DAMAGE DUE TO TSUNAMI AND DISASTER RESILIENT HOUSE CONSTRUCTION ACTIVITIES IN SRI LANKA

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Abstract

The tsunami erupted by the underwater earthquake in Sumatra on the 26th December 2004 caused a huge damage in seashore areas of Sri Lanka. It destroyed the lives of many people and brought hardship to the survivors too. The social impacts include more than 31,000 deaths and 15,000 injuries, nearly 150,000 houses destroyed or damaged, representing about 13% of the housing stock in the affected areas and 450,000 people displaced. The damage estimation indicated housing damage loss of US$ million 344 and total need assessment is US$ million 487. Fourteen districts of the coastal belt were severely affected by this tsunami. Total number of fishing houses affected by tsunami is 69,320 and that is 55% of the total fishing houses. Out of total 131,000 fishing households 72,372 (55%) affected by tsunami. Within 100m limits from sea coast 20,604 houses damaged, between 100- 300m range 19,226 houses and over 300m limit 29,490 houses damaged due to tsunami. Since the family is the basic social unit and the house is the basic special unit where the act of dwelling takes place, permanent house construction started with several designs. A holistic approach to house design should essentially be people centered and custom-made and the architect has to work within these two considerations in designing house. Low cost house construction technology is used in these districts based on those considerations. Also this technology is more environmental friendly and the dwellers comfort because it used less timber, cement quantity. In this technology house wall preparation was done as *Rat trap* bond. Hence it has more tolerance for seismic vibrations as well as due to air column in wall reduced heat conductivity. The low cost concrete roof prevent from cyclones. More than 700 houses were constructed using the above technology in tsunami-affected areas of Sri Lanka. This housing technology is considered as a critical measure disaster reduction and more environmental friendly. This paper analyses this housing construction system in detail.

Introduction

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Sri Lanka a tropical country, lies between 60 and 100 N latitude and between 800 and 820 E longitude has an area extent of about 65,610 square kilometers. On 26th December 2004 an undersea earthquake registering 9.0 on the Richter scale, later upgraded to 9.3, struck in the Indian Ocean off the western coast of Sumatra, Indonesia at 6.59 am Sri Lanka time (National Disaster Management Center 2004). This tsunami tidal wave of up to 15m in height traveling a speed of more than 500 km/hour caused devastation along the coastline of Sri Lanka was affected after about two hours (Central Bank of Sri Lanka 2005). Not even 1 per cent of coconut trees were affected (Gunaratne 2005).

Total coastal line is about 1585 km in length and affected nearly 1200km in southwestern, southern, southeastern, eastern and northeastern cost of Sri Lanka (Fig 1). This tidal wave destroyed not only human lives but also houses and our economy. The houses were severely affected by the tsunamis.

The total damage is estimated is estimated to be around US dollars 1 billion (4.9 per cent of the GDP) and the reconstruction, is estimated to cost around US dollars 1.8 billion (Central Bank of Sri Lanka 2005). Economic growth in 2005 has been revised downward by about 0.5 – 1.0 per cent from the original estimated value mainly due to disruption to the fisheries sector.

