# BRICKS FOR GREEN BUILDINGS: A REVIEW

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**Abstract:** Brick is a key product which really can enhance the quality of the buildings. Green buildings integrate sustainable technologies aiming at the conservation of natural resources demonstrating less damage to the environment. The present manuscript aims at identifying properties of green bricks while selecting a brick as a more suitable building block. Literature survey, web survey and market survey carried out enables to identify the properties of green bricks.
This study has been undertaken to investigate the determinants of stock returns in Karachi Stock Exchange (KSE) using two assets pricing models the classical Capital Asset Pricing Model and Arbitrage Pricing Theory model. To test the CAPM market return is used and macroeconomic variables are used to test the APT. The macroeconomic variables include inflation, oil prices, interest rate and exchange rate. For the very purpose monthly time series data has been arranged from Jan 2010 to Dec 2014. The analytical framework contains.

***Index Terms*** **- Green buildings, bricks .**

## I. INTRODUCTION

Green building is one of the most important trends in the construction industry today. In fact, the construction sector is one of the biggest contributors to climate change and buildings are responsible for much of the world's energy waste. In terms of sustainability and green buildings, brick is the major and most important component. As a building material it has gained importance in the construction sector in the recent past. Scientists and researchers have developed many types of bricks and blocks for green buildings. It is essential to identify properties of most suitable bricks or building blocks.

## II. METHODOLOGY

A detailed literature review and market survey was carried out to find out properties of eco-friendly, bricks /blocks for green buildings.

### 2.1LITERATURE REVIEW

Fly ash is getting generated on a very large scale from various industries. If we don't recycle the fly ash generated, it will only become a burden to the environment. Continuously utilizing clay for bricks will make the soil infertile. D. Eliche-Quesada (2018) investigated the use of coal fly ash (CFA) as raw material for the manufacture of two construction materials, fired clay bricks and silica-calcareous non-fired bricks [1]. It was found that CFA-clay fired bricks and silica-calcareous CFA-Geosilex non-fired bricks presented optimal technological properties that attain the quality standards [2].
Yongliang Chen et al. (2011) investigated the possibility of making construction bricks by using the hematite tailings from the western Hubei province of China. Besides hematite tailings, the additives of clay and fly ash were added to the raw materials to improve the brick quality. The results showed that the main mineral phases of the product were hematite, quartz, anorthite and tridymite, which were principally responsible for the mechanical strength of bricks [3]. Alaa A. Shakir et al. examined effects of wastes on the bricks' properties. Enhanced performance in terms of making more environmental and an economical brick neither consume energy resources, nor emits pollutant gases gives an economical option to design the green building. Certain bricks are produced without firing, which is an advantage over other manufacturing of bricks in term of low embodied energy material [4].

Kung-Yuh Chiang et al. presented the feasibility of building bricks produced from reservoir sediment sintering using various sintering temperatures and clay additions. The experimental results indicate that sintered specimen densification occurred at sintering temperatures of 1050–1100 °C. Increasing the sintering temperature decreases the water absorption and increases the shrinkage, density and compressive strength of sintered specimens. The experiments were conducted at a temperature ranged from 1050 to 1150 °C with clay addition contents varying from 0% to 20%. All sintered specimens made from reservoir sediment were in compliance with Taiwan building bricks criteria. This means that raw materials for producing building bricks can be replaced with reservoir sediment [5].

S.P.Raut et al. (2011) developed waste-create bricks (WCB) and showed that recycling of unmanaged industrial or agricultural solid waste is a viable solution not only to pollution problem but also an economical option to design of green buildings [6].

Saeed and Lianyang (2012) investigated the feasibility of utilizing copper mine tailings for producing eco-friendly bricks based on the geo-polymerization technology. The mixed material was placed in a miniature compaction cylindrical mould with minor compaction. The compacted specimens were then compressed with a Geo-test compression machine at different loading rates ranged from (0.5-30) MPa. Physical and mechanical properties of copper mine tailings-based geo-polymer bricks were investigated using water absorption and unconfined compression tests. Results showed that copper mine tailings can be used to produce eco-friendly bricks based on the geo-polymerization technology to meet the American Society Testing Material (ASTM) requirements [7].

