"Transitional Relief Housing for Tsunami Victims of Tamil Nadu, India"

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Abstract

In the wake of the recent tsunami that swept across Asia, there is a dire need to salvage and rebuild the lives and livelihoods that were swept away. The aim of this thesis project is to design and model a transitional shelter for the Indian region of Tamil Nadu. Tamil Nadu is located on the southern coast of India, and was the region most affected by the recent tsunami. The transitional shelter should be a shelter that serves as an infrastructure that can be absorbed into a more permanent structure with the flexibility to promote future expansion. The design of the structure takes into consideration climactic concerns such as ventilation or seismic issues, and tries to suggest cultural continuity between the new architecture and previous architectures.

Thesis Supervisor: Harry Asada
Title: Professor of Mechanical Engineering

Introduction:

Transitional relief housing is needed for victims of natural disasters everywhere. Hurricanes, earthquakes, and floods can upturn the lives of families leaving them with little to no possessions and no place to stay. Even with the help of governments and relief agencies, the problem is often too widespread to provide comprehensive and immediate relief to all families. This issue is especially relevant when placed in the context of current events. In the wake of the tsunami in Asia, the need for immediate shelter solutions is great.

The aim of this thesis project is to design, and develop a transitional shelter for tsunami victims in the coastal region of India, Tamil Nadu (Figure 1). Tamil Nadu is located at the southern point of India, and is the region in India most affected by the recent tsunami. In Tamil Nadu alone, the tsunami left more than 8,000 people dead and more than 100,000 affected. The tsunami damaged or destroyed more than 118,000 huts and houses. Poor rural communities were affected the most, pushing poor people even deeper into poverty (Tiding over Tsunami 2005).

The definition of a transitional shelter is a shelter that is neither a permanent shelter nor a temporary shelter. Temporary shelters are meant to be used as emergency housing for a brief period of time before more suitable housing becomes available. Unlike temporary shelters such as tents or lean-tos, transitional shelters serve as the bridge between impermanence and permanence. The structure of a temporary shelter serves as the infrastructure and fundamental building block from which later expansion and permanence can be built. Furthermore, the transitional shelter should provide a safer foundation more resistant to future tsunamis and other regional climactic concerns.

Finally, the architecture of the transitional shelter should reference and address previous building types of the region in order to ensure cultural continuity and decrease the psychological trauma involved in coping with life after the tsunami. An emphasis on using recycled and ecologically friendly materials will also be placed on material selection. Other constraints will be determined by careful evaluation of geographical, climatic, and cultural factors.

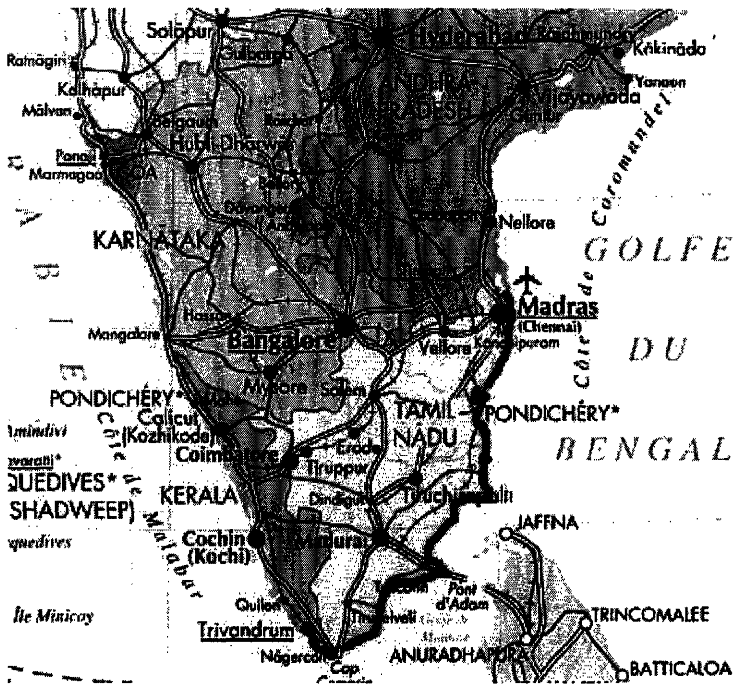

Figure 1 Map of Tamil Nadu and Tsunami Affected Region

Background:

Currently, there are many organizations and foundations involved in the rebuilding process of the tsunami ravaged regions of Asia. The rebuilding efforts range from providing refugees with ready made temporary shelters to the rebuilding of entire villages. The temporary shelters provide quick solutions to housing with the most basic amenities while the more long term permanent housing projects are completed. Among these projects, several are concerned with the issue of transitional shelters. The need for transitional housing is thus one of creating a structure that is quickly erectable in the wake of a disaster, whose structure can be "filled-in" as the rehabilitation process continues. Thus, disaster refugees can live in and build upon the structure until the transitional shelter is absorbed into the fabric of the permanent house.

The Isha Foundation has developed a semi-cylindrical concrete shell housing unit that can be quickly fabricated as a transitional shelter that can later expand into a house. The house is hemispherical to allow the passage of wind across the shell with least resistance, and the concrete material allows the building to be fire-proof. In a similar vein, the Tsunami Safe(r) house, developed by Harvard GSD students, proposes a new safer infrastructure for coastal Sri Lankan villages. In the Tsunami Safe(r) House, modular concrete units are used to create flexible floor plans. The concrete units are arranged to provide the least amount of resistance to oncoming water, so that in the case of a tsunami, the water flows through the house without damaging the structure. The rectangular plan and modularity of the pieces, allow for the house to be easily expandable.

