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**Paper Tube Application
(A Paper Tube Shelter)**

By

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Abstract

Emergency events caused by natural disasters can cause people to be homeless as their homes destroyed due to such events. Architects and structural researchers proposed several aspects (concepts) to adapt the matter case. One of such concepts is the paper tube which in the last decade considered being a new trend.

The paper discuss the application of the paper tube structure that was first been innovated by Shegaru Ban. The paper analyzes a temporary structure in a form of modular panels that was made of wooden frames filled with paper tubes. Paper tubes are to be arranged linearly taking the length of the panel (parallel to the long direction of the panel frame side).

The aim of this research is to examine a shelter that was been built as an emergency shelter with the use of paper tubes. The paper examines the shelter individual parts (wall panels, roof panels, floor panels, and foundation panels). The research begins with how the criteria being specified, and the reasons that govern the selection of such system of construction. The paper tube shelter and system due to serve in both fields of application the civilian and the militaries.

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The paper discuss the paper tube history and its characteristics whether or not is it practical, functional, durable (long lasting) and aesthetical proposal. The paper describe analytically some applications that were been used in various parts of the world.

1. Concept Criteria

In case of disasters the normal concept of construction will be inefficient for these reasons:

- The need for large period of time during both design and construction
- The enough funds to sponsor the destroyed building rebuilding process
- People need temporary place in order to be transferred to until there houses are to be rebuilt
- The main challenge is the creation of emergency (temporary) shelter.

The creation of temporary structures depends on the basis of different criteria, which determine the kind of construction system that answer most of it specifically to the local circumstances.

1-1 Constructional material availability

A structure that is to be made of construction material which is locally available hence then it is need not to be exported (If the material locally not available then we need to export such material, which mean both extra cost and extra time, due to the time lost in shipment process). Temporary structures are highly affected by the availability of the material. The structure designer should also bear in mind that the structure erection should not relay on skilled workmanship. The need for especial skilled workmanship will affect on the building overall construction cost. The demand for appropriate simple technology is essential otherwise it may take several years to rebuild the structure.

1-2 Appropriate structural and constructional systems

Appropriate constructional system from the researcher point of view is that structure in which the following characters are to be specified:

- (Appropriate) means that structure is to be planned and be built whenever intend to
- The structure should consist of individual prefabricated elements (panels or units) that are to be easily assembled at the site of construction.
- The structure should be constructed from light weight individual elements (panels and constituents) that are easy to be transported thus there should be no restrictions on the structure elements weight and size.
- The structure should consisted of individual parts that are easy to be handle (the structure should be handled by 2 to 6 persons)
- The structure assembly process and foundation technique are to be simple enough as they should not relay on or affected by the weather conditions or the quality of the subsoil.
- The structure should be re-usable when finishing the proposed usage (commission) operation the structure should be easily dismantled and either stored or reconstructed in another place.

1-3 Quickly built inexpensive shelter

In some circumstances thousands of shelters need to be quickly erected with a limited amount of available budget or need to cover an entire array of social

demands and physical needs, like water supply and sanitary. The combination of rapid construction and simplicity in the structure construction technology make the structure to be constructed in a few hours rather than months or days with a limited budget.

1-4 Healthy shelters

Temporary structures are intended to specify some conditions:

- The structure must keep the people inside in dry and warm conditions
- The dwelling should have a sanitary system that's supply the structure with water and get rid of the waste water
- The structure should protect people from severe weather conditions

The following example is an example for rapid construction shelter that consists of coherent modular system with different types of load resistant panels. The panels are sandwiched type of construction (two layers of oil treated hardboard and of a resin-impregnated paper honey comb core). The prototype unit is dependent on truncated octahedron primarily consisting of hexagon and squares. It composed of 20 panels of 5 different shapes fig. (1). People themselves may design such structures with the use of available types of panels. Thus shelters of great variety may exist with the sizes which are suitable for the community. The tent is the most famous prototype example for rapid temporary construction shelters figure (2).

