

Straw Bale in construction of building and its future in India

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ABSTRACT

The advancement in the field of technology have influence environment in utmost extend so everyone is worried about the environment and its tremendous impact in our life. It is obvious that people want to live in eco-friendly houses making it as a part of environment and their life. Thought it is a challenging job, we can still use our resources and manpower for the creation of innovative eco-friendly houses. Straw house can be one of the best alternative for the country like india where agriculture is still the main source of income and production of straw is tremendous. But, those straws are either burned or ploughed back to soil leading to the production of harmful gas as carbon forming black cloud which seriously cause chronic chest diseases and also burning fills the air with gaseous and particulate pollutants, and soils generally can't absorb all the materials as quickly as needed so ploughed back to soil is also not a effective implementation. Straw bale construction can be one of the best alternatives as it is renewable resources having tremendous features as cost effective with high health value, Aesthetics value, thermal performance, Fire resistance, light weight and eco-friendly in nature. We also can go with the various techniques of construction as load bearing straw bale construction or non load bearing construction as per the circumstances. Straw bale construction can be one of the best alternative for all kind of people for constructing a economic building with a sustainable material.

Keywords –Straw bale construction, renewable resource, Eco-friendly houses, high health and aesthetic value, sustainable material.

I. INTRODUCTION

Straw is a natural fiber which we get as a byproduct from the agriculture. It is the plant structure between the root crown and the grain head which is composed of cellulose, hemi cellulose, lignens and silica. It is being produced by the process of photosynthesis, a natural and non polluting process by solar energy. We can get this from wheat, rice, oats, hops, barley. Among this rice straw is the toughest one due to high silica content. It is an annually renewable agricultural residue which is being produce in ample amount in most of the countries. It is also considered as the waste product and is being wasted by burning or any other way which is having impact on the environment directly or indirectly. It is being produced by the collaboration of environment so use of this in construction would be obviously a environmental friendly and would have a lots of merits for our quality life. Burning of the straw lead to black cloud which cause serious chronic cheast diseases and

carbon evolved from it would affect the quality of environment. Straw which is produced has become one of the headache for the farmers as it won't decay easily. The world largest straw producing countries like China, India and other agricultural country have not been able to utilize it for productive work up till now. In india it is used for paper factory for production of papers and some other purposes but this is not enough for proper utilization and still these country are wasting in ample amount. The use of straw for the construction has been commenced long back. Straw bales were first used by the settlers of the sand hills region of Nebraska. In 1890's Nebraska commenced this straw bale for building buildings, churches, schools, officials and grocery stores. In those times they focus in stability of bale wall system , structural stability, plastering and moisture control. So, straw bale construction has been a boom for the economic environmental building alternative.

Straw bale is simply a compressed bundle of straw which is arranged in square, rectangular or round shape attached with wire or twins. Straw is the dry steams of cereal grains left after the seed heads have been removed (Austin city code Volume-II, section 3603). Bale density varies according to the type of grains, moisture level and degree of compaction provided by the baler¹. The dimension of straw bale can vary as per circumstance but the standard size can be 900mm x 450mm x 350mm / 584mm x 1168mm x 400mm.Straw bales are light which means a straw bale wall weights 65% less than an equivalent brick wall and 62% less than concrete block wall.

Size of bale(in mm)	900 x 450 x 350/ 584 x 1168 x 400
Modulus of Elasticity	1379 KPa
Compressive Stresses	More than 482.7 KPa

Compressive test on unplastered walls 2438mm high gave yield stresses of 27.6-34.5KPa(straw bale construction by Bruce King ,P.E).

II. ANALYSIS

Straw bale have omnipotent scope in India. As, India is one of the largest country enlisted in production of straw bale. Since, still large population is solely depended upon the agriculture so potential of straw bale construction in India is exclusively high. As, 46% of total land(32,87,590 sq.km) of India is agricultural land so out of total population (1,17,09,38,000) 58.4% is solely depended upon agriculture

as per 2010 study. Among them 41.6% of total population lies below poverty level(2005 world bank estimation) which means these people are not able to meet quality shelter and being in a good house is a dream for them. It is clear that building construction in today's context is very expensive and it can't be accessible to them so quality of life stander for them is very low but it is basic human right to get access for good shelter and this can be possible through straw bale construction. As straw is considered as a waste material and it is locally available in ample quantity so use in construction is environmental friendly. According to the 1995 report from Department of Energy(DOE) House of straw adds that the construction cost of a structural straw bale wall is about one fourth that of comparably insulated conventional wall.