Like architecture everywhere, the form and individuality of the traditional rural architecture of Tamil Nadu is based largely on the demands of the climate, and availability natural resources. Located in the highly vulnerable part of the Peninsular India, the Bay of Bengal is on average subjected to one serve cyclone in the pre-monsoon period and two in the post-monsoon season. The coastal districts from Chennai to Ramanathapuram are at highest risk in the face of these yearly storms (Guidelines for

Reconstruction). The heavy yearly rainfall demands steeply pitched roofs with extended eaves to protect the house from penetration by the elements. Similarly, the materials that make up the roof house must be resistant or adaptable to the moisture; often paddy thatch, coconut thatch, or tile is often used for the roof. The heat of the region makes natural ventilation necessary through large high roof spaces, though the strong winds that accompany the cyclonic weather demand the houses to be lower and squatter. Because Tamil Nadu is situated in a region with a continuing cycle of cyclone and disaster, the houses on the flood plains are usually built with cheap, light materials for easy repair and rebuilding.

Though Tamil Nadu is safer from earthquakes than parts of western and northern India, small to moderate earthquakes that are mid-plate in nature have occurred. The frequency of earthquakes is low, and most of the state is categorized into low to moderate risk. The current seismic response is to build buildings with integrated tensile timber elements. Wood and bamboo give the house tensile strength in response to wind and moving people, while heavy walls hold the heavy roofs above the heads of inhabitants. The predominant house form is the rectangular form with walls of woven coconut thatch or grass thatch and mud with bamboo roof frames. Each house also has a small shaded verandah or sheltered porch (Traditional Buildings of India, pp 137-143)

Design Parameters:

The climate of Tamil Nadu is tropical; the temperature ranging from 20°C in the winter to 40°C in the summer with little variation in summer and winter temperatures. From April through June the hottest period of the summer, ventilation and solar heat gain issues must be considered. However, the temperature never decreases enough so that heating becomes an issue. The average annual rainfalls in Tamil Nadu range between 25 and 75 inches a year.

In the recent tsunami, most of the victims died of drowning, the wave height ranging from three to ten feet high (Tiding Over Tsunami 2005). Thus, the shelter should either be built on raised land, or be raised by a platform. According to the guidelines set by the government of Tamil Nadu for the reconstruction of houses affected by tsunami, site selection for houses should be at least five meters above sea level. Throughout the year, Tamil Nadu is subjected to high wind speeds that can cause damages to buildings. In consideration of the frequent cyclonic winds, in the design of the structure, walls that are too long or too high should be avoided. Furthermore, the walls should have enough support from buttresses or supporting walls. Interconnecting walls are preferable to freestanding walls, and small building enclosure is also desirable.

Tamil Nadu is located in a region of low to moderate seismic activity. Thus, the design of the transitional shelter should include some provisions for dealing with seismic activity. In the event of an earthquake, the highest incidences of death are caused by heavy walls and roofs caving in; some consideration should be taken into designing bearing walls that will not collapse on the inhabitants during an earthquake. Heavy masonry walls are dangerous without proper support. Similar precautions should be made for potential seismic damage as for potential cyclone and wind damage. Again, long unsupported walls should be avoided, as well as walls that are too high.