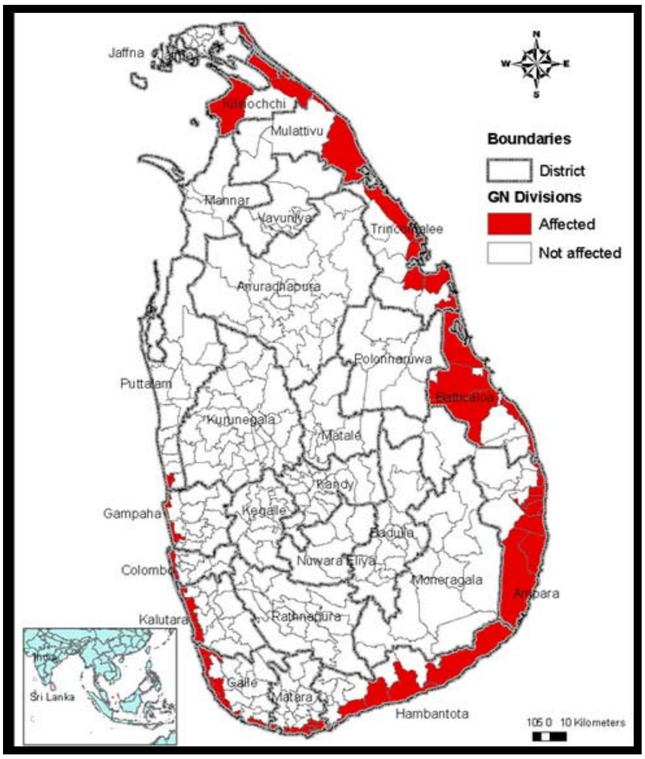


Fig 1: Tsunami affected areas in Sri Lanka

Shanmugarathnam (2005) stated “A fundamental concern shared by all the displaced groups I interacted with was that relocation could not be seen in isolation from livelihood security, which implied people’s ability to achieve decent states of being. Housing is an integral part of a household’s livelihood system”. This shows the essential requirement of house construction for tsunami-affected areas.

While emphasizing the need for decentralization and local participation it is also important to recognize some of the immediate action priorities at al locations (Philips 2005). These priorities are identified as follows:

- Temporary housing and facilities
- Clearing and disposing of tsunami debris
- Clean-up of wells and agricultural lands
- Coastal land use planning through community participation and strategic environmental assessment
- Resettlement planning through community participation

The housing facilities became the priority area.

According to Department of Censes and Statistics (2001) Sri Lanka had 5.4 million housing units and required more than 500,000 houses due to civil war in the north east and other houseless families. Low cost housing technology was introduced by Intermediate Technology Development Group (ITDG- now Practical Action) to Kenya, Peru and India.

As a national level research and training institute HK. Agrarian Research and Training Institute conducted 52 training programmes for village leaders on Disaster Management and Low Cost House Construction Technology with financial assistance from ITDG-Practical Action. Those programmes conducted from Trincomalee, Ampara, Hambantota, Matara, Galle, Kalutara, Colombo, Gampaha, Nigambo and Puttlam where tsunami affected areas except Northern Province. The author was resource person in this training programmes and got understanding and experience on house construction. Based on the experience this paper developed.

Permanent resettlement of the victims followed tsunami disaster, hundreds of thousands of permanent houses may have to build and the process kook time more than fourteen months. In between the stage of immediate helter and permanent shelter, there comes the stage of temporary shelter, which stretches for more than one year until the completion of the construction of permanent houses.

<u>Semi –permanent house for temporary shelter</u>

The basic concept of this housing is the use of cement fiber sheets for the external walls, internal partitions, roof doors and windows. The idea of that once the permanent house is built to the level of the roof structure, the temporary house can be dismantled and the cement fiber sheets can be used for roof of permanent house. Four people can erect this temporary house, in fact semi-permanent, house in one day (Jayawardana 2005). Once all the sheets are connected in monolithic fashion, the wind resistance can be enhanced burying the sheets by about 150 mm with a soil fill. This soil fill can be compacted and rendered so that even in a rainy day this house gives a dry space for the occupants. This will also enhance the cyclone resistance of this house. After seeing this house completion in one day at the University of Moratuwa premises, Prof MTR Jayasinghe of the Department of Civil Engineering has suggested that this model can assist the post disaster reconstruction in any situation, not only tsunami reconstruction.

This semi-permanent house out of cement fiber sheets comprises four spaces; Living room, kitchen and two bedrooms. Its doors and windows are also from cement fiber sheets (Jayawardana2005). They should be constructed separately.

For the construction of this house, the following materials are required

- 25 Nos 8 –feet cement fibers
- Nos 10 –feet cement fibers
- 20 Nos angle iron connection measuring 25x25x3 mm

The following precaution should be taken when fixing the sheets as well of the semi-permanent houses. The cement fiber sheet has two sides. The side is recommended to face the sky when used in roof, should be arranged facing indoors when fixed as well of the semi permanent houses. Those are on semi-permanent house constructions used in Sri Lanka this paper emphasizing the permanent house construction.