Chao-LungHwang & Trong-PhuocHuynh (2015), investigated the feasibility of using the densified mixture design algorithm (DMDA) method to incorporate unground rice husk ash (URHA) as a partial fine aggregate replacement (0–40%) in the production of eco-friendly construction bricks. Fly ash (FA) and residual rice husk ash (RHA) were the main binder materials considered in the study. The results demonstrated a significant potential for applying URHA in the production of eco-friendly construction bricks [8].

RosaTaurino et al. (2019) presented a study of lightweight bricks manufactured from wine wastes (stalks, grape seeds, and wine lees) by controlling the nature and concentration of additives. The wine wastes (WWs), completely characterized before their use in the matrix, were furnished by a co-operative wine-growers association located in the Emilia-Romagna Region (Italy). Physico-mechanical properties of fired clay bricks manufactured with different percentages of WWs were reported and discussed. The results showed that the density of fired bricks was reduced up to 13%, depending on the percentage of WWs incorporated into the raw materials. Similarly, the flexural strength of tested bricks decreased according to the percentage of WWs included in the mixture. The best results, in terms of mechanical and physical properties, were obtained with 5 % weight of wine lees (WL). The results showed as the lightness of these samples is associated to the porosity increase that directly influences the increase of the thermal insulation making the bricks useable for partitioning walls application [9].

Syed Minhaj SaleemKazmi (2018) explored the thermal properties of industrially manufactured burnt clay bricks incorporating waste gas sludge(WGS). Burnt clay bricks incorporating different dosages of waste gas sludge (WGS) (i.e, 5%, 10%, 15%, 20% and 25% by weight of clay) were prepared in an industrial kiln and were studied for different physico-mechanical and thermal properties. It was observed that dense brick specimens can be manufactured by using WGS in replacement of clay. Increase in compressive strength of clay bricks was observed after addition of WGS. Burnt clay bricks incorporating 25% WGS showed a 37% increase in compressive strength. Reduction in apparent porosity and water absorption was also observed with increasing content of WGS in brick specimens. Microscopic images also showed dense and homogenous structure with reduced porosity after adding WGS in brick specimens, which increased the thermal conductivity of burnt clay bricks incorporating WGS. Control brick specimens showed thermal conductivity of 0.53 W/mK, which increased to 0.59 W/mK after incorporating 25% WGS in brick specimens. However, results were observed within the thermal conductivity range (i.e., 0.4–0.7 W/mK) of traditional burnt clay bricks for masonry construction. Based on this study, utilization of WGS (up to 25%) in the production of burnt clay bricks can be helpful in reducing the landfill and associated environmental problems of WGS. Moreover, burnt clay bricks with improved properties can be manufactured on industrial scale, leading towards sustainability and cleaner production [10].

Djamil Benghida (2015) found out that adobe bricks treated with ecological and low-cost components followed by natural fibers is an effective solution for the water absorption and weathering, cycles of wetting and drying. The composition of the adobe bricks should be 100% eco-compatible and biodegradable, avoiding any stabilization with unsustainable compounds like cement and asphalt [11].

P. Bulkade & G. Deshmukh (2017) showed that AAC blocks are 7 times bigger than the size of the conventional bricks. Bigger size means a smaller number of joints. Less joints results in lesser quantity of mortar for building. There is an overall 60% reduction in use of Mortar. AAC blocks have uniform shape and texture, which gives even surface to the walls. There is overall 35% reduction in the cost of plastering. Breakage in Acc block is negligible as compared to ordinary brick (Approximate 10 to 12%) It reduces wastage of the block and increases the percentage utilization approximately (99.99%). If any breakage in the blocks, it would be in - to two or three pieces which can be utilized in masonry as "brick bat". AAC blocks are resistant to thermal variations. It reduces the total load of refrigeration and air conditioning. Though initial installation cost may remain same but AAC blocks reduce operation and maintenance cost drastically. There is overall 25% savings in operation cost. Due to lesser HVAC load, cost of power infrastructurei.e. is a lesser capacity of the transformer, DG set, and cable etc. also reduces considerably, which in form results in savings in electrical charges.

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, we can conclude that use of AAC blocks over burnt clay bricks is recommended [12].