The tent although light weight and easy to be constructed have some problems:

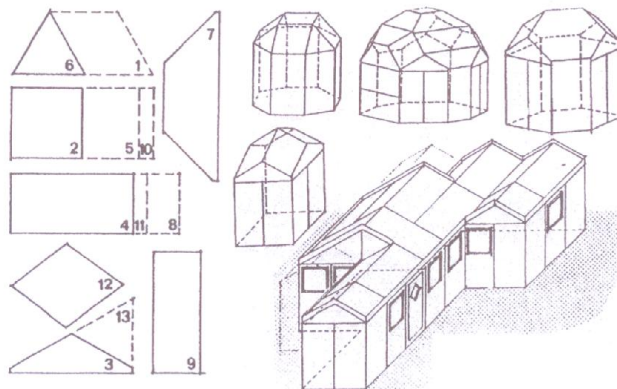


Fig (1) panel system for temporary shelter

- It has poor environmental control qualities
- It is generally unsafe from intruders
- It is too small to accommodate the inhabitant various functions

- Most of the tent are not prepared to cope with the severe weather conditions, if one need to treat the tent for such reason it might cost a lot
- Also fire resistant tent are uneconomic
- Tents cannot deal with the ground humidity conditions

Thus architects and researchers are devoted this to develop technique and technologies and also materials and its application in concepts not only to specify the advantages of the tent but also to treat the disadvantages of it.

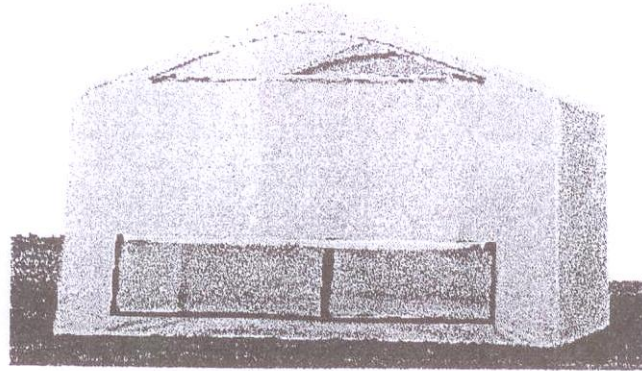


Fig (2) tent shelter

2- Historical Background of the Use of Paper tube as a Building Material

It was an idea for Shigeru Ban a Japanese Architect, to use the paper tubes as a unit for walls as a construction material. In 1986 was his 1st project with the use of paper tubes as a structure material, he used the paper tubes in the construction of an exhibition for Aivar Aalto's work.

He used the paper tubes in several various types of buildings of different uses, reference (8) gives several examples of Shigeru Ban works also Shigeru Ban web site demonstrate his works.

In 1995 Shigeru Ban used the paper tubes in building a rescue camp for people whom their homes were destroyed by an earthquake in Koba fig (3)–(8). The shelter were designed to be quickly erected shelter and intended to be sustainable. The research will focus on this example as the research prototype when compared with this example one can come up with some point of weakness which will be demonstrated in the comparison between the two examples.

3- Paper tube Properties as a Building Material

Reference (8) gives the following properties for the paper tube which are summarized as follows:

- The structural strength of paper tubes
- Paper tub is light
- Paper tubes are easily manufactured

- Paper tubes have aesthetic qualities

4- Paper tube as a Building Material case study

The following shelter was designed by Shigeru Ban to people of Koba whom their homes were destroyed due to destructive earthquake. "...For these victims, Shigeru Ban constructed temporary log homes using paper tubes, bringing an element of security to them. His idea was to create designs that consider the criteria, which help to develop a construction system for emergency shelter by using:

- Readily available, cheap materials (such as cardboard tubes, beer crates and plywood)
- Relatively easy to assemble in low-cost lightweight construction system
- Quickly erected or dismantled in short period of time even by people with no knowledge of building construction
- Succeed in terms of aesthetics and livability to meet the pressing need for shelter

The architect Shigeru Ban has developed both a new architectural language and a radical engineering technique through his use of large tubes made of recycled paper as a primary construction material" (8)

Ex.: The Paper Log House in Koba



Figure (3) Exterior view for the shelter

Figure (3) shows the exterior view of the Kobian shelter, designed by Shigeru Ban; the temporary paper log house is square in plan, measuring 4*4m. The structure is almost as big as the size of standard refugee shelter designated by the UNCHR. The floors, walls, and roof trusses are all constructed from 108mm diameter and 4mm thick paper tubes. The structure foundation was made of sand filled beer cases, to protect from ground dampness and to which the super structure of the building is tied through a floor made of cardboard tubes covered by sheets of plywood fig (3-8).

