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SUSTAINABLE ARCHITECTURE FOR THE EARTHQUAKE PRONE AREAS OF INDIA

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Abstract

The word sustainable is defined as using a resource so that it is not depleted or permanently damaged. Sustainability is one of the most significant concepts of this decade influencing the design of global government policy, economics, energy resources, technology, manufacturing, community planning and architecture. Such a concept is of prime importance in the developing countries like India where majority of population have limited resources and technical know-how. The sustainable architecture in Indian context is that which respect climate, site, culture and region. It should be cost effective, efficient and most simple solution for shelter, which is designed to cater for spatial requirements of traditional lifestyle of the local inhabitants. It should be constructed with techniques optimized to alleviate extreme climatic conditions, which prevails in majority of earthquake prone areas like, Kutch, Uttarkashi and Assam. Considering the socio-economic aspects it is required that the selection of construction technology and material should be such that so as to conserve resources and put them to better productive use instead of dead investments in buildings.

Failure of walls is the single largest factor responsible for collapse of structures in case of calamities like earthquake. Inadequate constructional practices and substandard material used for construction, which faced catastrophic failure in recent earthquakes required re-examined and appropriate measures should be taken to improve their performance as far as earthquake occurrence is concerned in order to create a sustainable architecture.

India is producing about 150 million ton of fly ash per annum, which is one of the major waste materials from thermal power stations using pulverized coal. This waste material can be utilized as an integral mix with brick making soils for manufacture of good quality building bricks. Rattrap bond construction using fly ash bricks as suggested in this paper, can provide not only an earthquake resistant construction but also offers a substantial saving (up to 25%) in the cost. Besides it provides a high degree of thermal insulation, which is very much desirable to check the severe climatic conditions. The present paper presents an analytical study of rattrap construction using fly ash bricks for the buildings located in the earthquake prone areas of India. It analyzes the physio- chemical properties of fly ash bricks and examines the suitability of rattrap bond in the present context. It endeavors to suggest solution for a sustainable building technology for earthquake prone areas of India considering various socio-economic, cultural and climatic dimensions, in order to take sustainable practices from lab and libraries to land.

1. Sustainable Architecture For Earthquake Prone Areas of India

The past history of earthquake occurrence indicates that it is one of the most vulnerable countries to damaging earthquakes. The country has faced tremendous economic losses, thousands of lives lost in addition to destruction of living environment in five major earthquakes and the destructive tsunami, which occurred recently. Damage scenario in these events has been more or less similar, where disaster was caused largely by due to ignorance of the local inhabitants about the behavior (response) and poor strength of their buildings to resist the imposed seismic loads. Architectural building systems are the predominant kind of facility in the built environment, which are vulnerable to earthquake damages and must be analyzed with reference to earthquake occurrence. The extent of damage was further increased with the un-preparedness of the local people in addition to the poor quality of building stock to resist earthquake forces. In majority of the cases the damage was basically attributed to inadequate or poor construction material and technology.

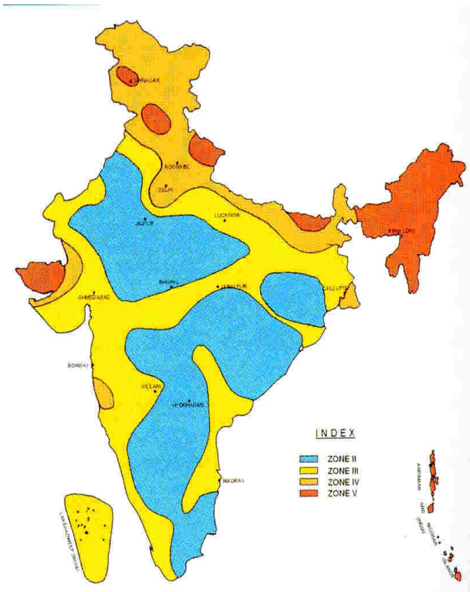

Figure 1 Earthquake Zoning Map

The 32,87,263-sq. km. area of India has 24 states and 7 union territories in all. Being a developing country the settlement pattern is predominantly composed of villages and small to medium sized cities The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different location is different. India is divided in four seismic zones – II, III, IV, and V. The maximum Modified Mercalli (MM) intensity of seismic activity expected in these zones are V or less, VI, VII, and Ix and higher respectively. It shows that over 60% of India's area lies under seismic zones III, Iv and V., where parts of Himalayan boundary in the north and northeast, and the Kutch area in the west are classified as zone V, having high degree of seismic risk.'

