STRAW BONDED SOLID PANELS AS A WALLING MATERIAL – A TWO STOREY HOUSE WITH "DURA"

S. Jayakody[1], M. Kondadeniya[2], M. T. R Jayasinghe[3]

[1]Deputy Geneal Manager, International Construction Consortium, Kalubowila, Sri Lanka.
[1]E-mail: samitha@icc-construct.com
[1]Telephone: +94-11-4768600 (Ext: 8647); Fax: + 94-11-4768666

[2]Sales Manager, International Construction Consortium, Kalubowila, Sri Lanka.
[2]E-mail: madavi@icc-construct.com
[2]Telephone: +94-11-4768600 (Ext: 8647); Fax: + 94-11-4768666

[3]Professor, Department of Civil Engineering, University of Moratuwa, Moratuwa, Sri Lanka.
[3]E-mail: thishan@civil.mrt.ac.lk ; mtrjayasinghe@yahoo.com
[3]Telephone: +94-11-2650567-8 (Ext.2006 - 2001) ; Fax: + 94-11-2651216

Abstract: From the point of greater degree of sustainability, the use of renewable materials for at least part of a built environment can be appreciated. In this context, the straw bonded solid panels manufactured as boards with a thickness of 58 mm can offer an ideal solution to be used as loadbearing walls and floor slabs panel. This paper describes the uses of "Dura", a straw bonded solid panel and the various strategies that can be employed to ensure strength, durabilityand safety.

1. Introduction

The use of rapidly renewable building materials has been identified as an important concept that can reduce the depletion of finite raw materials and long-cycle renewable materials. In projects recognized by LEED, the use of rapidly renewable building materials and products is promoted for 2.5% of the total value of all building materials and products used in the project based on the cost [1]. The examples can be drawn from the use of agricultural fiber such as wheat in composite panels as a substitute for wood products. In Sri Lanka, straw obtained from paddy cultivation can be a good candidate for manufacturing of straw bonded solid panels. According to data available, a land extent of more than one million hectares would be cultivated each year leading to a significant quantity of straw as a by-product [2].

Figure 1: A building constructed with "Dura" panels and steel channels to be used as a site office

Straw bonded solid panels are manufactured by Dura building systems, a subsidiary of the International Construction Consortium, is known as “Dura” panels. They are manufactured to a width of 1.2 m. The length can be 2.4 m, 2.7 m, 3.0 m or 3.3 m. The thickness of the panel is 58 mm. The general applications have been internal partitions and semi – permanent detachable buildings such as site offices, store rooms, etc. Due to densely packed straw, the fire resistance of Dura is high [3]. Figure 1 shows a building where “Dura” panels have been used with a steel channel system to create a site office for the consultant team at a hotel project.

Figure 2 shows the roof arrangement used with Dura as the insulation material and while providing structural support to the roof cladding. Steel members have been used as the truss system. One of the main drawbacks of this truss system was the high cost involved in the steel components used with the panels to produce sufficient rigidity. The advantages have been the use of light weight panels promoting modular construction that can considerably reduce the construction duration. One of the key issues of this system of single storey buildings was the durability of the panels since they could be susceptible to water absorbed especially at plinth level. For this, many precautions have to be taken during the construction of the building shown in Figure 1.

Figure 2: Arrangement of the roof used with Dura as the insulation material and steel members as the truss system.

Tropical climatic conditions that prevail in countries located close to equator have few main features. One is high intensity of solar radiation in days without rainfall. During monsoon times, there could be very high rainfall. Thus, roof is one of the key elements that allow a significant heat gain during the daytime in days with clear sky. Roof will also need considerable strength and preferably weight to ensure cyclone resistance. A key advantage of Dura in tropical climates is the ability of Dura to fulfill structural requirement of the roof while providing adequate resistive insulation for thermal gains through roof. This can be considered as a major advantage since the structural rigidity of “Dura” would be able to provide a robust, cyclone resistant roof structural system with minimum amount of additional structural members. With the vast experiences gained by constructing these semi – permanent detachable buildings, an attempt was made to extend the applications of “Dura” to two storey houses where the straw panels are expected to act as one of the main structural system consisting of loadbearing walls, floor slabs and roof structure.

2. Objective

The main objective of this research was to develop a structurally stable, durable and cost effective two storey houses with straw boarded solid panels.