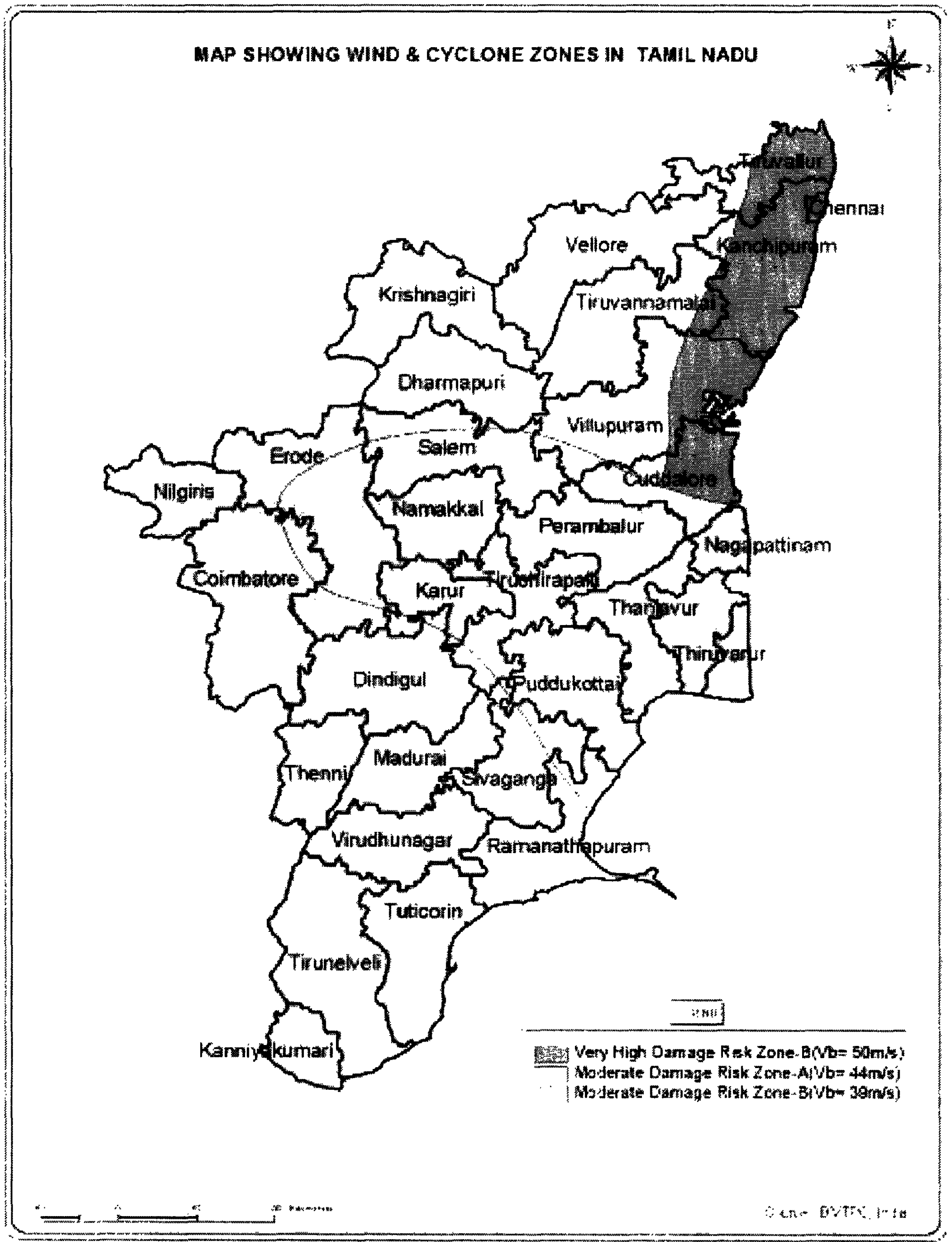

Figure 2: Cyclone Zones in Tamil Nadu

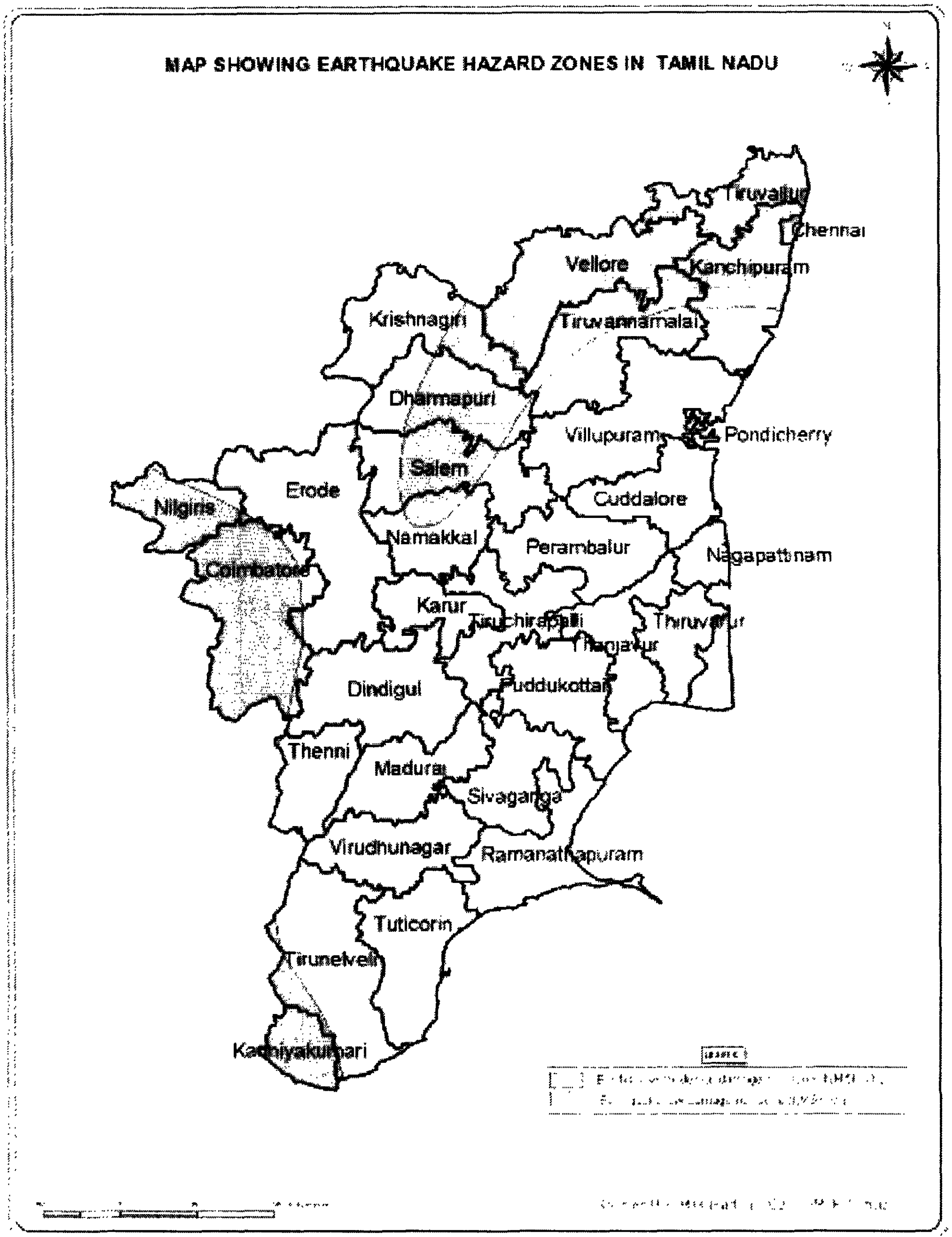

Figure 3: Earthquake Zones in Tamil Nadu

Design:

The shelter is designed to accommodate a family of five people, the average family size according to census reports. According to the 2001 Census, the average number of rooms in a typical rural household for the region of Tamil Nadu was one (Table 2). The total square footage of the shelter was determined through researching the current living standards for Tamil Nadu, and through research of other organizations involved with the rebuilding process. The interior size of the shelter was determined to be from 250 to 300 square feet with flexibility for a larger floor plan depending on the needs of the family, and an outdoor verandah. A rectangular floor plan was chosen in order to maximize the functional efficiency of the space, furthermore, a symmetrical building is more stable than a zigzag plan or a plan with empty pockets. Plans with empty pockets are more susceptible to damage in high winds.

The whole structure is elevated seven feet off the ground, to preclude shorter waves from entering the house during cyclone and hurricane season, and allow the inhabitants to keep their heads above water level in case of larger waves. The modular concept of rooms is based off of the Tsunami Design Initiative project. The load bearing parts of the house are oriented parallel to the path of cyclone winds, the short walls providing less resistance in the case of tsunami, allowing water to flow through the house instead of sweeping it away (Figure 4). The walls protect the inhabitants while providing the least resistance to the oncoming water.

