water-Curing-and-Air-Dry-Curing.pdf

[18] Zhang, L. (2013). Production of bricks from waste materials - A review. Construction and Building Materials, 47, 643-655.

[19] Hwang, C. L., Huynh, T. P. (2015). Investigation into the use of unground rice husk ash to produce eco-friendly construction bricks. Construction and Building Materials, 93, 335-341. https://doi.org/10.1016/j.conbuildmat.2015.04.061

[20] Janbuala, S., Kitthawee, U., Aermbua, M., Laoratanakul, P. (2013). Effect of Rice Husk Ash to Mechanical Properties of Clay Bricks. Advanced Materials Research, 770, 50–53. https://doi.org/10.4028/www.scientific.net/amr.770.50

[21] Sutas, J., Mana, A., & Pitak, L. (2012). Effect of rice husk and rice husk ash to properties of bricks. Procedia Engineering, 32, 1061-1067.

[22] Khoo, Y. C., Johari, I., Ahmad, Z. A. (2013). Influence of Rice Husk Ash on the Engineering Properties of Fired-Clay Brick. Advanced Materials Research, 795, 14–18. https://doi.org/10.4028/www.scientific.net/amr.795.14

[23] Sultana, M. S., Hossain, M. I., Rahman, M. A., Khan, M. H. (2014). Influence of rice husk ash and fly ash on properties of red clay. Journal of Scientific Research, 6(3), 421-430.

[24] Reddy BVV, Jagadish KS. (2003). Embodied energy of common and alternative building materials and technologies. Energy and Buildings. 35(2). 129–37.

[25] IS 12894 (2002): Pulverized Fuel Ash-Lime Bricks - Specification

[26] IS 13757 (1993): Burnt clay fly ash building bricks-Specification

[27] IS 383 (2016) : Coarse and Fine Aggregate for Concrete – Specification

[28] IS 13311 (Part 1) 1992: Non-destructive testing of concrete – Methods of test, Part – 1 (Ultrasonic Pulse Velocity).

[29] http://www.ricehuskash.com/details.htm

## BIOGRAPHIES

Student (B. Tech 4th year), (16131A0111), Dept. of Civil Engineering, Gayatri Vidya Parishad College of Engineering (Autonomous), Visakhapatnam, A.P., India

Student (B. Tech 4th year), (16131A0110), Dept. of Civil Engineering, Gayatri Vidya Parishad College of Engineering (Autonomous), Visakhapatnam, A.P., India