The walls are made of paper tubes (cardboard) tube with 108mm diameter and 4mm thick paper tubes and 2m high. It is fixed on the plywood through metal joints and joined laterally by bolted metal rods Fig (3- 8).

The roof construction is made of cardboard tube and plywood, such roof elements were constructed in a truss form. The roof is covered by a double layer of Teflon tarpaulin coated fabric like a tent, which diffusely lights the interior and incorporates a ventilation flap at one of its gable ends. Through symmetrical, the house is oriented by a shade awning jutting from one of its faces Fig (3-8).



Fig (4) Shelter erection (8) Fig (5) Roof fastening (8)

The shelter could be constructed in 6 hours, by the resident, and carry a cost of only \$ 200 per structure. (8)

In this case the application of paper tubes construction was not only innovative, but also very practical economic example.

This prototype is a notable example of the use of standard, low-energy components, not intended for building purposes, being adapted to pressing social and ecological needs and can be developed to be suitable for many other countries.

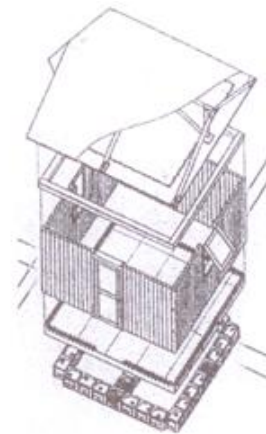
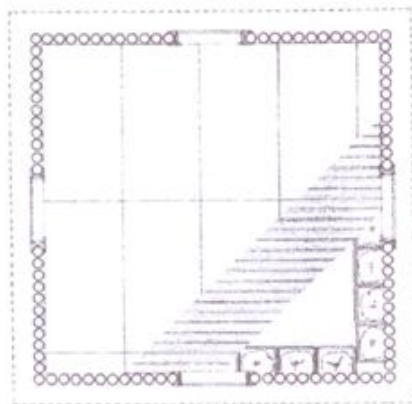
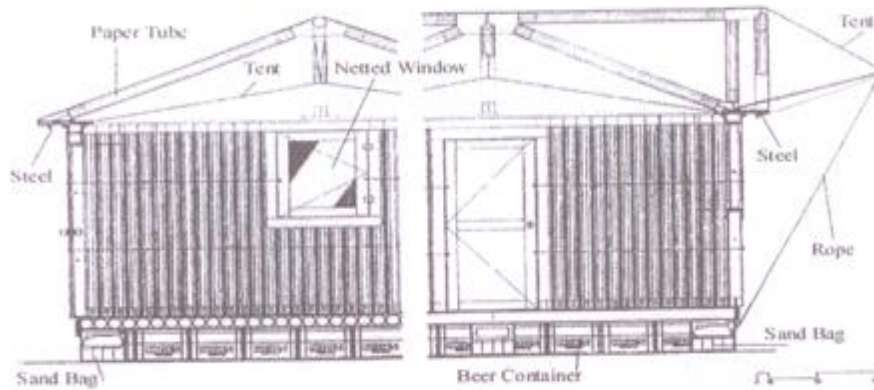


Fig (6) Shelter detailed plan(8) Fig (7) isometric detailed section(8)



Fig(8) Elevation view for the shelter showing the roof details (8)

Paper Tube Shelter Contribution: A trial of application

The structure consists of the following vocabulary members which been discussed separately:

- Roof modular units
- Walls modular units
- Floor modular units
- Structure foundation units

The following project figures (9) to (19) are for works been done by The author this to apply the idea of paper tubes in Egypt. The structure erected in Cairo, the use of paper tubes became a fact thus this paper exam the experiment of erecting a paper tube structure. The ministry of defense sponsored the experiment of building a dwelling using paper tubes using locally made constituents.



