

## Research on the Application of Straw in Rural Buildings

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**Abstract.** This paper concludes on the application of straw in rural buildings and analyses problems existed in the application. Based on this, some new ways for straw application in rural buildings are explored in order to decrease the pollution from directly burning of straw in countryside and increase the reuse of straw.

### Introduction

Straw is a general name for stalks and leaves of ripe crops (Fig.1), for instance, the rest part of harvested wheat, rice, corn, potatoes, oil plants, cotton, sugarcane and so on<sup>[1]</sup>. China is a great agricultural country. According to 'Chinese Statistical Yearbook' published in 2012, China produced the most straw in the world—about 900 million tons<sup>[2]</sup>. Furthermore, with the improvement of agricultural production capacity, the production of straw is still increasing. As a result, how to take advantage of a huge amount of straw is becoming the challenging project for government and agriculture-related organizations. In recent few years, the improving of production machine and life quality in rural areas decreased the need for straw as burning fuel. Therefore, every year, a substantial number of straws are left without any uses. People in rural area always burn all left straws, which wastes natural resources, triggers air pollution and threatens human health. Especially, during burning, the dark smoke (Fig.2) is likely to bring negative influence on transportation since the dense and dark smoke decrease visibility for drivers and even threaten their lives. Nowadays, Chinese government attaches importance on the usage rate of straws critically. National Development and Reform Commission publishes '125 Straw Usages Implementation Plan'. This implementation plan declares that in 2013, the usage rate of straws would reach to 75%, and in 2015, the target is 80%. Currently, a large percentage of recycle straws are used on cultivation and papermaking<sup>[3]</sup>. Moreover, by the spreading viewpoint of green power on construction industry, an increasing number of construction companies demand more new environmental-friendly raw materials. Straw—a renewable and natural green material, is qualified to be the environmental-friendly construction material. If people are able to take advantage of this natural and green material on modern village construction, the usage rate of straw will increase and the 'Green Construction' idea will be deeply implemented in village construction



Fig. 1 Rice straw



Fig.2 Straw burning

## The application situation of straw in rural buildings

**Thatched cottages.** Thatched cottages are the most significant form of natural buildings made by straw in agrarian age (Fig.3)<sup>[4]</sup>. The ancients dig a quadrate or rounded hole down from the earth's surface, which is surrounded by baled straw or branches. And then, they paint mud on the wall to fill up interspace of the wall. Finally, the cottage is covered by baled grass and tree branches in original method, so that people can prevent damage from rains, winds and animals, etc. Thatched cottages have advantages of low costs, easy material availability, convenient construction, and hence are treated as a precious shelter by the poor. However, because of the limit of materials property and construction technique, the integrity of cottages is so poor that the performance of resisting natural disaster is also insufficient. The poet Du Fu in Tang Dynasty once wrote in 'Hut for autumn song': In the eighth moon the autumn gales furiously howl; they roll up three layers of straw from my thatched bower, which proves that thatched cottages are destroyed by wind load. It also shows the shortcoming of integrity in resisting external load. Therefore, considering to the security of structure, thatched cottages appear few in rural buildings. Recently, it makes them new life that natural characteristic combines with modern architectural technology. People mainly treat them as entertaining buildings which return to customers' original nature (Fig.4).



Fig.3 The humble thatched cottage



Fig.4 The modern thatched cottage

**The adobe house.** The adobe house is one of the typical constructions in the villages and towns by the mixing use of straw and other materials (Fig.5). Its wall is made of adobe and grass-mud clay. By adding straw into adobe or grass-mud clay, the tensile property of brickwork is enhanced. At the same time, due to the hollow property of the straw, the water in the clay wall can be easily released so that the wall has excellent thermal insulation performance. Besides, the construction of the adobe house is convenient and it's good to be applied in the villages and towns. One of the normal construction processes is:

- (1) Get the yellow-clay in high quality and smash it.
- (2) Make the rice straw into pieces with the length of 3-5 centimeters for each piece.
- (3) Mix the straw and smashed clay uniformly.
- (4) Add the rice-water or water into the mixture and stir it equally until the mixture is well mixed and become sticky. The tread with feet can be allowed if necessary.
- (5) Put the well-mixed yellow-clay into the model, press it tightly and shape it in the form of brick.
- (6) The brick can be used to build the house after the brick is well air-dried. With the mixed use of straw and other materials in the adobe house construction, the advantages of materials can be better presented which improves property of the house.

However, after the research on earthquake damage of the adobe house in big earthquakes in recent years, it is found that due to the lack of the strength in the component, the weakness in the connection and the instability in its structure system etc., the structure of the adobe house is easy to be damaged during the earthquake (Fig.6). Therefore, some specialists propose a new structure system of column and beam-adobe composite wall. In this practicable way, the anti-seismic property of the adobe house can be enhanced with no or a little increase on cost for the construction.