Occurrence of a disaster cause a tremendous physical and psychological trauma for the victims considering this phenomenon the architectural development in such areas needs to be socially acceptable and economically viable leading towards a sustainable habitat.

"Sustainability" is one of the most used yet least understood terms in India. India built stock majority of which consists of vernacular structures or architecture without architects provide many basic lessons for architects. India is a country of villages, where various building types are built by anonymous local craftsman with local techniques and materials. They invariably reflect the society's accumulated wisdom and collective images and are imbued with cosmological and religious values, social and political structure, sensibility and attitude towards time and space. Their forms proportions, craftsmanship and decoration are symbolic and meaningful. It is important to give greater insight into these aspects because sustainability in Indian context refers to the structures, which is a direct and unselfconscious translation into physical forms of the culture, its needs and values as well as the needs, dreams and passions of the people. This phenomenon is of great importance not only for the new development, but also for rehabilitation, reconstruction or restoration works in the areas, which are prone to earthquake disaster.

1.1 The Socio-Economic Aspects

Architecture is an integrated outcome of living and cultural patterns, social structure, history, climate, materials, economy the technology prevalent to that place, and the aspirations of people. It is generated by various layers physical as well as cultural. Each layer contributes varyingly, weaving a complex yet united whole. These layers form the character of a context, which is very specific to a place.

In a developing country like India providing for earthquake resistance is predominantly an economic problem. The main cause of earthquake damage as observed in past earthquakes is the poor quality of Indian building stock, which is developed under certain socio-economic constraints. In such circumstances where majority of population have limited resources and technical know-how, construction activities with reference to choice of material, construction technique, configuration characteristics etc. should be seen with a broader perspective in order to create a sustainable architecture. The right choice of material, constructional technique and other architectural parameters like adequate fenestration design, optimum size, height of the usable spaces, adequate strengthening and detailing at the strategic locations where failures may occur, are some of the points which can lead to a sustainable built environment with adequate degree of earthquake resistance with a minimum or negligible increase in cost. Sustainable architecture is not simply an equation of utility and economy in a country like India where varied social institutions interact mutually and where basic data is difficult to obtain.

1.2 Respect for Climate

Architecture unlike other art forms is inseparable from its locale. Thus any architectural design must respond to place. For example Hawamahal the palace of winds in Jaipur, a direct result of climate and social system; or Sabarmati Ashram at Ahmedabad- a response to the climate, at the same time expressing the ideology of Mahatma Gandhi. This is vivid also in different parts of India, where each region has its own expression of traditional architectural form and language responding sensitively to its climate and culture.

Indian cities and villages do have a distinct personality and character. Within the areas occupied by people, climate, soil, availability of building materials, occupation, have a fairly wide range of variability resulted in the varied pattern and form of built environment. To evolve a sustainable architectural form and spatial organization with respect to the climate and culture of the region, it is important to study indigenous architectural forms and constructional practices in such areas in order to find appropriate solution.

Figure 2 Typical House Type in kutch " bhunga".

For example Kutch, Gujrat in India, with its enterprising people, hostile geography, colorful history, diverse society, rich traditions, indigenous architecture, has a tradition of incredibly beautiful crafts, which form an essential part of its habitat. The architectural forms developed in this highly earthquake prone area are invariably developed in harmony with the climatic conditions in addition to the earthquake resistant features. The circular or semicircular form and low-rise load bearing structure of these houses called "Bhungas" enable them to withstand the lateral movements developed on earthquake occurrence (figure 2).

1.3 Walls: An Important Building Element

Considering the characteristics of building stock in India 56% of which is consists of non engineered load bearing type failure of walls is the single largest factor responsible for collapse of structures in case of calamities like earthquake (6). Walling material constitute approximately 30% of construction and the largest mass and surface area of buildings as far as type and nature of building stock in India is concerned. Maximum thermal exchange in a building takes place through walls and this phenomenon is of great importance in this tropical country.

Figure 4 catastrophic Failure of Wall Constructed with Bricks and Mud Mortar in 26th January 2001, Bhuj Earthquake.