3. Methodology

The following methodology was adopted:

1. The research on load bearing characteristics of "Dura" panel obtained as part of product development was used to predict the structural adequacy when used as a structural material.
2. The structural requirements were identified with a number of typical two storey houses.
3. The structural solutions have been developed with several cycles of optimization.
4. A model house was constructed that can be used for long term research and development while paying sufficient attention for durability.

4. The loadbearing characteristics of Dura

Dura panels are manufactured with a thickness of 58 mm. The length of a panel can vary from 2.4 m to 3.3 m. The width of a panel is 1.2 m. Dura panels have been found to be a good material for partition walls. It has also been successfully used as a floor board when supported at 1.2 m intervals. However, its application as loadbearing walls in a two storey house needed special attention.
There were two key issues to be resolved. One is the tendency for buckling when carrying significant loads. The other is any local failures that could occur due to bearing failures under the timber joists used to support the floor boards. Both these issues have been successfully addressed by using a full scale model that was load tested to obtain a clear understanding on the behavior of Dura panels. Figure 3 shows the loading arrangement of the model with loads and the floor joists used for supporting the floor boards. The loads applied were well in excess of the maximum load of 2.0 kN/m^2 that can be expected in a two storey house [4].

Figure 3: The load testing carried out for Dura panels with full scale model
With this load testing, it was found that Dura panels could be successfully used for three applications:

a. The loadbearing and partition walls
b. The floor boards
c. *To create part of the structural system of the roof*

a. The load bearing and partition walls

The load bearing walls can be either external or internal. External walls would have sufficient number of openings for windows and doors. Since the thickness of the panel is only 58 mm, it has a tendency to buckle when subjected to heavy loads. Since, the failure by buckling of the panel is not a desirable mode to failure, this had to be avoided. The strategy adopted was the use of staggered panels side by side that completely eliminated the weakness that could occur at joints between panels while ensuring a wall of 58 mm x 2 = 116 mm thickness. Previous experience has indicated that there would be a tendency to form a crack on the finished surface when Dura panels are combined to form

walls. Figure 4 indicates the installation of Dura panels to form an external wall. In the initial phases, an insitu-cast *wet joint* has been used to connect the panels. In order to ensure adequate rigidity while minimizing the tendency for shrinkage, a polymer modified cement grout has been used to form this *wet joint*. However, this *wet joint* was found to be labour intensive in the actual construction of the two storey house. Hence, for the upper floor, this *wet joint* was eliminated with mechanical joints effected using screws.

Figure 4: "Dura" Panel wall used for load bearing external walls along with anchors used to connect to the foundation

b. The floor system

One of the main advantages of straw based solid panels is its ability to be used as floor boards supported on a suitable structural system. Generally, it is sufficient to use Figure 5 indicates the ability of "Dura" to carry structural loads, even when they are of concentrated nature. For two storey houses, a floor structure consisting of timber beams that will act in composite with Dura panels could be used as shown in Figure 6. If a greater degree of rigidity is required for the floor, it is possible to use short intermediate beams between the timber beams that would enhance the ability of floor boards to withstand point loads behaving as a two way slab system thus effectively eliminating any localized deformations. Such localized deformations could give some kind of softness under the foot of the users. Hence, its elimination could be important.

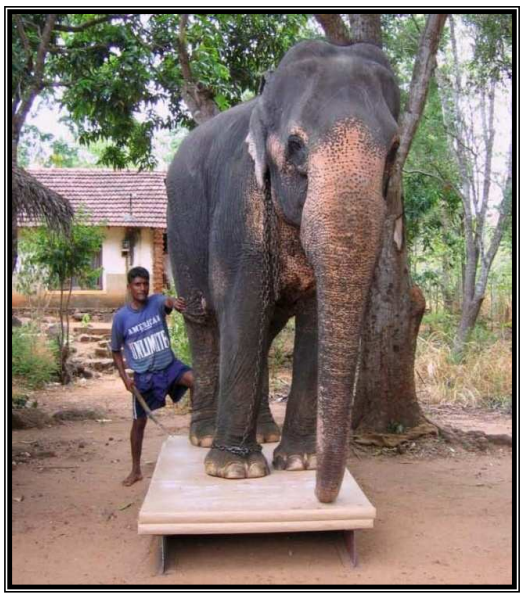

Figure 5: Dura panels were tested for larger concentrated loads

Figure 6 also indicates the additional timber framework that has been used to ensure proper connectivity of the timber floor beams to the Dura panels used for the upper floor. Such connectivity is important with respect to cyclone resistance. Since the two storey house is of light weight construction, it has to derive the cyclone resistance by mobilizing the rigidity provided by the panels locally coupled with the weight of the completed structure for overall stability. This two storey house has been checked as for BS 6399: Part 1: 1997 [5].

