The viability of straw bale as a construction material in Indian context

Dr. Monika Shekhar Gupta
Associate Professor , Architecture Department
Indus University , Ahmedabad

Abstract: India has the largest area under rice cultivation as rice being the dominant crop in the country. India produces 98 million tonnes of paddy with roughly 130 million tonnes of *straw.* To increase the crop yield, farmers do not keep the field idle and they try to make the field ready for the next crop. Thus managing the residual straw for site clearance is always an issue. Burning these residuals is the quickest solution for them. Again, Architects, engineers are in desperate search of environmentally responsible building material. Straw- bale can be a very good solution to meet all the related issues for a environmentally sustainable material. Straw is not a new building material in our country. The image of the entire rice producing rural belt area in the country has changed over the past few decades. The roof cover has shifted from thatch made of straw to tin or asbestos. While, the use of straw bale in contemporary construction has increased significantly in recent years in many countries like US, UK, Canada, Australia and Japan,in India, formally the straw bale construction is not yet so popular and accepted in spite of a felt absence of sustainable building materials. The aim of this paper is to examine the viability of straw bale as a material-technology to meet our future construction needs especially in pre-urban and rural areas.

Keywords: Strawbale, sustainable, embodied energy, prefab construction material.

1. Introduction

Agricultural production has increased a lot in India due to the new irrigation schemes, use of agrochemicals, advancement and mechanization of farming practices which finally leads to an ample amount of agro-waste. Our country needs to get a solution for sustainable management of agricultural waste due to the increasing population, production rates and economic growth. We get the majority of crop residue from wheat and rice crops which needed to be managed or reused. Northern Indian states such as Punjab, Haryana and Uttar Pradesh are suffering from severe air pollution because 92 Mt of crop residue is burnt each year. Out of 500Mt crop residue of India majority of it is used as raw material for energy production, for fodder etc. Due to the lack of proper disposal opportunities and lack of technical awareness the small-scale farmers find burning the best way to dispose of the crop waste. According to the National Center for Biotechnology Information advances science and health the air quality has become really poor in northern India to nearly twice the permissible Indian standard and ten times higher than the WHO standard because of large scale burning of crops in that leads to CO2, CO, N2O and

NOx emission in the the atmosphere and has led to a shocking increase in air pollution not only locally but in nearby cities also.
Many campaigns were done by the Indian Government to stop crop residue burning and for handling it the Indian Agricultural Research institute (IARI), Indian Ministry of New and Renewable Energy are continuously promoting research and innovative measures. The National policy for management International Journal of Environmental research and Public Health crop residue recently formulated by the Central Government, has laid out policies and regulations to be undertaken by the local agencies to curb crop burning and initiatives towards sustainable management practices. As a result, the National Remote Sensing Agency and the Central Pollution Control board (http://www.ncbi.nlm.nih.gov) monitor crop burning through aerial surveillance and penalize farmers who burn crops. After so many attempts of different government agencies air pollution is still increasing especially in the months of November and December suggests that the above policies have no fully prevented crop burning.
As per Building Materials and Technology Promotion Council the demand of building materials for 2021-2022 (http://www.kspcb.gov.in)has been estimated as cement 380 million tons,sand 750 million tones , steel 50 million tone , bricks 600 million numbers, aggregates 400 million cubic meters, timber 40 million cubic meters. Data shows there is a considerable amount of shortage of conventional and traditional building materials in India. The National Green Tribunal (iasscore.in) issued a restraint order against all sand mining activity being carried out across the country without environmental clearance. Thus obtaining EC for sand mining activities being a formal process, it would take a longer time which in turn might have a huge impact on ready availability of sand in near future. According to a research by Prof V. Kathuria (http://www.downtoearth.org.in)about Environmental Cost of using top-soil for brick making, India is the second largest producer of bricks in the world and manufactures nearly 200 billion bricks a year and 65 per cent of these bricks are produced in the Indo-Gangetic plains, which have one of the world's most fertile alluvial plains. This implies that there will be gradual decline in the production of clay burnt bricks with the increasing awareness in future.

On the other hand, lot of construction works is needed in rural areas because of increasing population. Demand for easily available building materials is always there in rural context. Designers, Architects are in search for sustainable, alternative, locally available building materials for the construction works in rural context. Strawbale construction is an appropriate alternative in order to fill up the gap.