Considering the extent of damage to stonework in recent earthquakes it is desirable to use an alternative building material in the present context. Brick is one of the widely used walling materials used for its suitability and adaptability as far as socio-economic and climatic considerations in India are concerned. Brickwork is supposed to provide a better earthquake resistance for low-rise buildings and damage to brick buildings is generally attributed to the poor quality bricks and inadequate constructional practices. Such constructional practices are required to be re-examined and appropriate measures should be taken to improve their performance as far as earthquake occurrence is concerned in order to create a sustainable architecture.

1.4 Sustainability in the Terms of Architectural Form

The increasing use of traditional forms as a resource of contemporary design has been widely discussed in recent years gaining momentum particularly in third world countries. In the face of a self-indulgent architecture of postmodernism and reductive universality of modern architecture these rapidly developing countries has begun to look built forms as an expression of their aspirations and identities. Furthermore, within the vast variety of multi-faceted traditions are the repositories of history and an intricate fabric of myths and symbols, which can be tapped creatively. One unchanging element of all buildings is the roof – protective emphatic and all-important. Ubiquitous pervasively present, the scale or pattern shaped by the building beneath. The roof, its shape texture and proportion are the strongest visual factor (Figure 5).

Figure 5 Conical Roof on Circular Plan Shape

The architectural form has major influence on earthquake performance as observed in past earthquakes. The circular and semicircular form of houses in Kutch, with their conical lightweight roof and adequate structural detailing, enable them to withstand the horizontal shear forces generated by the earthquake occurrence. Various structural elements like the tie beam at plinth kevel, the ring beam at the junctions of the wall with the roof and the radial beams from the central shaft to the ring beam all together formed an integrated structural system, which performed excellently

Physical properties of the materials used in construction and constructional methods influence seismic design to a great extent. Broadly speaking various types of construction' which are commonly used in rural and semi urban areas of the country are, buildings constructed with mud and thatch, brick buildings, stone buildings and timber buildings. Adobe construction is one of widely used constructional practices. This type of construction has been employed extensively in India for rural and suburban housing because it is available within the economic limitations. It is understood that this material does not in itself have the necessary qualities to provide an earthquake resistant construction and it has three serious disadvantages it is weak, brittle and heavy. If combined with a braced wooden frame, it can provide a certain degree of earthquake resistance. Mud and Stone construction is certainly the lowest in the resistance scale still a considerable number of people live in this type of houses in the country. When the roof is built-up with heavy layer mud this type of dwelling presents a high degree of risk to the life of its occupants in an earthquake of even moderate intensity.

Considering the importance of building material in the creation of sustainable structures one solution is the use of fly ash bricks, which are not only economical but also favorable to the climatic conditions that prevail in majority of the earthquake prone areas of India.

1.5 Sustainable Material: fly - Ash

India is producing about 150 million ton of fly ash per annum, which is one of the major waste materials from thermal power stations using pulverized coal. A 100 MV thermal power plant generates about 0.15 million tones of fly ash per annum when using coals with an ash content of 40%. Fly ash on the other hand, possesses both ceramics as well as pozolana properties and therefore it can be utilized in a unique way for manufacture bricks, which would be useful for building constructions.

The quality of fly ash bricks largely depends on the physio-chemical properties of the soil to be used for their manufacture. To ensure this soil has to tested in order to find outs suitability for the manufacture at a large scale. Generally red, black, and alluvial soils are which are free from alkalis are found suitable. Fly ash which is to be added in the required quantity generally contain un-burnt carbon varies in the range of 5 to 8 percent. In general, fly ash has a composition similar to raw materials used in brick manufacture. Some fly ashes contain amounts of calcium (from calcite) and iron oxide (from pyrite and marcasite), which should not present excessively. The high level of each of these constituents can be accommodated with special procedures. For example high levels of calcium if present as CaO or Ca (OH) 2 can be corrected for by adding water in the cool-down part of the firing cycle. Both the color and lower melting point caused by high levels of iron are best adjusted for by increasing the quartz or kaolinite content of the clay-shale, or by removing magnetic iron oxide from the fly ash.

1.5.1 Chemical Testing

Insert graphs, line drawings, and photographs into the finished document as digital objects. Use a resolution of 300 x 300 dpi (dots per inch) for photographs and drawings. Place figures as close as possible to the text in which they are mentioned; do not append figures at the end of your paper Provide a figure number (in consecutive Arabic numerals) and caption below each figure and photograph.