Figure 6: The beam arrangement for supporting floor slabs made by Dura panels

c. The roof system

One of the key uses of straw based panels for the roof is enhancing the cyclone resistance. A robust structural system consisting of timber beam and straw panel acting as a composite could be designed to withstand wind forces induced due to heavy wind loads generated by 33 ms^{-1} or 42 ms^{-1} basic wind speeds. With few additional precautions, even the wind loads due to 47 ms^{-1} could also be resisted. The roof covering material will be Zinc – Alum sheets.

5. The two storey house

A view of the completed two storey house is shown in Figure 7. The internal dimensions have been carefully selected to ensure functionality while enabling modular form of construction. The durability issues were handled in the following manner:

1. The house is located at an elevation with no possibility for flooding as shown in Figure 7.
2. The straw boards are started on a foundation with a plinth beam that would hinder the upward moisture movements while ensuring robustness required with respect to earthquake resistance.
3. The roof is provided with adequate eaves as shown in Figure 8 coupled with provision for the installation of a well detailed gutter system.
4. The balconies are tiled to ensure water tightness. The tiles have been laid on a Ferro-cement based system as shown in Figure 8 to ensure proper adherence of the tiles and effective water proofing.
5. Bathrooms have been tiled as shown in Figure 9. These tiles could also be combined with a thin layer of Ferro – Cement based structural system to further enhance the robustness and water – tightness.
6. The roof is provided with properly fixed fasteners connected to Dura panels to ensure a leak free roof that has sufficient cyclone resistance. An additional layer of polythene was also located as an additional protection underneath the roofing sheets as shown in Figure 10.
7. Whenever, additional water proofing is needed, it is possible to laminate the Dura panels with a fiber based boards of 3 mm thickness as shown in Figure 11.

Figure 7: The two storey house that has been constructed with Dura panels being used for ground and upper floor walls, floor slabs and the insulation in roof

Figure 8: The two storey house under construction

Figure 9: Bathrooms provided with a tiles to ensure proper water proofing

Figure 10: Roof with Dura boards supported on timber joists and also provided with a polythene sheet

Figure 11: Additional water-proofing provided with fiber cement boards

6. The cost aspects

The solid straw panels are manufactured with straw as the main ingredient. Therefore, the cost of panels could be contained at about Rs 500/= per square meter. For the two storey house shown in Figure 7, the cost of Dura panels could be maintained at about Rs 10,000/= per square meter of floor area. With the experience gained with this house, many new innovations have been introduced to reduce the cost of construction in future. One of the key improvements was the elimination of the polymer based wet joint shown in Figure 4. The strategy used was the adoption of a mechanical connection with staggered panels. With many such innovations, straw bonded solid panels could offer a product that can be effectively used as walls, floors and roofs of two storey detached houses.

7. Conclusion

The extensive use of natural resources as building materials has caused many environmental issues. Therefore, the development of alternative materials that can provide adequate strength and durability

could be a significant step in improving the sustainability of built environment. In this context, innovative approach and extensive use of structural concepts have been successfully utilized to explore effective usage of straw bonded solid panels for two storey houses. This new application can have many benefits with respect to cost and sustainability related issues.

Acknowledgement
The authors are grateful to Dura Building Systems for providing financial assistance and "Dura" panels needed for this research.

References

1. LEED Reference Guide for "Green Building Design and Construction", US Green Building Council, 2009 Edition.
2. Annual Report 2009, Central Bank of Sri Lanka.
3. Technical report by ITI, "Fire rating of Dura Panels", ITI, Sri Lanka.
4. BS 6399: Part 1: 1984, Code of practice for dead and imposed loads, BSI, London.
5. BS 6399: Part 2: 1997, Code of practice for wind loads, BSI, London.