2.0Strawbale as a building material: advantages & disadvantages

Conventional building materials used in the construction like cement, steel, brick, wood etc all are dependent on natural resources and thus limited in supply. The larger demand for these materials for the growing population caused exploring other engineered building materials to keep the resource minimally disturbed. All geographic locations are striving day by day for new materials as a consequence of the depleting natural resources. On the contrary, the straws which are coming out of agro-waste are not limited, rather renewed every time a fresh crop is produced. Therefore, the future of building materials is lying on renewal, recycle and reuse. The future of renewed building materials rests largely on the materials which come out from agro waste, like straws. The use of agro-waste based straw bale is directly related to the protection of land cover and natural resources which contributes to sustainable development (Figure 1). Whereas the continuation of use of conventional materials contributes to the depletion of natural resources and contributes to undesired consequences of population increase. Thus a vicious cycle of using conventional material and the virtuous cycle of using renewable material, like straw bale, can be represented in Figure 1.

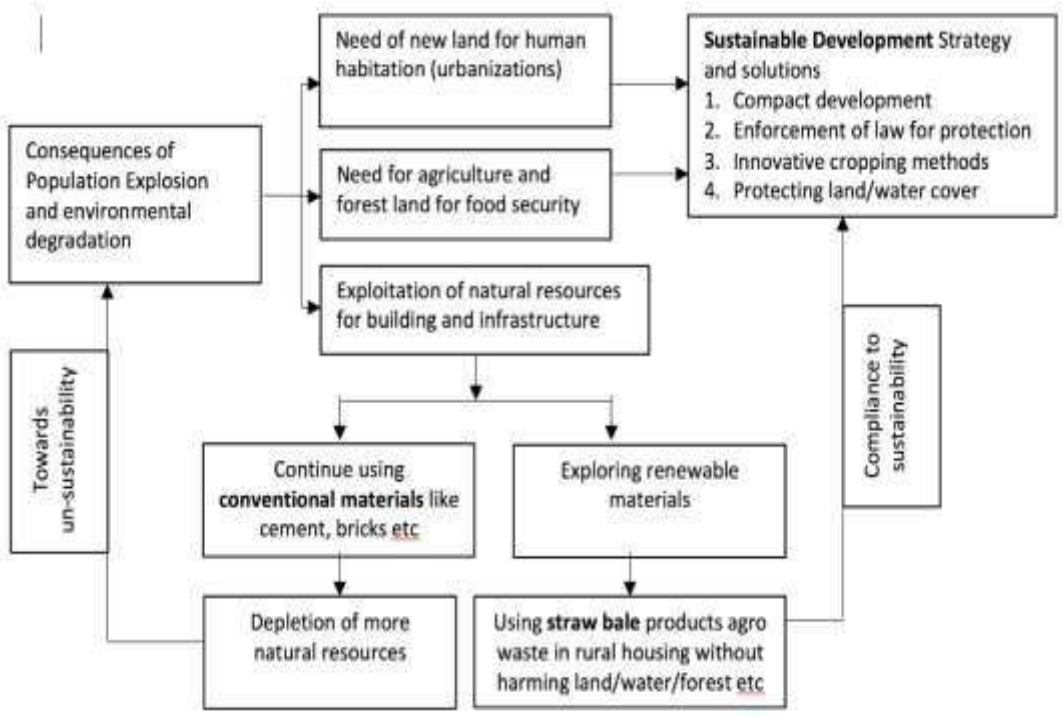

Figure 1: Implication of using strawbale in construction

2.1 Strawbale and Energy Efficiency

One of the reasons for claims that strawbale construction is that, it is environment-friendly and it is purported to have low embodied energy compared to other construction techniques. Some sort of waste is produced in all constructions today, most of which ends up in landfills. On a straw bale construction site, the waste straw can either be composted or used for animal bedding. It can simply be biodegraded by exposing it to the elements promoting biodegradation. Insulation is also an important issue in construction.

The energy required for the heating and cooling of buildings caused by air leakages is approximately 40%. Additional energy can be consumed occasionally by these leakages, in order to maintain a constant ideal indoor temperature. This energy can be reduced by up to 30% by proper insulation. Straw bales are natural materials, unlike many manufactured building products. Straw bales are chemically stable, as they do not contain any toxic ingredients. In case of fire, they will also not emit poisonous fumes. Organically grown straw must be used to avoid the use of pesticides in buildings.