Utkarsh Jain (2018) showed that the use of AAC block also reduces the requirement of materials such as cement and sand up-to 55%. 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, we can conclude 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 [13].

(Chee Ming, 2011) examined the mechanical properties of clay brick made by adding two natural fibers like oil palm fruit (OF), and pineapple eaves (PF) to clay-water mixture with baked and non- baked conditions. Compressive strength, water absorption and efflorescence were performed according to British standard BS3921:1985, and Malaysian Standards MS 76:1972. Results indicated that the compressive strength of the bricks was fulfilled the minimum requirement of BS3921:1985 for compressive strength which is 5.2 MPa for conventional bricks. Efflorescence was only feasible for baked samples as the non - baked ones formed severe deterioration while testing. The prevailing benefit of the fiber inclusion was more beneficial for baked specimen where the strength gets surpassed that of non - baked added only specimen [14].

Alonso et al. (2012) developed a comparative study to produce ceramic bricks from clay with two types of foundry sand (green and core sand). Clay/green sand bricks with 35 % green core and 25 % green sand, fired at 1050°C have the better physical properties values, while the mineralogy is not significantly affected. It was shown that foundry sand is recommended as raw material in the manufacture of ceramic product, whereby saving in costs of brick production [15].

D.Eliche-Quesada (2017)analysed the feasibility of using biomass combustion ash waste (rice husk or wood ash from boards) as secondary raw materials in the manufacture of clay bricks.The ash was characterized using particle size distribution analysis, chemical composition analysis by X-ray diffraction (XRD) and X-ray fluorescence (XRF), thermal analysis, elemental analysis, and scanning electron microscopy (SEM). Either rice husk ash or wood ash was used to replace different amounts (10–30 weight %) of clay in brick manufacture. Brick samples were formed by compression at 54.5 MPa and fired at temperatures of 900 or 1000 °C for 4 h, at a heating rate of 3 °C/min. The bricks' properties were compared to conventional products containing only clay and prepared following standard procedures. The bricks' technological properties depended on type and amount of ash used and firing temperature. The results showed small variations due to firing temperature. Firing at 1000 °C achieved greater densification and thus lower water absorption and higher compressive strength firing at 900 °C produced higher porosity, which reduced compressive strength. Based on the results, 1000 °C was selected as the optimal firing temperature; and 10 weight % rice husk ash and 20 wt% wood ash as the optima amounts of biomass ash waste. Moreover, the bricks containing wood ash showed properties similar to the control bricks containing only clay and improved thermal conductivity. Finally, the bricks containing 10 weight % rice husk ash and 30 weight % wood ash fulfilled standard requirements for clay masonry units.

The history of bricks making dates back to 7000 BCE, when the bricks used to be in the form of sun-dried mud blocks. Since then, a lot of modifications have been done in the composition of bricks and in brick making procedures. As a result, in today's world, brick is considered as one of the most sought after materials used in the construction of various civil engineering structures. Now-a-days, bricks are mostly made of clay and sand mixed in suitable proportion, to which binder is added. Many-a-time, the bricks are also made up earth blocks stabilized with different materials. The stabilized block is then pressed to a suitable shape and size that can be either fired or sun-dried. However, much variation is observed in the properties of bricks, and especially in its compressive strength, depending upon the composition of bricks and the manufacturing procedures (viz., moulding, pressing, firing, autoclaving, cementing, geo-polymerization etc.). Moreover, the bricks are specified and classified differently in various international standard codes, depending upon the importance of structures and the severity of environmental conditions. Hence, a thorough review of the composition and properties of bricks and the various factors related to its manufacturing process is highly required for better standardization of bricks. The same has been done in the present study. A better understanding of different wastes as the brick composing material is supposed to act as a catalyst in the utilization of various mining, industrial as well as solid municipal wastes in the brick industry, which will help in achieving the goal of sustainable development [16].