Abayakoon (1996, 1998) initiated the seismic risk analysis in Sri Lanka and demonstrated that Colombo is more vulnerable to seismic events than any other part of country. Dissanayake and Mohadevan (2005) stated an earthquake make ground motion in all directions, shake buildings and lead to collapse or cause components to fall, either of which can be life threatening. This shows the risk of seismic events and Sri Lanka should improve housing technology to tolerate seismic events.

Methodology

This paper is to study the impact and nature of damage to houses especially in the fisheries sector. The basic data collected based on secondary data of houses and damages to houses of fishermen. This paper analyses this housing construction systems in detail.

The secondary data used in this study were from the Department of Census and Statistics, and other papers. Based on the secondary data house damaged due to tsunami at each district are analyzed. Also the percentages of house damage based on distance from sea cost are analyzed. Also temporary house and permanent house construction methods indicated.

Compared house construction traditional technology with ITDG –Practical Action technology based on construction cost, disaster tolerance and environment friendly characteristics. Main emphasis was given to new house construction method suitable for fisheries families. Because fishers are prefer to live close to seacoast. Those areas are under high wind prevailing and houses should strong enough to tolerate them. Also tsunami and earthquake may be affecting them more than inland people.

Island wide house damage

The social impacts include more than 31,000 deaths and 15,000 injuries, nearly 150,000 houses destroyed or damaged, representing about 13% of the housing stock in the affected areas and 450,000 people displaced. The damage estimation indicated housing damage loss of US$ million 344 and total need assessment is US$ million 487 (Philips 2005). Nationally, there are an estimated 4.6 million dwelling units, 29% of which are considered temporary (built with non-durable materials). It is reasonable to estimate that Sri Lanka requires over 200,000 new housing units. Total number of fishing houses affected by tsunami is 69,320 and that is 55% of the total fishing houses. Out of total 131,000 fishing households 72,372 (55%) affected by tsunami. These figures show the important of new low cost housing technology.

Temporary housing with amenities therefore became a priority at initial stage but now permanent hosing is important. The planning and development of permanent settlements to proceed in orderly, consultative and participatory manner is important.

Results

District level fishery house damage

The highest number of completely damaged houses in Batticaloa (3,705), Jaffna (2,227), Trincomalee (2,156), and Ampara (2,148) districts. The highest number of partially damaged houses in Batticaloa (2,830), Jaffna (1,242), Trincomalee (1,751), and Ampara (1,378) districts.

Island wide fishery house damage based on distance from sea coast

Within 100m limits from seacoast 20,604 houses damaged, between 100- 300m range 19,226 houses and over 300m limit 29,490 houses damaged due to tsunami. This distances as well as elevation should consider on damage cause factor.

District level fishery house damage based on distance from seacoast

Within 100m limit the highest number of fisher house damaged in Trincomalee District (3,586) the second and third highest number of fisher house damaged districts is Jaffna District (2,381) and Matara District (2,292) respectively. The least number of fisher house damaged districts are in Batticaloa (802) and Hambantota (884) districts. This is special situation because those districts face tsunami directly as they are in the eastern side of the country. Mangroves and other tree cover on the sea coast and less number of houses prevailed within this limit may be the cause. The damaged of fishery houses between 100-300m horizontal distance from sea coast are indicated in Fig 3. The maximum number of houses damage within this range is in Batticaloa District (2,779). The least number of fisher house damaged districts are in Kalutara (836) and Colombo (465) districts. This may be due to high elevation of housing lands and Mangroves and other tree cover on the seacoast. But for most of the districts less number of houses damaged comparing with other two ranges.

The highest number of fishery houses damaged over 300m horizontal distance from sea coast is in Batticaloa District (6,773). This is very high number comparing with other districts. Number of houses damage in Gampaha (3,443) and Hambantota (3,400) districts are in second and third in order. Least damage took place in Colombo (128) and Kalutara (883) districts.

