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Model SB-1.1 is a one-storey building which accommodates 3-6 people. It consists of two rooms with dimensions of 4420 X 3530 rooms, a kitchen 2030 X 2300, an optional room 2030 X 2300, and a veranda 4670 X 2500. The building is constructed with a stone masonry foundation with mesh-reinforced cement plaster, stacked straw bales (compressed straw blocks) stiffened with bamboo and covered with mesh-reinforced clay or lime plaster, a wood roof structure, and CGI roofing.

The design uses locally available materials of stone, bamboo, straw (paral), wood, sand and clay-soil. The straw bale walls are highly insulating, and together with straw-clay ceiling insulation keep the interior warm in winter and cool in summer. Social and cultural aspects have also been factored into the design of the house. The design concept and the objective is to contribute towards sustainable, durable, resilient housing models in Nepal that are safe in future earthquakes.

The earthquake-resistant design is consistent with the 2015 International Residential Code, Appendix S – Strawbale Construction, and is based on a house design and construction method used by Pakistan Straw Bale and Appropriate Building (PAKSBAB) since 2007 which was seismically tested at the University of Nevada, USA in 2009. Adjustments have been made for the context of Nepal. Earthquake-resistant measures include shock-absorbing straw bale walls with through-tied bamboo stiffeners and mesh-reinforced plaster, a CGI roof diaphragm, and well-connected components from roof to foundation.

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CONSTRUCTION MATERIAL AND MANPOWER

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MAN POWER</th>
<th>MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skilled</td>
<td>Unskilled</td>
</tr>
<tr>
<td></td>
<td>Md</td>
<td>Md</td>
</tr>
<tr>
<td>Up to Plinth Level</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Ground floor</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Roofing work</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>130</td>
<td>130</td>
</tr>
</tbody>
</table>

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TOTAL AREA: 65.5 sqm (54 sqm enclosed + 11.5 sqm Veranda)
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Technology for Earthquake Resistant Straw Bale Construction

Construction Sequence 1
Excavation, Foundation

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Technology for Earthquake Resistant Straw Bale Construction

Construction Sequence 2
Straw Bales, Bamboo, Top Plate
Technology for Earthquake Resistant Straw Bale Construction

Construction Sequence 3
Roof Trusses, Wall Mesh

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Technology for Earthquake Resistant Straw Bale Construction

CGI Roofing and Roof Diaphragm

Exterior Plaster
1st Coat: Clay
2nd Coat: Clay-Lime
Finish Coat: Lime

NOTE: All Plaster Mixed with Sand

Interior Plaster
2 Coats Clay Plaster w/ Lime Wash Finish

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Construction Sequence 4
CGI Roofing, Plaster

NOTE:  ALL PLASTERS MIXED WITH SAND

2 Dec 2015
Straw, Straw Bales and Straw Bale Construction in Nepal

Straw is produced annually in Nepal as an agricultural by-product of rice, wheat and barley cultivation at elevations up to 3000 meters. It is normally used as a low-grade animal feed, and sometimes for roof thatch. There is great potential for using straw in Nepal to make compressed straw blocks to construct buildings with a technique known as straw bale construction.

Straw bale construction is a wall system using stacked bales of straw that are covered with plaster or other finish. It originated in Nebraska, USA in the late 1800s, and buildings from that first era over 100 years old are still in service. Straw bale construction was rediscovered in the 1980s in the American southwest and further developed, including considerable testing and research regarding structural performance (under vertical and lateral loads), moisture, fire resistance, and thermal properties.

Since the 1980s the use of straw bale construction has steadily increased, and there are now straw bale buildings in all 50 U.S. states and more than 50 countries throughout the world. These buildings are durable, safe, energy and resource efficient, and have proven affordable compared with predominant building systems in developing countries. When detailed properly they are highly resistant to earthquakes.

In Nepal straw is stacked or bundled, but not made into bales. Straw bales for building can be made with a compression mould and farm jack. This potentially creates a new industry. Two persons can produce 30 1'x1'x2' bales per day. The SB1.1 design requires 390 bales. A compression mould design is shown on this page. The following page illustrates the bale making procedure.

The straw bales must be kept dry, from the time they are made until plastered in the wall. Light, surface wetting is acceptable, but deeply wet bales or straw or bales that show signs of mold (by vision or smell) should be discarded.

Compression Mould for Making Straw Bales

A steel compression mould can be fabricated in Nepal for approx. 12,000 Rs. A farm jack can be imported from China or US. Approx cost 6000 Rs.

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STRAW BALE CONSTRUCTION

Bale Making Procedure

A locally fabricated compression mould (see page 5) and manually operated farm jack are used on site or nearby to manufacture 12" x 12" x 24" straw bales. The straw used for making bales should be long, dry and free of mold or discoloration.

1) Prepare two 8’ long strands of twine with loop at one end.

2) Place loops over hooks at top rear of mould, run twine down the inside of the rear panel, and run excess straight out front under the door. (Fig. 1)

3) Place straw bundles in bottom of mould to hold twine in place (Fig. 1). Close door.

4) Fill mould with straw bundles to top of door. With another person holding the mould steady from the rear, climb onto top of mould from the front and tamp the straw down with feet (Fig. 2). Repeat. Top off with straw bundles to top of door.

5) Position steel plate over the straw, place the jack foot on the plate, and the jack lift under the steel cross-beam. Compress straw with the jack. (Fig. 3)

6) Open door and pull bottom end of twine until tight. Tie bale tightly. (Fig. 4)

7) Release jack and remove bale.

See Figure 5 for finished straw bale.

Ideal bale is 22” to 24” long in the mould (depending on elasticity of twine). Final size is 24” long and weighs 14 to 16 lb (6.5 to 7.5 kg).

All bales should be fabricated before construction and kept dry. See page 13 or 19 for discussion.

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For one-storey buildings (in all soil types) (max. total design load on foundation is 30 KN/m2)
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Roof Framing and Roofing

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