III. ENVIRONMENTAL PERFORMANCE

The study of straw bales shows that it is highly eco friendly in its production, placement, function and operation and maintenance to reconstruction. It depicts that it is produced in environment and it requires low energy for procurement for comfort, creativity and aesthetics. The environmental issue encompasses the following features.

1. Fire Resistance	It has good resistance against fire since straw bale are tightly packed making it too dense (i.e lack in oxygen) which do not support the combustion (American Society For Testing and Material). The test conducted at the Richmond Field Station in 1997 by student of California Berkeley reflect that timber resist fire for 8 minute, un-rendered straw bale resist fire for 30 min and rendered straw bale resist for 2 hours.
2. Thermal insulation	Straw bales has thick straw wall, which creates the insulating gap between external and internal part of wall, helps to resist the flow of heat at higher level and it aid to save energy. Rice straw is class A insulating material

3. Sound Insulation	Straw is fibrous material and it resists the sound waves controlling noise pollution which also helps to save energy.
4. Structural capacity	The structural performance of straw bale construction is high. Load bearing straw bale method can withstand up till three storied whereas frame helps to improve the stability more than load bearing straw bale method.
5. Durability and moisture resistance	Though straw is the biological product and is biodegradable, It is highly durable in absent of excess moisture (>15%) and the air. Till the straw bale is well protected and is allowed to become waterlogged ,it can last many years with moderate maintenance and Reasonably expected to have lifetime of 100 years or more.(5.8 straw bale, Paul Downton)
6. Resistance against termites and pests	Clean and dry straw have less nutrition so it is unable to support paste population for long in itself. Also wall build with tightly pressed straw bale provide fewer space to paste to live.
7. Toxicity and moisture resistance	Being a naturally available material straw bale is nontoxic in nature and produces no harmful chemicals due to its inert nature. The straw bale is also having

	good breathability allowing air to slowly permeate the structure without moisture penetration.
8. Availability	Straw is agricultural by product and locally available .so it is easily accessible for any one. Transportation is not require which also helps in controlling the fuel consumption .

Table1. Features of straw

In this way straw is having lots of benefits which helps a lot for the quality of life and it also aid in fulfilling the green concept to some extent due to its tremendous features. There might be several problem that we might encounter but tactful and astute plan can lead for the best straw house. Water penetration is also major problem, straw left in a moist generally above 20% moisture content and 10 degree temperature will support for the growth of molds which leads to decay of straw. Long term creep deflection of the bale wall can be the major problem so to avoid this pre-compression of the wall is highly admired. Load bearing straw bale building in high snow or earthquake prone areas can tentatively be designed by using cement stucco skins.

With this observation we can conclude that straw is one of the promising materials for the green construction because of its performance in collaboration with the environment.

IV. COST EFFICIENCY

Straw is easily, cheaply available material and require limited transportation and do not require any transformation and can be easily handled. It does not require much skilled man power for procurement and construction. As it is agricultural product so it acts as renewable resource which helps to reduce the use of non renewable resource and reduce the cost whose relation is depicts in figure 1.

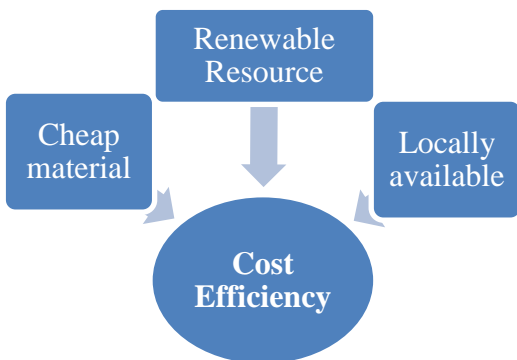


Fig.1 Relation of cost efficiency with various components.