Percentages of destroyed houses due to tsunami indicated in the following Figure 2. It depicts that the districts on the east and southeast areas are Batticaloa, Trincomalee and Ampara.

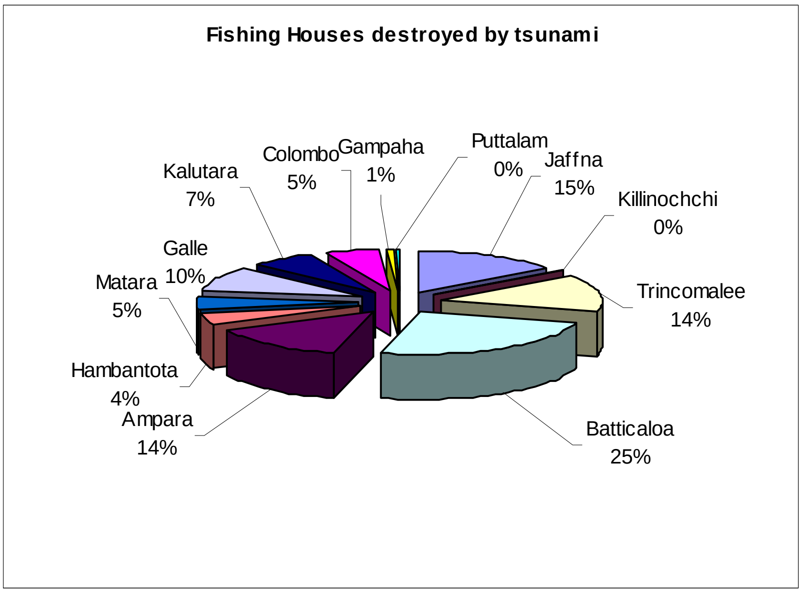


Fig 2: Percentage of destroyed fishery houses based on districts

Figure 3 depicts that the highest percentages of completely damaged houses in Jaffna, Batticaloa, Ampara and Matara districts. The lowest damaged houses in Puttalam and Gampaha districts. The highest partly damaged houses in Kalutara, Colombo and Batticaloa districts. The lowest partly damaged houses in Puttalam and Gampaha districts.

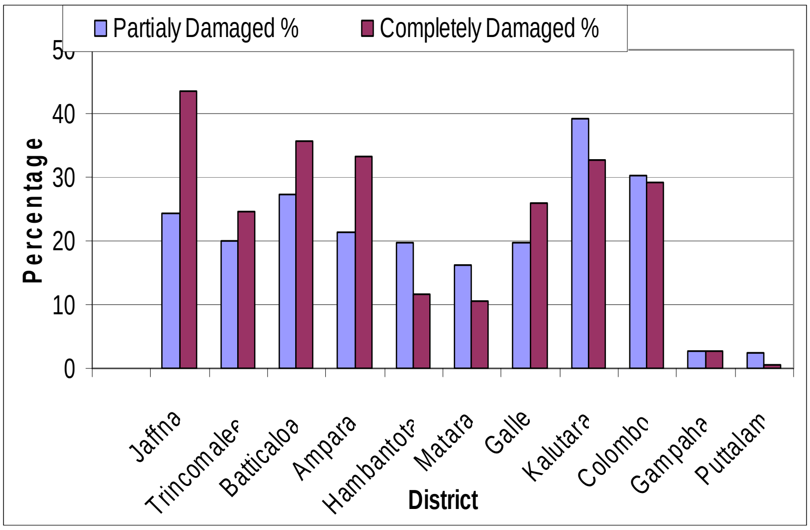


Fig 3: Percentage of partly and completely damaged fishery houses

Based on distance from seacoast percentages of damaged houses are given in the Figure 4. Within 0 -100 meter range the highest damage took place in Colombo and the lowest in Batticaloa. From 100m to 300m range the highest damage took place in Kilinochchi and the lowest in Colombo. More than 300 m from coast the highest damage took place in Batticaloa and the lowest in Colombo.