As compared to most of the traditional constructing materials, straw has very low embodied energy required for generating it for extracting, processing, transporting and many others. As the production and transport to the building site of straw bales consume little or no strength consequently, this production technique has minimal effect on the environment. Straw absolutely has lower embodied energy than wood on the grounds that, wood calls for a lot greater energy for the manufacturing and processing, and it also produces an awful lot more carbon dioxide in the production and processing in comparison with straw bales.

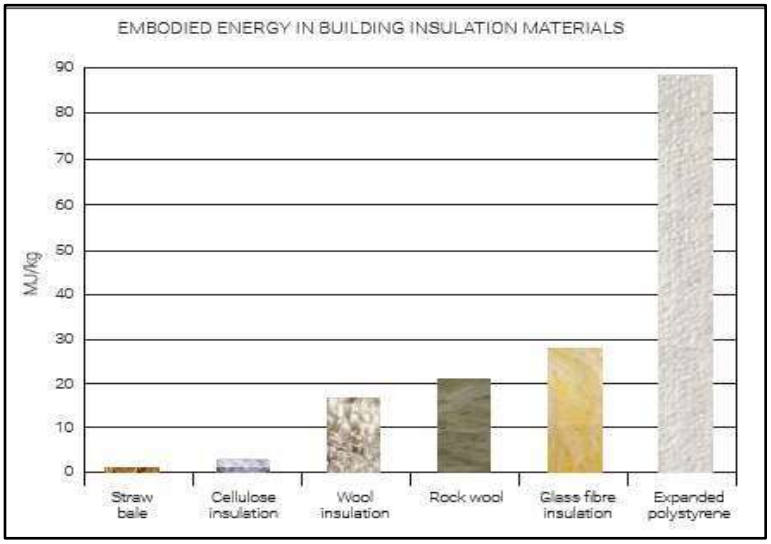

Fig 2: Embodied Energy in Building materials

The figure 2 shows the embodied energy of building substances with the use of figures from the sustainable energy research group(SERT) concluding that strawbale has the least embodied energy as compared to other isolative materials. Embodied energy is right here defined as 'the full primary electricity consumed at some point of all activities from cloth extraction, manufacturing transport until the finished product is ready. Straw

bales are one of the first-rate substances in terms of embodied energy. A graph of embodied electricity in extraordinary insulation substances is shown in Fig. 2.

Straw additionally, soak up and store carbon dioxide during photosynthesis, consequently it acts as a carbon sink 15 kg (Assessing and minimizing embodied energy by Offin Maria).of carbon dioxide is being absorbed by means of each 10 kg of straw, and seals it inside the walls for the lifetime of the constructing. Wood might appear as a better carbon garage in comparison to straw, as bushes can seize almost three times the quantity of carbon dioxide, 15 heaps of carbon dioxide consistent with hectare, and it may take 50 years to develop new bushes for wooden, while straw is produced each year with the cereal vegetation.

3.0 Limitations of using straw bale

The first and foremost limitation that hinders the fluent construction of strawbale is lack of standards or specifications accepted by the construction industry and problems have to be solved as they arise which takes more time and money than using a conventional building method. This could prove to be a barrier to mass builders building with straw.

- Its Inconsistent properties like its massive size, its density and its behaviour with moisture can be problematic during construction as an agricultural co-product.
- Details restricted by the need to protect the straw from water entry; careful details required for exposed areas.
- Limited to relatively lightweight fixtures.
- Requires shelter before finishing.
- The suitability of rendered external finishes limits the application in certain areas.

These limitations could be overcome by taking some measures as follows:

3.1. Placing of base plate

The additional width of the wall compared to standard construction and the size of the foundation required to support it is one of the challenges of straw bale construction that will reduce the economic viability of the wall. Therefore the foundation must be designed carefully considering the added cost of a perimeter foundation.

3.2. Moisture

Water vapor is stored in strawbales in the same way as cellulose insulation. For maintaining the desired level of moisture inside the wall lime plaster must be used as plastering material because it is porous, breathable and grips easily to the strawbale. The moisture content percentage of bales should not be more than 20% (http://www.usgbc.org). The foundation must rise above the surrounding grade by at least 6” to protect the bottom of the wall from moisture and snow does not pile against them. The roof needs to have a large enough overhang. The plaster should be earth plaster topped with lime plaster. Plastic or tar paper placed along the top of walls will protect against any water that may come through your roof. Windows and doors also can be installed with proper flashing and drip edges that shed water away from the walls. A lime plaster slurry can be used as the final finish of the wall maintaining the breathe-ability of the wall and eliminating the need for paint.