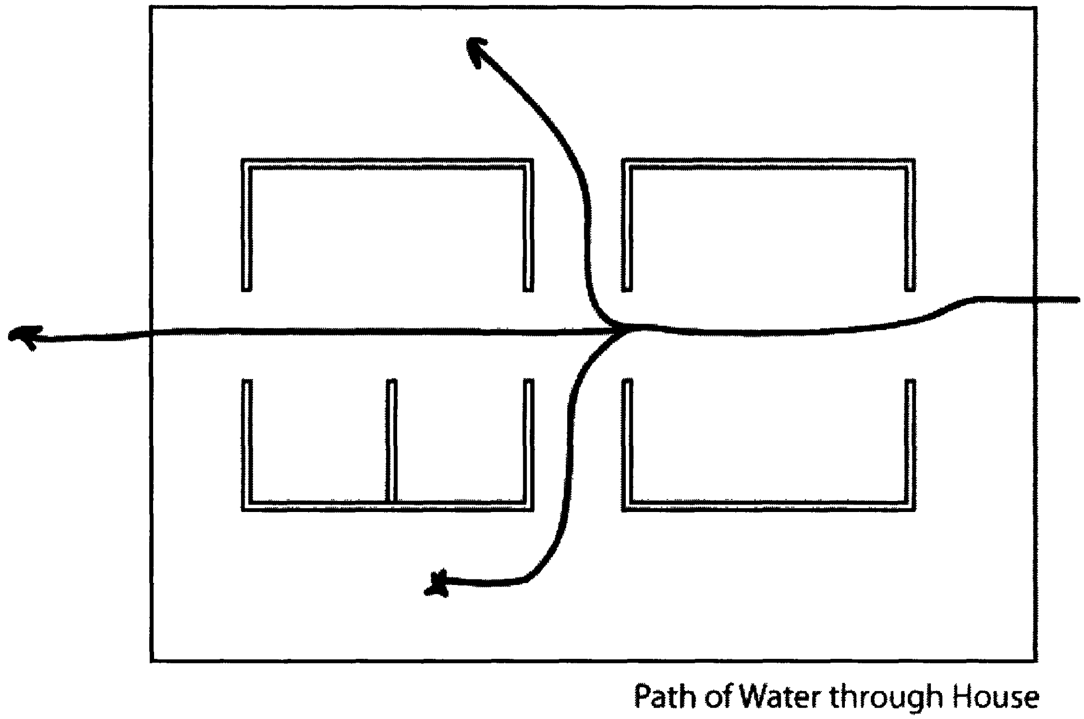

Figure 4: Tsunami Safe Design

The four modules that make up the living units needed for a family will be fabricated out of plastic instead of reinforced concrete, and the modular wall units can be arranged to create a variety of floor plans (Figure 5). The design of the shelter tries to aim for flexibility and versatility. The load bearing walls are designed to be made out of sandwiched plastic parts that would be prefabricated in larger industrial areas and then distributed in the case of an emergency. The plastic load bearing walls are made of two types of plastic; two sheets of 1½ inch thick structural polymethylmethacrylate that sandwich a 2 inch layer of recycled, weather resistant plastic (Figure 6). The walls are fit together through joints that can be fixed together for structural support. In the sandwiched plastic windows can be created or cut where desired. Because the load bearing walls of the shelter are made of plastic, in the event of an earthquake, the walls will not crush the inhabitants of the house. Instead, because of the natural flexibility of the material, the shelter will be more earthquake resistant than current designs. Furthermore, the plastic material is ideal for the climate of Tamil Nadu. The plastic walls will withstand the moist and humid weather without rotting or parasitic infestation.

The foundation of the shelter will be made from cellular lightweight concrete made from waste fly ash, and can be filled in after the shelter has been built. The cellular lightweight concrete is preferable to standard concrete because it minimizes use of cement, is more environmentally friendly, and much cheaper than normal denser concrete. After the plastic structure has been erected, the ground around the structure can be excavated and poured around the plastic. The basis of filling in the foundation after the building is built, is so that the shelter can be quickly constructed for immediate use. The roof structure and porch structure are made of composite recycled plastic and lumber.

Like the Tsunami Safe(r) house, the shelter concept for Tamil Nadu also uses the idea of infill. Ecologically sound and local materials can be filled in with time according to the preferences of the inhabitants. The side paneling of the house can be later filled in with materials of the resident's choice or suggested bamboo or panels made from agricultural waste. Rooms can be created or left open depending on the needs of the inhabitants. The floor tiles of the house ideally can be constructed from recycled plastic waste or tiles constructed from Red Mud Jute Fibre Polymer Composite (RFPC). Similarly, the recycled plastic sandwiched between the structural plastic can be replaced with local material with time if desired.

Initially, the roofing material will be made of plastic sheeting that serves as a temporary barrier from the elements. As the reconstruction process continues however, the plastic sheeting will be replaced with bamboo mat corrugated sheets (BMCS) or another material of the family's choice. The bamboo mat corrugated sheets are light and strong and are resistant to water, fire, decay, and parasites (Table 3 and Table 4). Furthermore, bamboo is a very ecologically renewable and the production of BMCS sheets is a process that supports micro industries in India. The floor tiles will also be made of tiles of prefabricated recycled plastic that can eventually be replaced with other materials if desired (i.e. bamboo, wood, ceramic tile, etc).