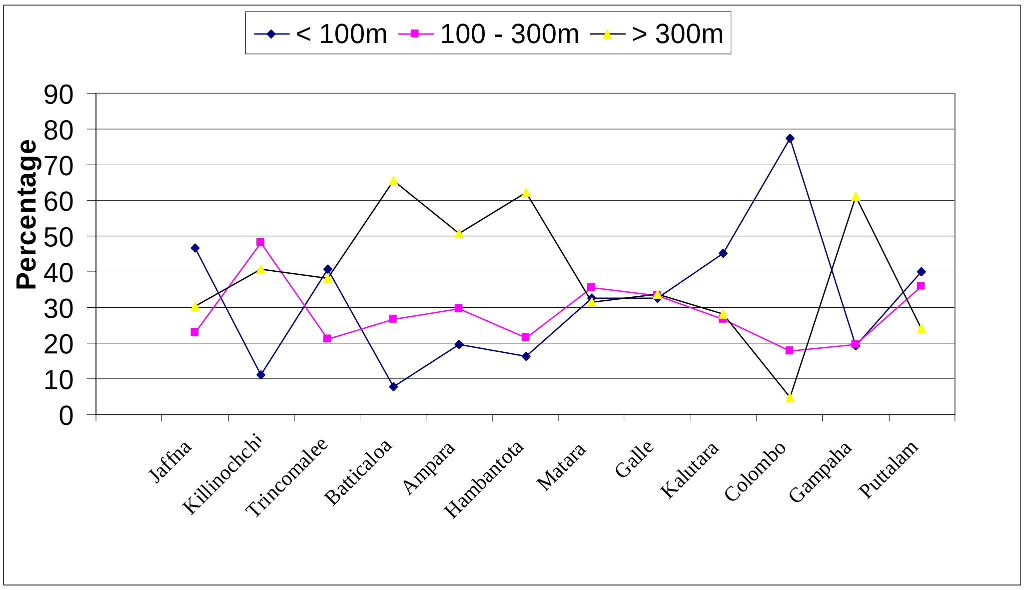


Fig 4: Percentage house damage by district based on distance from seacoast

House construction

Government policies initially prohibit new construction within 100 meters of the mean sea level (in some areas 200 meters). The re-building process has been painfully slow with almost no new homes yet constructed in the most severely affected areas. An important process of community mapping has taken place in eastern and southern coastal areas, led by NGOs, but the local authorities are reluctant to accept such bottom up initiatives.

In Sri Lanka, hundreds of thousands survivors continue to live in temporary shelters or tents some six months after the disaster (Leckie 2005). Reports indicate that the government has planned to build new housing four to five kilometers from traditional coastal villages. This may have an impact on people's livelihoods, especially fishing families dependent on the sea and immediate access to it. When one visits temporary resettlement sites in Sri Lanka, it is not difficult to get the feeling that tsunami survivors are going to waiting for many years before all of the housing that is needed is actually in place.

Throughout the tsunami-affected countries, reconstruction efforts have generally been top down initiatives, excluding many affected communities from decision making.

Harris, (2005) stated livelihood in Sri Lanka have been affected not only by initial devastation of the tsunami but also by the policies and practices of government and the humanitarian aid communities post disaster response. Initially displaced people lived in tents and then transfer to transitional shelters and finally permanent houses.

<u>Low cost house construction</u>

Low cost house construction consists with three steps at wall construction, roof preparation and concrete roof finishing.

<u>Wall construction</u>

Rat trap type wall construction using normal bricks (2, 4, 9). This method saves 20% of bricks than normal 9-inch traditional wall construction method (Fig 5). This method is control heat transfer in and surrounding environment due to air column in the wall. This will improve human comfort of the dwellers of these houses. Good finish on both side of the wall need not plaster. Hence by using this method we are able to serve expenditure for plastering.