3.3 Building Codes

With today's emphasis on sustainable building construction, straw bale construction methods have received renewed attention in India. With any new or unusual building product or method, building codes play an important role in their acceptance. The lessons learned with this specific construction method can be extended to other types of non-conventional construction. Several specific issues concerning straw bale construction are addressed as this construction technique is attractive in developing countries where affordable housing using local raw materials is essential. In these areas, where building codes do not exist, experimentation with new techniques is often easier and product or method development can occur much faster. There has been a recent trend to legitimize straw bale construction. In order to accomplish this, building codes are not only necessary but mandatory. As is the case for any unusual building technique, there is a required evaluation period by the local code enforcement before any permit will be issued.

Currently, straw bale construction is believed to be in a pivotal point in its development process. In terms of its cost-effectiveness, ease of installation, energy-efficiency, and sustainability, this building technique is not only ready to be accepted in the industry, it may be needed in the near future as difficult times approach. Natural building resources are becoming scarce and the world's the population is rapidly increasing, so alternative building techniques must be necessary consequences of these truths.

4.0 Relevance of Strawbale as Pre-fab Construction material in India

The prefabricated construction has been proved successful in delivering affordable mass housing to solve the housing problems in many countries. Prefabricated construction reduces the wastes of materials and time required for the same using conventional site based construction. Most of the manufacturing and production of building components take place in the factory and the site involves limited activity like assembly of the components. The technology transfers from site based construction to prefab construction need massive reform at the policy and planning level. In India the target for housing for all (HFA) is being streamlined with the central government programmed Pradhan Mantry Awas Yojona (PMAY). The main objective of PMAY is to bring shelter for all by intervening at supply and demand side of the housing market.

A Technology Sub-mission (TSM) under the PMAY has been set up to facilitate adoption of modern, innovative and green technologies and building material for faster and quality construction of houses (MoHUA, 2015). Basically the TSM aims to promote faster and greener technology for housing construction. Technology Sub-Mission will also facilitate preparation and adoption of layout designs and building plans suitable for various geo- climatic zones. It will also assist States/ Cities in deploying disaster resistant and environment friendly technologies. The Sub-mission will coordinate with various regulatory and administrative bodies for mainstreaming and up scaling the deployment of modern construction technologies and material in place of conventional

construction. Technology sub-mission will also coordinate with other agencies working in green and energy efficient technologies, climate changes etc.

The Sub-Mission will work on 1) Design & Planning, 2) Innovative technologies & materials, 3) Green buildings using natural resources and 4) Earthquake and other disaster resistant technologies and designs. Simple concept of designs ensuring adequate sunlight and air should be adopted. Figure 4 shows the approach for Technology Mission with it's focus:

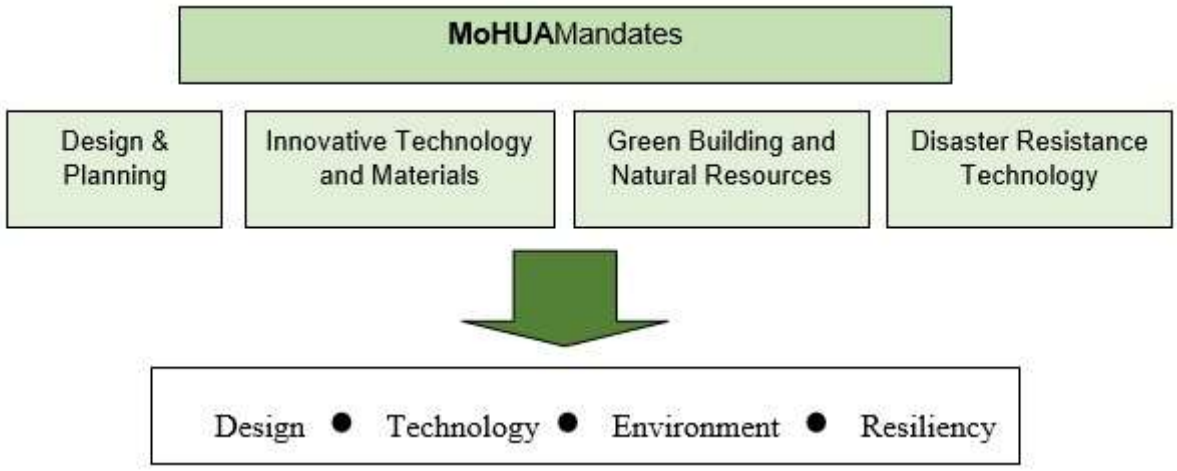

Figure 4: MOHUA's Approach & focus for Technology Sub-Mission (TSM) for housing

India being a vast country, the available indigenous technology and the same which are developed in the research labs are many. However, to fulfill the objective of technology sub- mission some specific criteria for identity, develop, design of selected technologies is required. Government of India published a 'Compendium of Prospective Emerging Technologies for Mass Housing' in continuation of initial activity under technology sub-mission (Fig 5). The broad parameters to select such technologies are, Structural performance against vertical & lateral loads, Fire resistance, Protection against rain & moisture, Thermal behaviour, Acoustic, Ease of fixing services, Quality assurance and Durability.

1. Monolithic Concrete Construction System using Plastic - Aluminium Formwork
2. Monolithic Concrete Construction System using Aluminium Formwork
3. Expanded Polystyrene Core Panel System
4. Industrialized 3-S System using Precast Reinforced Concrete Cement (RCC) Columns, Beams & Cellular Light Weight Concrete Precast RCC Slabs
5. Speed Floor System
6. Glass Fibre Reinforced Gypsum (GFRG) Panel Building System
7. Factory Made Fast Track Modular Building System
8. Light Gauge Steel Framed Structures (LGSF)

Figure 5: Eight emerging technologies (First phase) identified by BMTPC

Strawbale construction are clubbed with the advantages of prefabrication then a more efficient product with minimal the disadvantage could be made available to achieve a cost-effective and socially acceptable housing supply for economically weaker sections and lower-income group who resides in rural areas as well as in slums in urban areas.

Straw is abundantly available in India, enough to build millions of houses and also an answer to solve the housing demand for the growing population. As per the future need the construction material should be capable of reducing emissions, storing carbon, reducing waste and saving both energy and non-renewable resources to enter in the industrial construction market. Strawbale construction fulfils all these criteria. To overcome the disadvantages like variation in bale size, weather delays, negative perception to straw and fire risk during construction the development of prefabricated panels must be undertaken to address the practical concern for the delivery of strawbale construction and for the successful development of panel products to provide an opportunity for addressing much wider barriers to market acceptance through certification and warranty.
The benefits of strawbale construction are very clear when we compare it with other conventional prefabricating materials on the bases of their cost efficiency, energy efficiency material, its versatility, its structural behaviour and thermal insulative properties. If cities began using straw bale as affordable housing and growth of straw bale construction continue, the amount of money and energy that can be saved could reach millions, even billions by reducing the energy consumption by 60-70%. Moreover, the costs of the building could be greatly reduced if we could easily implement straw bale prefabricated housing for low-income housing. Money saved by using straw bale construction could be applied to other initiatives in cities. In addition to the monetary benefits, its time efficiency, its versatility the environmental advantages are evident. The use of straw bale rids an agricultural waste that ultimately results in major pollutants. The possibilities of straw bale construction are endless.

5.0 Use of Strawbale as prefab material in other countries

Straw bale construction could be a crop residue recycling sustainable building material alternative keeping in view the present Indian context. If the advantages since the Nineteenth century, strawbales have been used in the form of load bearing or non- load bearing external walls. The use of straw bales as insulation within wooden framed prefabricated panels has grown all over the world. It is found in various details in many countries including Australia, Belgium, Canada, France, Italy, Switzerland, the US and the UK. ModCell panels are one of the earliest examples with initial use in the UK in 2000. The panels are made in a flying factory a temporary panel manufacturing set up which is generally located within close proximity to the construction site. Despite its many benefits, it is yet to gain popularity in the domestic market energy require more resources and most likely cause more waste being discharged along the production line affecting the environment in a negative way. The embodied energy of strawbale wall section is six times less than that of the most common conventional material.