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Characterization of the raw materials showed that fly ash could be used advantageously in bricks. The advantages of fly ash over brick clays are as follows:

It saves the energy required to dehydroxylate or fire clay minerals. It contains spherical particles and mullite crystallites that are ideal for "opening" the brick and promoting thorough firing, its mixture of mineral components gives similar ranges of refractoriness to those for clays.

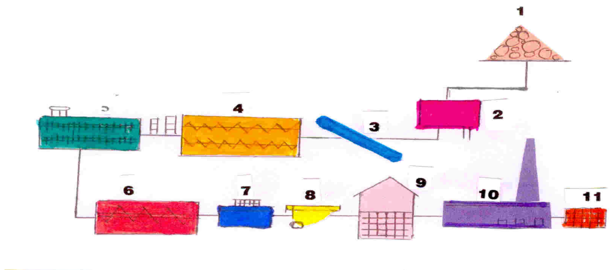
It can be selected to give special colors or other properties that are not possible from clays. It contains lime (CaO) or portlandite (Ca [OH] 2) that will capture pyretic sulfur from clays and reduce air pollution. A processed fly ash could provide even greater benefits of these types.

1.5.2 Manufacture of Fly-Ash Bricks

Fly ash bricks generally are machine made having uniform size and shape, which reduces the consumption of cement. It has more strength due to which less breakage occurs. The Fly ash bricks and blocks manufactured have strengths ranging between 100 to 350 kg/cm2, depending upon the proportion of the ingredients and low water absorption, making it a far superior product than the clay brick. Raw material required for fly ash bricks is Fly ash, Sand, and Lime & Gypsum. In fly ash brick making three machines are used, viz. Pan Mixture, Conveyor System & Main Brick Making Machine.

1.5.3 Effect on the Quality of the Bricks

The addition of fly ash in optimum proportion to the plastic, red and black soils reduces excessive linear drying shrinkage in body of the bricks. The compressive strength of the bricks is considerably increased. The addition of fly-ash admixture to the soil resulted in the manufacture of more number of bricks from the same quantity of the soil (up to 40% increase in production can be achieved).
Fly-ash which is an industrial waste can be utilized up to 30 to 40 tons per hundred thousand bricks in the case of alluvial and 100 to 125 tons in the case of red and black soils.
The bulk density of is reduced because of the addition of fly -ash; this phenomenon provides better thermal insulation properties to the masonry walls constructed using such bricks.
This also resulted in reduced dead load of the masonry and thus proved suitable for the construction in the earthquake prone areas by and large.



1	**WATER**	5	**DOUBLE SHAFT MIXER**	9	**DRYING SHED**
2	**GRIENDER**	6	**BRICK EXTRUDER**	10	
3	**BELT CONVEYOR**	7	**CUTING TABLE**		**BRICK KILN**
4	**PUG MILL**	8	**WHEEL BARROWS**		

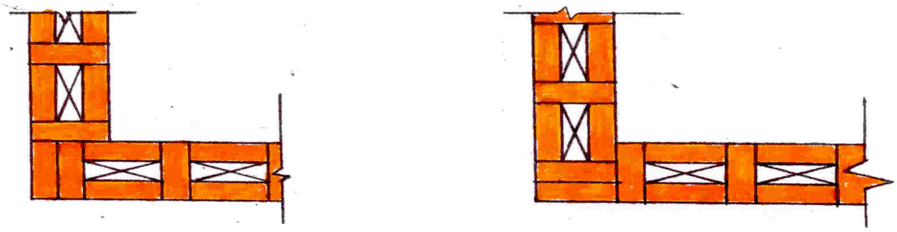
Figure 6 Manufacturing Process

A good manufacturing process as shown in figure 6 offers:

- Production of better quality well burnt bricks in addition to an appreciable economy in fuel consumption.
- Fuel saving in the range of 15 to 25 percent or coal saving up to 5 tons per hundred thousand bricks.
- Drying and firing losses during the brick production are checked to certain extent.