Fig 5: Wall construction in progress

Arches are common features in house today. It is a technology, which has been in use for hundreds of years and has withstood the test of time as evidenced by the numerous arches seen in ancient buildings and old houses in Sri Lanka. Practical Action has trained masons on the technology and the practical use of several types of arches, some of which were constructed at Practical action pilot project sites. Arches can be used not only to beautify buildings but also to minimize cost by reducing the use of steel and concrete. Arches can be used to make doors and windows look attractive from the exterior. Walls are decorated by introducing arches in Fig 6. This will improve internal air circulation of the house. Also it gives attractive inside look. Top of the walls cover air cavities (rat trap) by bricks and then roof construction done (Fig 7). Construction cost of 100 sq. feet is reducing from 8759 to 6454Rs. by this method. This wall has sufficient strength to construct two stair houses without concrete piles.


Fig 6: Arch preparation


Fig 7: Completed walls

<u>Roof preparation</u>

Due to high price of planks timber roof preparation is much expensive in house construction. This technology introduce substitute for 2x 4 inch plank prepared by three 1x2 inch flanks with similar strength. This ITDG technology on one way reduces cost for planks. On the other hand if we need ceiling, these constructed flanks have allowed doing it easily without extra expenses. The distance form one plank to next should be change based on roofing material tile or asbestos sheet or aluminum sheet.


Fig 8: Completed roof

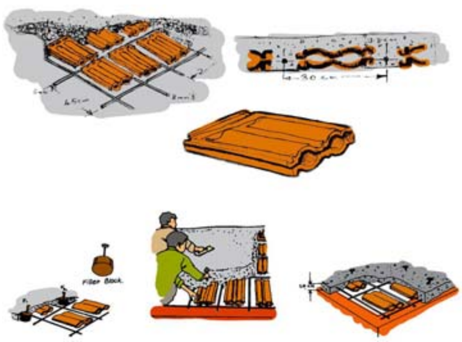


Fig 9: Concrete roof construction

<u>Concrete roof preparation</u>

Concrete roof preparation is better for high wind prevailing areas like mountain peaks. Initial steal wire bars laid 45cm x 30cm spacing. As figure indicated to reduce amount of concrete mixture, two (grade 3) roofing tiles put with design on the slant shattering. Then concrete mixture in the concrete at lower edge On the other hand these tiles control heat conductivity through concrete roof to inside.

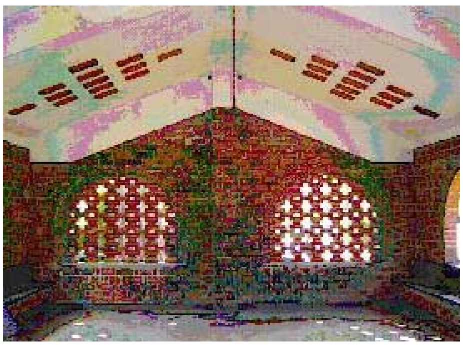


Fig 10: Completed concrete roof


Fig 11: Completed filler slab and sunshade

Filler slab and sunshade construction

The normal slab preparation high cost gone for concrete mixture. Similar to concrete roof preparation steal wire bars laid 45cm x 30cm spacing and two grade 3 roofing tiles place on the flat shattering and fill concrete (Fig.11, 12).
Sunshade can be turned out at a very low cost for covering doors and windows. They can be made very attractive and can be made by using only Ferro cement planks and bricks (Fig. 11, 13). This bricks that are used for construction should be between 2" –2.5" thick.