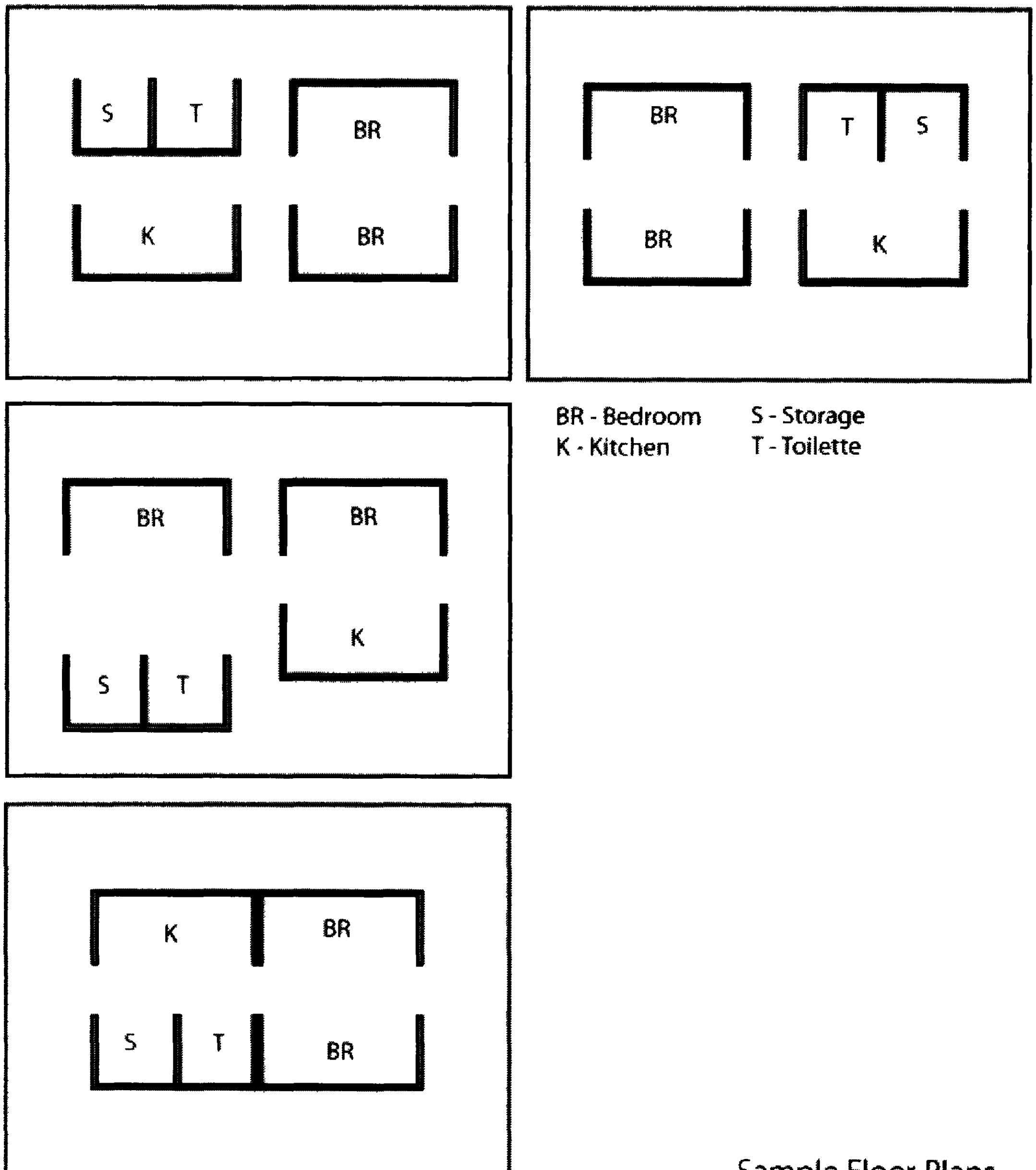

Figure 5: Example floor plan arrangements

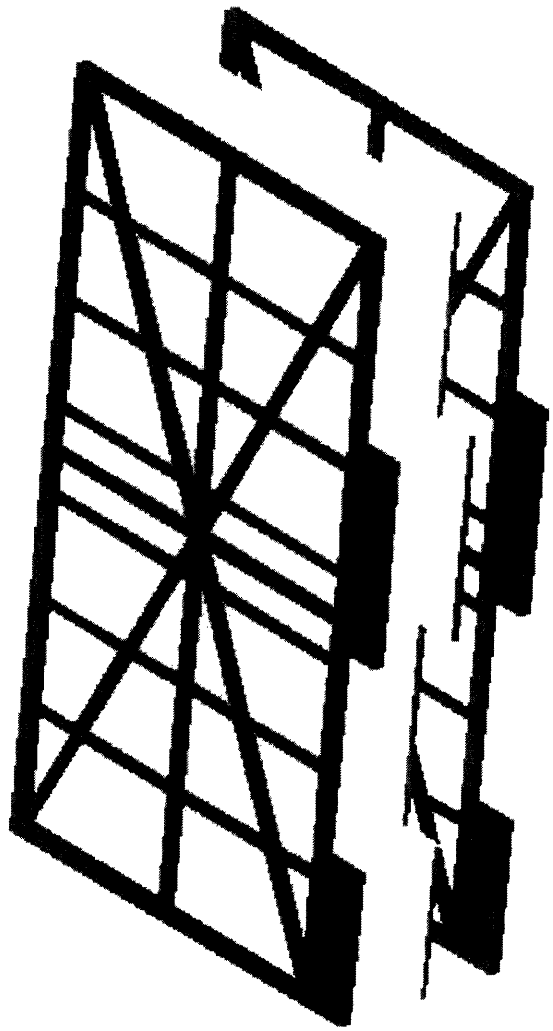

Figure 6 Bearing Wall Detail

The plastic bearing walls, composite plastic-wood roof beams, concrete foundation blocks, plastic sheet roof, and floor tiles will be mass produced, and in the event of disaster, distributed to disaster victims. The shelter is designed to be quick to setup, the livable part taking one to two days to erect. The foundation and party walls are filled in after the structure is built. Party walls and partitions along with the final roofing material will be filled in with time, giving the occupants flexibility in material choice. The partitions can be filled in with a variety of materials from bamboo, to thatch, to organic fiberboard, or other local materials. Similarly, the final roof material is also flexible. During the rebuilding process, the prefabricated parts of the house will slowly be absorbed into the filled in house. The variety of local materials that can be used to fill in the partitions lends cultural and local relevance to the structure, while the plastic and concrete building blocks provide a strong infrastructure from which growth and safety can be achieved.