1.6 Appropriate Construction Technology: Rattrap Bond Construction

Renowned architect develops this bond Ar. Lauri Baker practicing in India. Rat-Trap bond masonry also referred to as Rowlock or Rolock masonry may be defined as a bond comprising of two leaves of brick courses each of which is built with placing bricks on edge, separated by a cavity and tied together with bull header to ensure the integrity of two leaves. The dimensions of traditional bricks generally used for construction in India are 230 x 115 x 76 mm. The cavity left between the two leaves of Rattrap bond depends upon the size of the bricks, which is about 78mm as far as conventional bricks are concerned. All frogs of the bricks are kept towards the cavity. The cavity can also be used to place vertical reinforcement bars in order to provide additional structural strength against seismic forces (figure 7)



Plan of the Course 1,3,5…   Plan of the Course 2,4,6,

Figure 7   Rattrap Bond

1.7 Advantages of Rat-Trap bond Construction

Cost Effectiveness: This type of construction results in about 25% saving in construction cost as less bricks are required (on every three bricks there is a saving of one brick). In addition to this for every 230 mm height of the brickwork there is a saving of one layer f mortar.

Fast Construction Operation: This bond is proved faster to construct with only five courses to be constructed for about 700 mm high wall as against nine courses in conventional English bond. This phenomenon results in 25 to 30 % saving in time and subsequent lesser overhead expenditures on site.

Sound and Thermal Insulation: This type of construction offers high degree of thermal insulation because of the presence of built-in cavity in the masonry. It results in a high degree of comfort conditions inside the usable space without any additional cost, which is one of the important criteria in a tropical country like India. Besides it also provided good sound insulation properties to the structure.

Aesthetically Pleasing: this bond is aesthetically pleasing and can be used for exposed brickwork provided the exposed surfaces are painted with transparent Silicon or Epoxy paint to prevent moisture penetration.

High Seismic Strength: Based on test results this bond is found structurally sound to resist seismic forces for low-rise construction. Being lightweight construction a wall constructed with it offers more earthquake resistance as compared to the wall of the same thickness constructed with conventional English bond. The seismic resistance can be further increased with the provision of vertical reinforcement at the critical locations.

1.8 Analytical Study of Rat –Trap Construction and Conventional Construction

Considering the constructional practices in India, brick masonry construction is economical as compared to R.C.C. construction for low-rise buildings. Rattrap bond provides thicker walls with comparatively less weight resulting in an increased seismic resistance as well as improved thermal conditions inside, which is extremely desirable in the severe climate of Bhuj. Although 23% of the workers are employed in the construction industry in India only a small proportion of these are trained to use modern techniques of construction (6). This type of construction does not require skilled labor and also faster as far as speed of construction is concerned. The use of Fly ash bricks further decreases the total load of the structure and subsequent increased seismic resistance. Fly-ash bricks are now manufactured at a large scale in many parts of the country. Being locally available they do not require transportation from long distances hence proved economical in addition to the 25% saving offered by the Rattrap construction because of the saving in bricks and mortar. The manufacturing process and constructional operations also results in substantial saving as far as energy consumption is concerned. This is an important phenomenon considering the power shortage which prevails allover the country.

1.9 Conclusion

Creation of a sustainable architecture for earthquake prone areas is a matter of serious concern. The architectural development there must respond to the climate, living pattern of the inhabitant .It is indeed imperative for the people who suddenly lost their entire social, physical and cultural surroundings. This crucial issue often gets ignored in the enthusiasm or speed of rehabilitation programmes, creating totally alien built environment for the local people. For this traditional constructional methods can provide appropriate solution, which are to be transformed for new requirements of the future generation. The architectural design should evolve a contemporary language, and it needs reinterpretation of the climate, culture, craft and traditional architecture in the contemporary context. Such built forms must be constructed with using the material which is not only economical but also provide required earthquake resistance in addition to facilitate ease in constructional operations, fly ash bricks can be used to satisfy these requirements as suggested here. Although 23% of the workers are employed in the construction industry in India, only a small proportion of these are trained to use modern techniques of construction. This has result in highly vulnerable building stock as was evidenced in the recent earthquakes of Uttarkashi, Latur, Jabalpur, Chamoli and Bhuj. Creation of living environment is a process of giving physical form to human's socio-economic needs and aspirations. Living environment at different places have always been created, modified and used by the users in a different manner and are therefore very different in character. The sustainable design of built forms in a developing country like India, targets to developing economical and reliable structures and systems for different environmental conditions and technological constraints. Considering this the use of Rattrap construction for earthquake prone areas is found to be adequate as far as availability of resources and technology know- how is concerned. This approach towards design and construction to create an ambience familiar to the culture of inhabitants in the new architectural development can only create architecture, which can be said, sustainable in true sense.

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