V. CONSTRUCTION

Various methods are used for the construction. The main aim is to achieve good compression of bales to minimize settlement and movement to fulfill the structural and well being requirements. Well compressed bales of water content less than 15% is preferable.

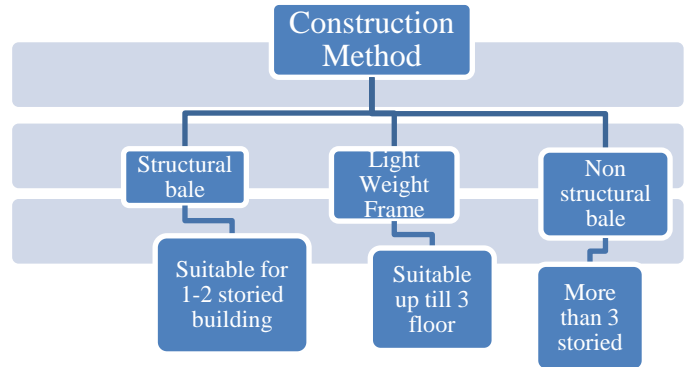


Chart1. Construction method of straw house

Construction of straw house can be done in various ways which is described below

Structural Bale House-

It is also known as Nebraska style and is considered as the first technique of construction. The entire load is being beared by the straw in this case so it is also known as load bearing method. It can be used for simple and one to two storied building. In this case door should not exceed 50% of wall surface. In this process roof of the building is constructed at last.

Light Weight Frame-

It is also known as timber framework method in which firstly timber framework is prepared and in those frame only straw is installed. This method would be suitable for up till 3 floors. In this timber would be an additional material or any other framework material. In this frame should be provided for doors and windows. In this roof should be constructed at first only.

Non Structural Bale –

It is also known as in fill method. In this building with post and beams are made with timber or steel. In this weight is supported by the frame. Wood, Steel or concrete framework and the bales are simply infill insulator blocks between the posts. It gives great stability and cost is also high in compare to others. In this also roof should be constructing at first. In this way, as per the accessibility we can select any one way of construction which encompass ancient till modern way of construction. If our budget is low than selection of Nebraska style of construction is more preferable than others.

Bale walls, when covered with plaster, drywall, or stucco are considered to have the equivalent fire resisting rating as a wood frame construction with same wall finishing system (Austin straw bale code, 3605.1 general). From the Austin straw bale code 3605.2 for all the method of construction the nominal minimum bale wall thickness must be 14 inches.

VI. OBSERVATIONS

Fig.2 clarify that straw bale house is sound resistance in compare to others types of houses. Sound can transmit more in open space where as straw wall resist sound more in compare to brick wall.

Fig3. Shows that energy consumed in straw house is far less than that of others. As it acts as sound and heat insulation and have other tremendous advantages so energy consumed in this type of building is reduced in maximum extend than that of others.

Table 2. Reflects that straw house is very cheap in construction and we can save a lot from straw bale construction making it affordable to all for constructing quality house for quality lifestyle.

Table3. Explains for the last 10 years a increasing number of load bearing straw bale buildings have been built in the UK. Walls formed from stacked bales of straw are used as load bearing walls in low rise, specially for one storied building. The average bulk density was 125 kg/m³ (average moisture content at testing was 13.5%), varying between 118 and 137 kg/m³. The bale density that was recommended varies between 100 and 110 kg/m³. The maximum loads for unplastered straw bale walls has been found at between 4.2 and 19.2 kN/m, with respect to bale type, orientation (laid flat or on edge) and the use of internal reinforcing bars. Displacements reported at a maximum load of unplastered walls similarly vary between 72 and 198 mm. The maximum reported loads for plastered bale walls, of comparable construction, vary between 21 and 66 kN/m.

bale walls demonstrated viscoelastic behavior. The walls creep with time under load following an initial instantaneous deformation, immediately recovering some deformation on load removal, followed by further time dependent recovery but exhibiting a final permanent deformation. Pre-compression improved initial stiffness of the straw bale wall. Maximum vertical load capacity and initial stiffness was improved by the inclusion of hazel spikes. Maximum vertical load capacity and initial stiffness was impaired by the use of half bales.