The rectangular form and modular units allow the building to be easily expandable with time. The steeply pitched roof and the gap between the modular units allow for cross ventilation and allows the sea breeze to enter the house during hot summer days. The roof overhangs above the verandah so that the outdoor space is useable year round. The roofing over the verandah can be further expanded to cover more outside territory with time or eventually screened in. From the given infrastructure, it is up to the inhabitants to decide the final design and layout of the building.

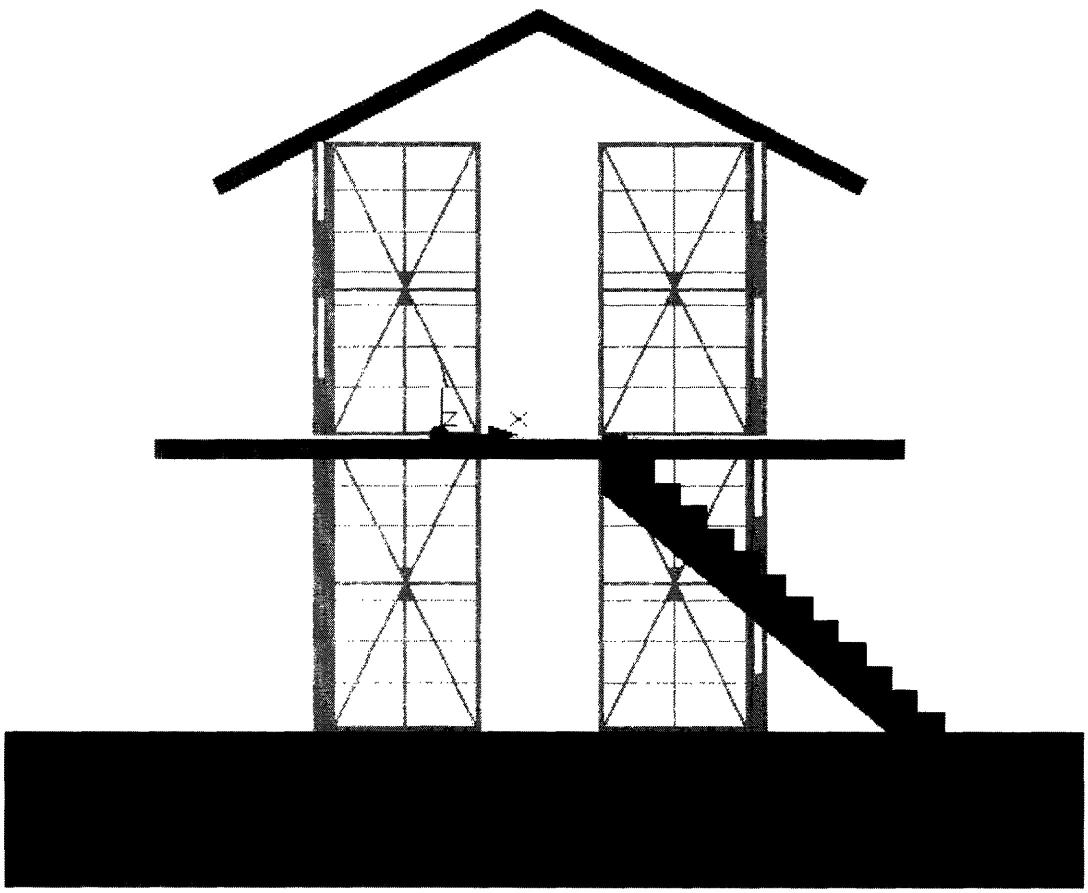

Figure 7: Section View

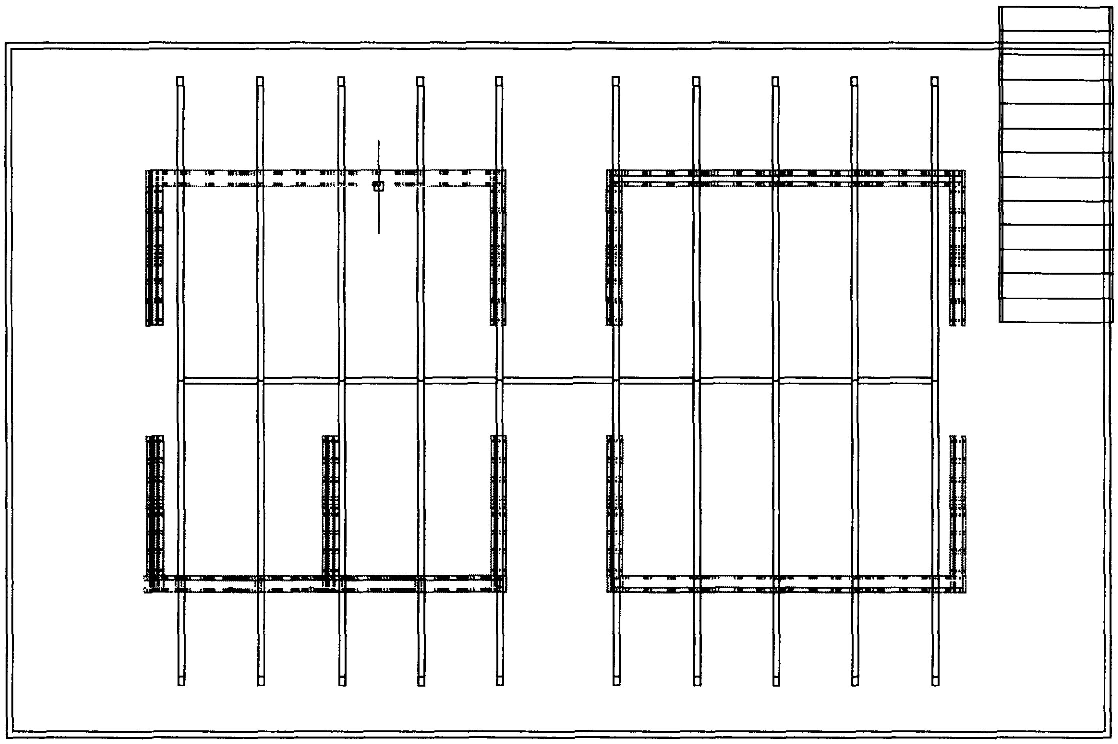

Figure 8 - Plan View

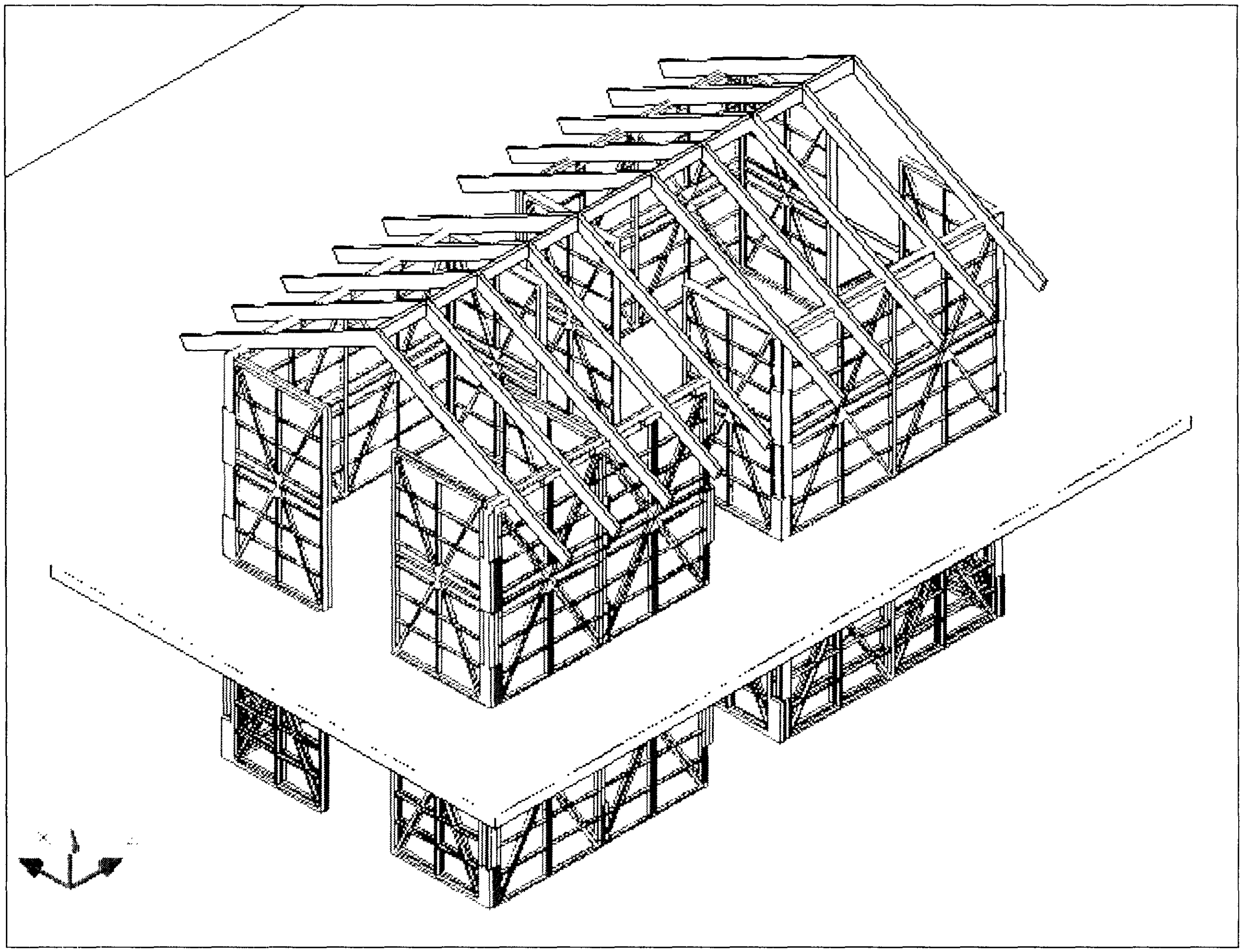

Figure 9 - Isometric View

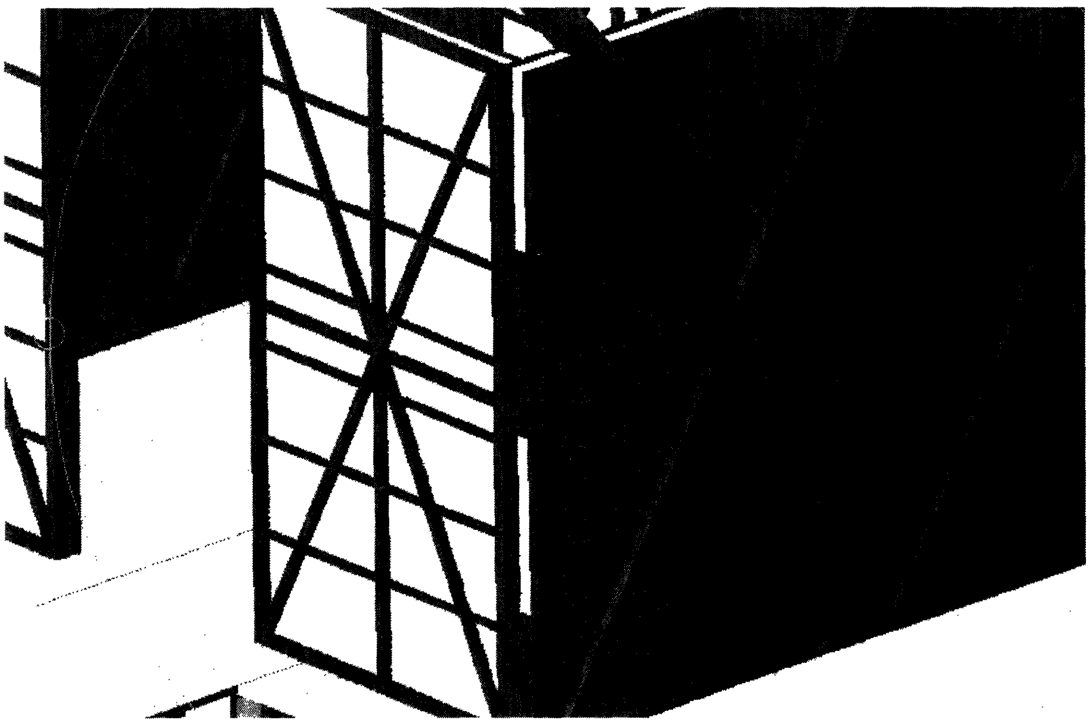

Figure 10: Detail – Joining Methods

Conclusions:

The design of the transitional shelter is aimed at achieving several goals: capacity for quick setup and inhabitability, a flexible floor plan that accommodates the varying needs of varying families, the concept of filling in and replacing the prefabricated pieces with time, replacing the traditional huts with tsunami and seismically safer infrastructure, and achieve cultural and local relevance through material selection.

In the event of catastrophe, the prefabricated pieces of the shelter can be quickly distributed and erected. Thus, the structure can serve as a temporary shelter that segues into a permanent shelter as the slow rebuilding process starts after the disaster. The foundation, partition walls, and roof can be slowly filled in while the shelter is lived in. Prefabricated pieces of the shelter can be replaced if desired with time, with the eventual absorption of the structure into the emerging house. The use of prefabricated materials with an infill of local or environmentally sound materials give the shelter individuality and local relevance. The rectangular and modular form promotes future expansion if desired. Furthermore, the new structure provides a safer infrastructure for future growth. The height of the building off the ground prevents the smaller waves from reaching the height of the house, while the modular design of the bearing walls will allow for the free flow of water through the structure in the event of high waves. The plastic structure ensures that in the even of an earthquake, there will be no threat of heavy walls collapsing, causing the death of the inhabitants inside the shelter.

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Appendix:

Table 1: Tamil Nadu - Lives Lost and Impaired

LIVES LOST AND IMPAIRED

S.No	District	No. of villages affected	No of kuppams affected	Population of the district as per 2001 census	Population affected by tsunami	Population Evacuated	Human lives Lost	Persons injured	Orphaned children	Women widowed
1	Chennai	4	25	4343645	73000	30000	206	9	-	35
2	Cuddalore	8	43	2285395	99704	61054	610	259	12	78
3	Kancheepuram	30	44	2877458	100000	60000	130	24	9	17
4	Kanniyakumari	16	33	1676034	187650	46280	799	754	3	106
5	Nagapattinam	38	73	1488839	196184	196184	6065	2375	179	294
6	Pudukottai	25	29	1459601	66350	4867	15	-	-	-
7	Ramanathapuram	40	114	1187604	84000	8315	20	2	-	4
8	Thanjavur	22	-	2216138	29278	4600	37	482	2	-
9	Tiruvallur	6	38	2754756	15600	-	29	-	-	6
10	Tiruvarur	-	-	-	-	-	29	3	3	14
11	Tirunelveli	10	-	2723988	27948	11170	4	6	1	1
12	Thoothukudi	23	-	1572273	110610	11625	3	-	-	1
13	Villupuram	8	19	2960373	78240	37500	48	46	-	5
	Total	230	418	28715578	1068564	471585	7995	3960	197	561

Table 2 Distribution of Households in Rural Tamil Nadu

Distribution of Households by Size and Number of Dwelling Rooms in Rural Communities of Tamil Nadu, India

(2001 Census)

House-hold Size	Total Number House Holds	Households having Number of Dwelling Rooms							Median Number of Rooms
		No Exclusive Room	One Room	Two Rooms	Three Rooms	Four Rooms	Five Rooms	Six Rooms and above	
#	8274790	1219903	3795106	2069274	730908	265365	82867	111367	1
1	474176	93529	275403	74927	19305	5533	1566	3913	1
2	1025678	162744	549218	221903	59112	17603	5148	9950	1
3	1291858	189653	631340	315462	100766	31470	9271	13896	1
4	2057314	288903	940961	534443	183249	64937	19202	25619	1
5	1669329	244827	727151	438939	160497	57268	18548	22099	1
8-Jun	1514603	212355	597043	417385	170331	69021	21973	26495	1
9+	241832	27892	73990	66215	37648	19533	7159	9395	2

Table 3

Material Properties Sheet for Bamboo Mat Corrugated Sheets

MOR (Modulus of Rupture)	40-45 N/mm^2
Internal bond strength(dry/wet*)	1.3 - 1.4 N/mm^2 (* sample subjected to 3hrs boiling is dried to 12% moisture content and tested)
Load bearing capacity	4.8 N/mm of width (span length - 1000mm) (Graph showing comparative performance of BMCS and Asbestos Cement Corrugated Sheet (ACCS) is enclosed).
Water resistance test	Withstands 72 hours of boiling test prescribed for BWP grade Plywood in IS:808
Permeability	No percolation of water observed after storing water for over 24 hours. However, considering the biological nature of the material, a protective water-proof / UV coating is recommended on the side exposed to sun/rain.
Fire resistance	Conforms to flammability test as per IS:5509 Indian Standard Specification for Fire Retardant plywood.
Thermal conductivity	BMCS has low thermal conductivity compared to other roofing materials. Tests are in progress.
Application	Roofing, walling, structural

Table 4

COMPARISON OF LOAD BEARING STRENGTH OF BMCS & OTHER SHEETS

TYPE	THICKNESS mm	WIDTH mm	MAX. LOAD N	LOAD BEARING CAPACITY N/mm	WEIGHT OF SHEET (1.05 M x 1.8 m) Kgs.
Bamboo Mat Corrugated Sheet (4-Layers)	3.7	400	1907	4.77	7.2
G.I. Sheet	0.6	400	1937	4.84	7.7
Aluminium Sheet	0.6	405	669	1.67	2.9
ACCS	6	330	1800	5.45	15.85