Fig (9) Shelter general view

a. Roof Modular Unit

- The roof inclination direction influence on its constituents (one direction roof inclination)

- Shigeru Ban, roof depends on tent cloth is to be preferred using a paper tube construction members, but in this paper, paper tubes make a load on the roof units that affect the wall units



Fig (7) Indoor view shows the roof panels with wall panels

- The roof panels units uses the paper tubes in a linear aspects and it could be distributed in the short direction that might be examined in further studies as it should be examined such impact on the overall panel weight

The panel unit is to be manufactured from the following constituents, roof panels are to be fastened to the wall panel. The roof is due to have either one direction of inclination or two direction of inclination.

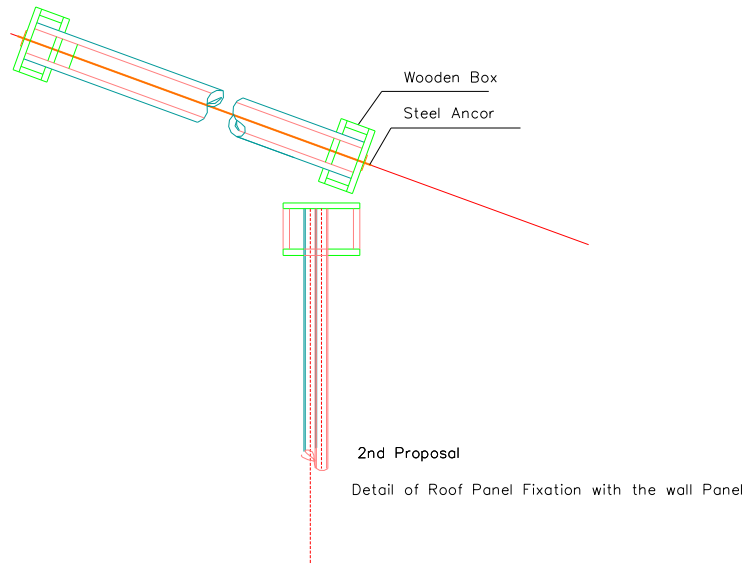


Fig (10) Indoor view

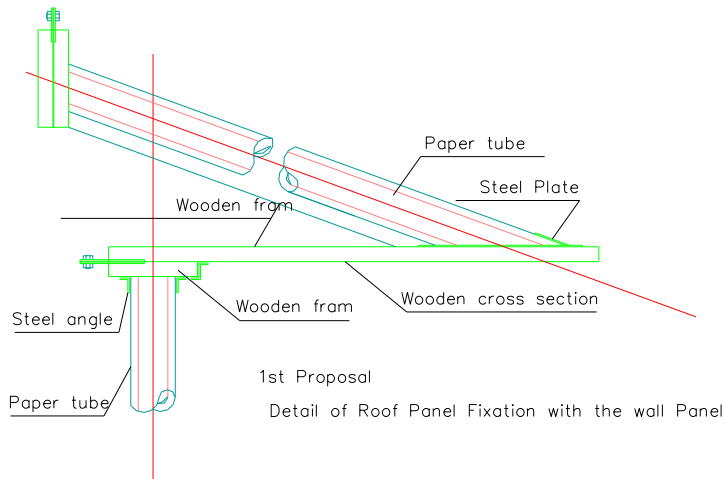
1. Wooden frame
2. Fixing Edges
3. 10cm paper tube diameter with 1cm thick
4. 2 tension rods (for each modular panel)

(1)Wooden Frames

The design of roof panels which consists of 2 wooden sides 2.5* 12.5 cm



A-



B-

Fig (11) the roof panels details of fastening with wall panels

(2)Fixing Edges

2 boxed elements that to be used as shown the paper tubes edges are to be installed in such boxes, which are a bit big in size. The box halls are to be drilled using arctic sow tooth. Figure (11) shows another treatment for the paper edge fixation.

(3) Paper tubes

Paper tubes 10 cm diameters and 1cm thick are to be arranged vertically (paper tubes take the longitudinal direction of the panel) paper tubes arrangement needs to be studied when rearranged horizontally (perpendicular to the proposed direction).

(4) Tension Cables

Tension cables are to be tensioned diameters 20 mm that are to be connected with metal rods. Such cables are to make the panel resistant to buckling.



Fig (12) general view shows the tension cables

(2) The wall modular panel design constituents

When looking to the dwelling plane figure (13) one can observe two types of walls. The 1st type of wall panels is panels with an opening. The 2nd type of wall panels is panels that have no opening at all.