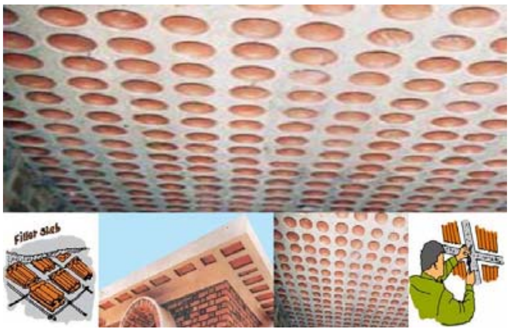
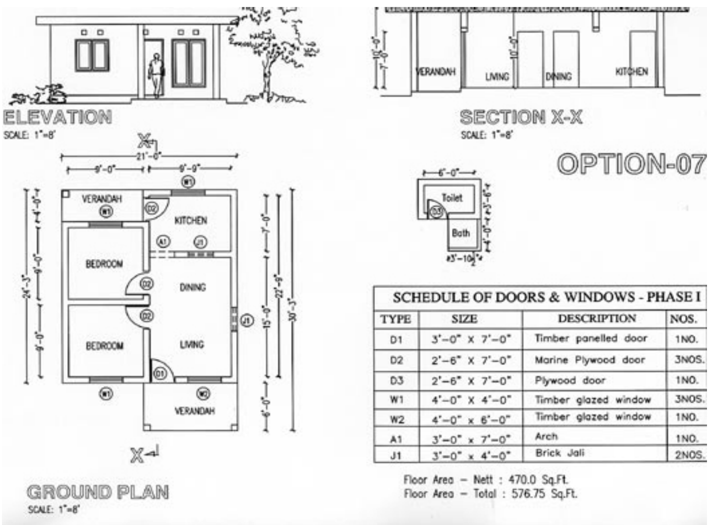


Fig 12: Concrete filler slab using empty curd pot (clay)

Fig 13: Completed flat concrete roof and sunsheds

Completed two houses based on ITDG (Practical Action) technology indicated in Figure 14.

Fig 14: Completed Houses



SCHEDULE OF DOORS & WINDOWS - PHASE I

TYPE	SIZE	DESCRIPTION	NOS.
D1	3'–0" X 7'–0"	Timber panelled door	1NO.
D2	2'–6" X 7'–0"	Marine Plywood door	3NOS.
D3	2'–6" X 7'–0"	Plywood door	1NO.
W1	4'–0" X 4'–0"	Timber glazed window	3NOS.
W2	4'–0" x 6'–0"	Timber glazed window	1NO.
A1	3'–0" x 7'–0"	Arch	1NO.
J1	3'–0" x 4'–0"	Brick Jali	2NOS.

Fig 15. Plan of 470 square feet net floor area house

Construction cost

By using this technology the construction cost per one squire foot is Rs.510 (5 US$) and for 350 sq. foot house with verandah, toilet, bedroom and kitchen Rs. 175,000 (1750 US$). Fig 15 shows a plan of 470 square feet net floor area house. This house includes two rooms, living room with dining space and two verandahs. Table 1 shows the total construction cost of proposed method reduced cost by 27%

Table 1 Estimated cost for 500sq feet house construction

Item	**Unit**	**Traditional method cost Rs**	**ITDG method cost Rs.**	**Profit %**
Foundation	Cu. Ft 325	34,125	30,875	10
Wall	Sq. ft 1200	117,600	80,400	32
Roof	Sq. ft 690	113,850	91,770	19
Beam, lintel		42,755	33,025	23
Door, Window frame	Ft. 141	23,970	10,716	55
Item	**Unit**	**Traditional method cost Rs**	**ITDG method cost Rs.**	**Profit %**
Doors	Sq. ft 56	12,320	12320	0
Windows	Sq. ft 64	25,600	25,600	0
Floor	Sq. ft 435	28,275	28,275	0
Finishing		77,250	34,000	56
Total		475,745	346,981	27%

Advantages of this technology

The advantages of this technology are utilization of available resource and based on peoples request construction plan able to change suitable way. Also based on the disaster in the area construction method can change. E.g. Cyclone prone of high wind prevailing area concrete roof house can construct with comparatively low cost. Flood prevailing areas flat concrete roof is appropriate. There are more than 700 houses were constructed using the above technology in tsunami affected areas of Sri Lanka. This is environmental friendly technology.

Conclusion

Based on this estimate the construction cost reduced by 27% and this new technology environment friendly. Hence new construction of about 200,000 houses will save high amount of money. That is highly important to developing county like Sri Lanka. Also Sri Lanka faces many disasters (floods, cyclones, and tsunami) within last few decades and damage and destroy large number of houses. The house constructed using this technology has more tolerance to seismic vibration than traditionally constructed house.

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