Country	Motivations	Limitations	Notes
European countries	To enable future construction to be: flexible, agile, value driven, knowledge-based, highly customer-centric, efficient and comparative [39].	-Negative perception associated with past practices, - Shortage of skills [39].	The average share of precast concrete systems in the construction industry across the European Union is 20-25% [38]
US	To reduce the construction duration, To reduce the overall project schedule, and To compensate for the effect of incremental weather conditions [40].	- Shortage of expert personnel that can design and manage building construction, -Inadequate education in the structural and architectural aspects of systems, -Size/weight restrictions on truck loads [41].	The current level of using these techniques is limited, predominately precast concrete products [40], which has only 6% share of the overall building construction market [42].
UK	To meet increasing demand for housing, and To improve industry's performance [43]	- Higher capital cost, - Complexity of interfacing between systems, - Nature of the planning system, - Negative perception [43].	The proportion of prefabricated building from total value of the UK construction sector is 2.1% [44].
Hong Kong	To increase quality, and To reduce waste [45].	- Lack of research information - Higher initial construction cost - Limited site space - Monotone in aesthetics - Lack of experience - No demand for prefabrication - Inflexible for design changes [46].	Using semi-prefabrication is limited, predominately Public housing. The most frequently used precast components were precast facade (51%), precast staircase (22%), semi-precast slab (9%) and semi-precast balcony (7%) [45].
Malaysia	To ease labor requirement pressures, To improve quality and enhance productivity [47].	- Cost and finance, - Skills and knowledge, - Project delivery and supply chain, - Perception of clients and professionals, and - Lack of government incentives, directives and promotion [48].	In 2003, prefabricated building share only 15% of overall construction projects, however, 10% used by 2006 [47].
Australia	To improve the performance of construction industry [49].	- Shortage of skills - Lack of industry knowledge[49]	Investment in prefabricated building development is largely non-existent[50].

7.0 Conclusion:

Strawbales are a natural material unlike many manufactured building products. They do not contain any toxic ingredients that might be released into the finished building in form of off-gassing and are chemically stable too. Sustainable materials and sustainable building techniques are important aspects to how the building industry can contribute towards creating a sustainable society for generations to come. Researchers need to study more and more sustainable options for future building materials, their local availability, affordability, ecological impact and social context. This paper emphasizes on Straw bale construction for Indian context in the delivery of rural and urban housing. It aims to create a niche to bring straw-bale as mainstream construction material in India for prefabricated construction in TSM, PMAY and also otherwise.

References :

1. Clarke Snell &Tim ,Building Green: A Complete How-To Guide to Alternative Building Methods (Earth Plaster, Straw Bale, Cordwood, Cob, Living Roofs.) Lark Books/Shelter Publishing, 2006.
2. Nisha , Snehal : Affordable and Sustainable Housing option for rural development ,International Journal of Latest Trends in Engineering and Technology (IJLTET) Vol 7 issue 1 May 2016
3. Bhuvaneshwari, Hiroshan, Jay :Crop Residue Burning in India: Policy Challenges and Potential Solutions ,International Journal of Environental Research and Public Health 2019, 16, 832; doi:10.3390
4. Ankit ,Sanjay ,Jayeshkumar :A Study on Utilization of Agro-Wastes as an Innovative Material in Indian Context, International Journal of Scientific Research,Volume : 2 , Issue : 2 ,Feb 2013, Pp 119-124
5. Pragyan , Dharma Raj , Keshab :Straw Bale in construction of building and its future in India ,International Journal of Modern Engineering Research ,Vol.2, Issue.2, Mar-Apr 2012 pp-422-426
6. Nathaniel :Building a Straw Bale House: The Red Feather Construction Handbook,Princeton Architectural Press, 2005.
7. Paul and Michel :Serious Straw Bale: A Home Construction Guide for All Climates, Green Publishing Company, 2000
8. Maria ,STRAWBALE CONSTRUTION :Assessing and minimizing embodied energy ,Canada (January 2010)
9. David ,Straw Bale Construction and the Building Codes, 1995.
10. Comparative Study between RCC Structures and Prefabricated Structures SiddhantSinghal, Bilal Siddiqui (IRJET) Volume: 06 Issue: 04 | Apr 2019 www.irjet.net
11. Ministry of Housing and Urban Affairs (MOHUA), GoI, Compendium of Emerging Technologies for Mass Housing, Retrieved on 29-07-2019
12. M. S. Gupta,U. K. Roy,M.RoyExpediting faster housing supply in India using straw bale as prefab building material, Elsevier