S. Joglekar et al. studied manufacturing of bricks, using clay or fly ash, is one of the major contributors to greenhouse gas emissions as their manufacturing involves utilization of coal and cement. To overcome this limitation, alternative construction materials are developed by the author using industrial and agro wastes like cotton mill waste, recycled paper mill waste, and rice husk ash. This work aims at performing a sustainability assessment of burnt clay bricks and bricks made of industrial and agro wastes used for brickwork in a low-cost house. The criteria considered for the assessment are economic, environmental, social, and technical aspects for manufacture of bricks and use of different bricks for brickwork. For the evaluation of environmental criterion, a life cycle assessment (LCA) tool is used. Overall sustainability index (SI) is calculated for alternatives. The relative SIs of clay and fly ash bricks were 0.25 and 0.26, respectively. Overall, bricks made of industrial and agro wastes are found more sustainable with the highest SI for cotton waste bricks (0.94). Sensitivity analysis also confirmed that brickwork from waste- based bricks is more sustainable compared to brickwork made from clay brick or fly ash brick [17].

This study presents the development of geopolymer bricks synthetized from industrial waste, including fly ash mixed with the concrete residue containing aluminosilicate compound. The above two ingredients are mixed according to five ratios: 100:0, 95:5, 90:10, 85:15, and 80:20. The mixture's physico-mechanical properties, in terms of water absorption and the compressive strength of the geopolymer bricks, are investigated according to the TIS 168-2546 standard. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analyses are used to investigate the microstructure and the elemental and phase composition of the brick specimens. The results indicate that the combination of fly ash and concrete residue represents a suitable approach to brick production, as required by the TIS 168–2546 standard [18].

Althaf Muhammed (2019) investigated and found out that waste plastic can be wisely used to make construction bricks. It can reduce the cement consumption in the construction industry, and it can reduce the problem of waste plastic accumulation in landfills and water bodies. At last we could find that molten plastic can be used as a good binding material. Plastic alone can make a brick and make a tremendous difference in waste accumulation. Waste plastic can prevent the accumulation of waste plastic. Fly ash, clay and glass powder are the raw materials for brick 1. Brick 2 Clay, fly ash, and incinerated ETP Sludge from paper mill are the raw materials for brick 2. The best results were obtained on constituents mixed in 15.5:12:72.5 (Fly Ash: Sludge: Clay). The brick achieved a compressive strength of 4.177 N/ mm2. C. Brick 3 Fly ash, cement and mixed waste plastic are the raw materials for brick 3.Constituents mixed at a proportion of 1:1.5:3 (Fly Ash: Cement: Plastic aggregate) can give out a compressive strength of 9.4 N/mm2 after a curing period of 28 days. D. Brick 4 Fly ash, lime mud and copper slag are the raw materials for brick 4.Constituents mixed at a proportion of 1:1:2 (Fly Ash: lime mud: copper slag) attains a compressive strength of 1.5 N/ mm2 after 28 days of curing. E. Brick 5 Fly ash, lime mud and waste shredded plastic are the raw materials for brick 5. Constituents mixed at a proportion of 1:1:2 (Fly Ash: lime mud: plastic aggregate) attains a compressive strength of 2 N/ mm2 after 28 days of curing. F. Brick 6 Fly ash, copper slag, lime mud and shredded waste plastic are the raw materials for brick 6. Constituents mixed at a proportion of 1:1.5:3 (Fly Ash + copper slag: lime mud: plastic aggregate) attains a compressive strength of 1.1 N/ mm2 after 28 days of curing. G. Brick 7 Fly ash, cement, lime mud and plastic aggregates are the raw materials for brick 7. Constituents mixed at a proportion of 1:1.5:3 (Fly Ash: cement + lime mud: plastic aggregates) attains a compressive strength of 1.5 N/ mm2 after 28 days of curing. H. Brick 8 Gypsum, lime mud and plastic aggregates are the raw materials for brick 8. Constituents mixed at a proportion of 1:1.5:3 (Plastic Aggregates: lime mud: Gypsum) attains a compressive strength of 7 N/ mm2 after 28 days of curing. I. Brick 9 Copper Slag is bonded together with plastic in a proportion of 1:3 (Copper slag: plastic) by hot process. The brick attained a compressive strength of 3.5 N/ mm2. J. Brick 10 M Sand is bonded together with plastic in a proportion of 1:3 (M Sand: plastic) by hot process. The brick attained a compressive strength of 11.5 N/ mm2. When the proportion was 1:2, the strength was 10.5 N/mm2. K. Brick 11 Single use plastic left over in the garbage is cleaned and shredded. This is remoulded into a brick shape by hot process. The brick attained a compressive strength of 8.2 N/ mm2. L. Brick 12 Single use plastic, HDPE and LDPE left over in the garbage is mixed, cleaned and shredded. This is remoulded into a brick shape by hot process. The brick attained a compressive strength of 8.2 N/ mm2 [19].