Fig.5 The simple adobe



Fig.6 A collapsed adobe in earthquake

**Straw bale building.** Thatched cottages and adobe houses were applied vastly in agrarian age, because of easy-building by hand. With the coming of industrial age, especially the birth of bundle press machine, straw bale (Fig.7) came out, which makes straw bale building come true. The earliest straw bale building dated from 1890s in the middle sand-mountain area of Nebraska, people replaced wood with baled straw to build houses. Therefore, it was called ‘Nebraska method’<sup>[4]</sup>, which means it’s a way that the wall made by baled straw was used to bear load (Fig.8). In China, the north area became to implement ‘The demonstration project and construction ability of building energy-saving houses with straw bale’ from 1999s. A few years later, there were hundred of ecological houses and three schools built, besides, Harbin got the reward of 2005 World Habitat Award<sup>[4]</sup> as a demonstration. The practice shows that straw bale building has excellent thermal insulation property, thus reduce energy consumption effectively. And it also has advantages of easy material availability, low costs, renewable materials, light weight, etc. However, it can’t resist strong fire and has a high demand on fireproof, anti- corrosion, anti-moth, etc. Moreover, it has an influence on inner space that the wall is too thick. Actually, the research of straw bale building is still on primary stage in China, and it has been limited by lacking referring standards in some degree.



Fig.7 Straw bale

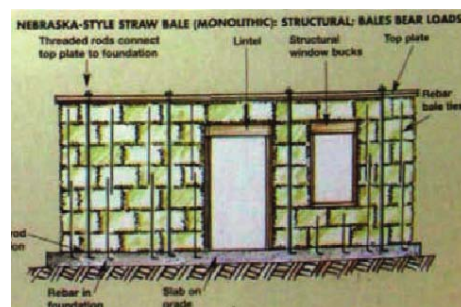


Fig.8 The load-bearing straw bale wall



## The application prospect of straw in rural buildings

The application of straw experiences the stage of thatched cottages, the adobe house, straw bale building, etc. On the one hand, straw presents adaptation on the application in rural buildings; on the other hand, there exist some problems in the early period, especially on the anti-seismic property, fireproof, anti-corrosion, anti-moth, etc. Therefore, how to further improve anti-seismic performance of straw bale building so as to satisfy recent Chinese anti-seismic standards, and also take measures to deal with fireproof, anti-corrosion, anti-moth, are very important under the new situation. After the previous research, the paper introduces that it's a good way to combine straw with reinforced concrete as a composite structure form in rural buildings, which behaves both good. There are several forms as follows.

**Straw wire aircraft sandwich panels.** Straw wire aircraft sandwich panel is a new-type composite energy-saving plates made by magnesium oxychloride cement and straw. Magnesium oxychloride cement is used as cementing material, and straw fills up both sides of the reinforced concrete layer. They are fixed by diagonal rebar (Fig.9). It not only has these advantages of enough raw materials, low costs, safe using, low density, high intensity, low thermal conductivity, but benefits for improving usage rate of straw so as to improve the environment. There is also a great prospect<sup>[1]</sup> to promote sustainable development. Recently, it's just beginning and exist lots of problems unsolved about application research on straw wire aircraft sandwich panels. For example, the control of costs; whether rural construction technology can fit the construction standards; lack of the strength in the component and the weakness in the connection. Therefore, in order to further generalize the application of straw wire aircraft sandwich panels, government could conditionally remould rural village and build temporary houses, so that earn some practical experience to get further research.

**Straw concrete block.** Straw concrete block is a block made by straw, water, cement, dinas, admixture, etc, according to certain proportion and condition (Fig.10), aimed at serving as wall of buildings. Due to the hollow in the straw, it has a significant effect on reducing quality of straw concrete. At the same time, the great performance of intensity, fireproof, anti-corrosion of concrete also promotes the property of straw. Actually, the new straw concrete block is becoming increasingly cheap and easy-getting because of enough output and low cost of straw. At present, it's still in research period to put it into use. With the implementation of new environmental law and strong control of burning straw, it would propel the application research of straw concrete block further more in villages and towns.



Fig.9 Straw wire aircraft sandwich panels



Fig.10 Straw concrete block

**Other applications.** Straw can also apply to the building decoration, besides directly use in structure during construction. For example, straw can be made into board as floors, stairs, doors and windows which are nonstructural components. Only by all-round development and full use of environmental protection, renewability, adaptability, low costs etc. can rural buildings obtain strong

vitality.

## Conclusion

- 1) From thatched cottages, adobe houses to straw bale building, straw shows sustainability, adaptability and building potential.
- 2) In early application of rural buildings, the problem of straw is mainly surrounded by lack of anti-seismic property, fireproof, anti-corrosion, etc. How to improve anti-seismic property of straw bale building, meanwhile take measures to deal with fireproof, anti-corrosion, anti-moth etc. are an important problem in straw application.
- 3) On the base of summarizing existing problems of straw application, this paper discusses the straw application in new ways in modern rural buildings. For example, it can be made into bar-mat straw sandwich board and straw concrete block etc. by combining straw with concrete. Not only can effectively improve anti-seismic property of straw bale buildings, but also perform well in fireproof, anti-corrosion, anti-moth and so on.
- 4) Straw cannot be confined to serve as structure components such as wall, but also be made into building decoration such as floor, door, window etc. In this way it makes full use of environmental protection, renewability, adaptability, low cost, so that can get strong vitality.
- 5) In order to promote the application of straw in rural buildings, it should set an example in conditionally transforming new villages and building temporary houses.

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