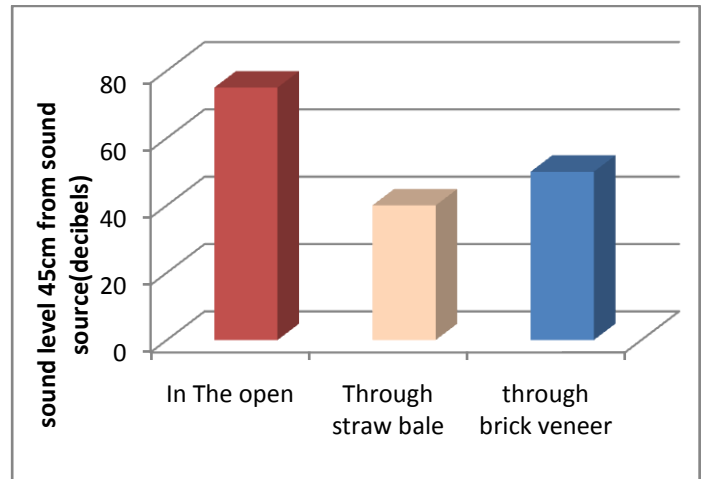


Fig 2- Sound transmission through straw bale and brick veneer walls compared with sound level in the open

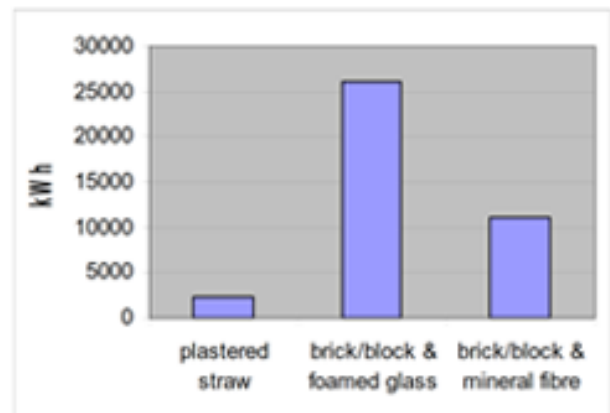


Fig 3.energy consumed by plastered straw



Fig 4. Static load test

A maximum permissible service load of approximately 19 kN/m² (9.6 kN) is often used in straw bale wall design. The maximum applied load of the lime rendered wall was over four times greater. However, the maximum load of one unplastered wall was only 13% higher, though the standard bale wall achieved a maximum loading nearly three times higher. Hence, under sustained loading unplastered straw

Building	Construction Cost	Energy	Total	Saving
Straw Bale	\$40000	\$60000	\$100000	\$102000
Conventional	\$82000	\$120000	\$202000	-----

Table2. Comparison of cost for construction between straw bale and conventional as per working group report.

Wall	Initial wall stiffness (kN/mm)	Maximum applied load (kN)	Settlement at maximum load (mm)
Standard construction	0.11	27.6	220
Pre-compressed wall	0.22	19.2	120
Half-bales	0.087	10.9	140
No hazel spikes	0.077	11.7	165
Lime rendered wall	5.62	41.1	55

Table3. Static load test

VII. CONCLUSION

In this emerging world where the rising need of housing is increasing day by day due to tremendous growing of rural and urban population has been a pressuring issue. Without compromising affordability, quality and maintaining the component of earth system has been a challenging task where Straw Bale can be one of the promising building material that meet the overall housing need and energy efficient goal of most of the developing countries like India, Nepal, Bhutan etc where agriculture act as the backbone of development. India being one of the largest countries for production of straw but most of those is considered as waste and limited are only used for productive type but if we can utilize them for construction in the form of straw bale then staying in good house won't be limited to dream for people. It aids to maintain the quality of living stander of people because straw house fulfills serviceability and helps to maintain the environmental quality. Straw is getting lots of preference in many countries because it is cost effective with high health value, Aesthetics value, thermal performance, Fire resistance, light weight and eco-friendly in nature. It also has good response against earthquake so it can be constructed in earthquake prone areas as well. So, profound research and awareness regarding straw bale construction should be enhanced in developing countries land agriculture countries like India for effective implementation of straw bale house.

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