Rani, Rahul Sikka (2018), carried out experimental study it was found that the compressive strength of fly ash brick containing 5% cement is 152.1 kg/cm2 which is more than that of class I conventional bricks by 63% approximately. Water Absorption of fly ash brick added 5% cement is 48% less than the conventional brick and the Effloresce value is half of the conventional brick. Fly ash brick masonry in 1:7 cement mortars can replace conventional brick masonry in1:6 cement mortar and fly ash brick masonry in 1:5 can replace conventional brick masonry in 1:4 cement mortars thereby saving the consumption of cement and brick [20].

**2.2 M**arket Survey

Clay bricks cost INR 4.73 [21].

Fly ash bricks, on a large scale, reduce the cost of the project as the dead load over beams are lesser, wastages are minimal and they require less labour time. 230 x 100x 75 mm fly ash brick costs INR4.5.

Autoclaved aerated concrete (AAC)is a derivative of fly ash that is combined with cement, lime and water and an aerating agent. It is an approved eco-friendly building material that comes from industrial waste and is made from non-toxic ingredients. With AAC, construction process can be about 20 percent faster. It can reduce building cost by 2.5 percent.It does not change air quality of building over time. Minimum price of 9’ x 4’ x 3’ size of AAC block is INR40.

Compressed earth bricks (CEB) have been in use for a long time and are made from clay, sand and cement. They are biodegradable and can be made locally from any soil with a proper mix of ingredients like sand and cement. It offers fire resistance and is soundproof. Building costs can go down by 15 per cent or more.

CEBS are, however, not suitable for smaller homes and buildings. 300 X 150 X 90 mm size of CEB costs INR28 [22].

Plastic bricks have been extensively used in highway and railway infrastructure. Plastic from the millions of the bottles and bags are melted and moulded in the form of bricks are used in the construction of the roads. This has considerably enhanced the elastic nature of the surface helping in more load-bearing capacity of highways. In India, this technology has been initiated on an experimental basis for railway sleepers but was stopped since the danger to fire is a major concern. This brick costs INR240 [23].

Bricks moulded using rigid PIR (polyisocyanurate) fire safe foam with a non - combustible blowing agent which has zero greenhouse gas emissions, zero ozone depletion, are non- toxic. The foam can be sourced from petroleum oils, coal oils and a series of vegetable-based oils like soy, corn, palm oil etc. [24].

## III CONCLUSION

A green brick shall be assessed for its suitability as a most suitable building block based on following properties.

1. Brick must have quality of durability.

2. It should be made of locally available material so that environmental impacts associated with the transport of materials are reduced.

3. Manufacturing processes of bricks shall be sustainable. Use of salvaged materials avoids the environmental impacts associated with new products. Use of recycled water for manufacture of brick preserves fresh water. Use of coal for firing of bricks shall be avoided.

4. Bricks should be evaluated over their entire life cycle, from raw material extraction to end of useful life. This life cycle assessment (LCA) of a brick must include accurate evaluation of brick's service life. Brick masonry has a service life of over 100 years. Environmental effects associated with brick shall be distributed over this long lifespan.

5. brick finish should not need paints or coatings so that brick can contribute to improved indoor air by avoiding volatile organic compounds (VOCs).

6. Maintenance should be minimal when used for masonry of buildings.

7. Brick should not be a food source for mold. It should not promote mold growth, even if wetted and should be easily cleaned if needed.

8. Brick should be resistant to sound penetration.

9. Brick should be fire-resistant and resistant to impacts and windborne debris.

10. Embodied energy used for making bricks shall be least.

11. Brick should be economical.

12. Minimal or no carbon emission during manufacture.

13. Bricks should be light in weight.

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