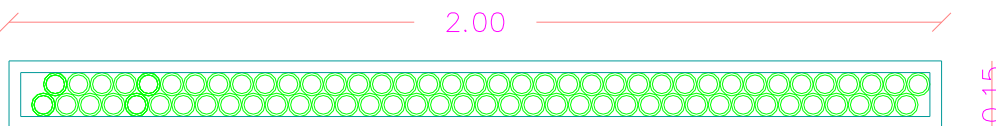


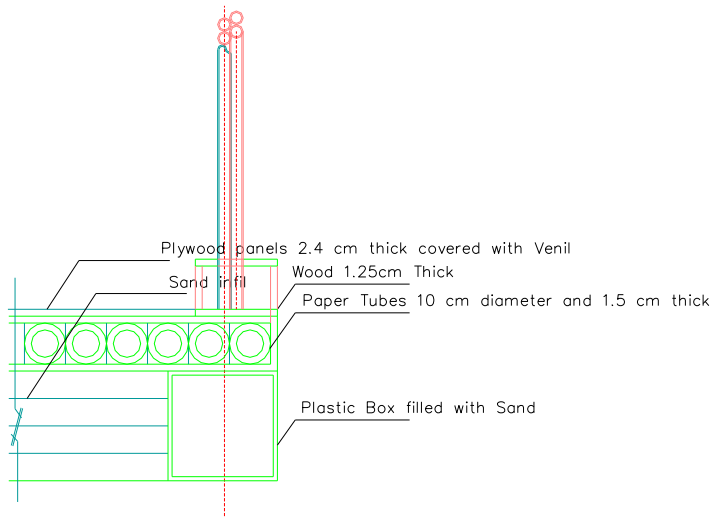
Fig. (13) Plan for the paper tubes sugared arrangement



Fig. (14) Wall panels and bracing

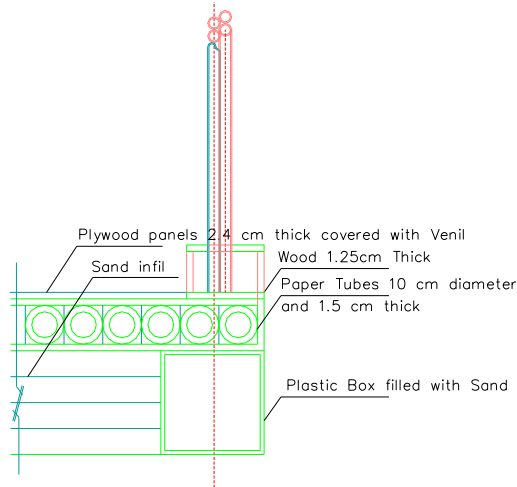


Fig. (15) Wall panels and roof panels



2nd Proposal
Detail of Wall Panel Fixation with the Foundation

Fig. (16) Wall panels fastening



2nd Proposal
Detail of Wall Panel Fixation with the Foundation

Fig. (17) Wall panels fastening

(3) The foundation design constituents

Wall panels are to be fastened to plastic boxes which are being filled with sand.

Fig. (18) Floor decking



Fig. (19) Wall panels on foundation



The Structure Advantages and Disadvantages

a. The Structure advantages

- The structure was easy to be build
- The structure as whole is not expensive (If the structure will be mass produced then it will be more cheap)
- The structure provides good weather conditions and provides the indoor environment with at least 5 – 7 degrees lesser than the outdoor environment (The structure was examined in July and the temperature was 35 degree and there was no feel of hot weather inside the structure)

b. The structure disadvantages

- The roof when being built in paper tubes (10cm diameter, and 1.5 cm thick) became too heavy on the wall units and we should do as Shegaru Ban did the roof with both paper tubes truss and tent as in figure (3-8)
- The roof need to isolation against water penetration in addition to fire treatment
- In order to prevent the open line space in between the wall units we use 4cm tube in two rows that was been placed staggered positioning as shown in figure (13)
- The wall units when left without painting has low visual qualities
- The structure was rendered with wood sellers rendering powder passed compound and the sprayed with cellos translucent rendering from outside and with (plastic-flout)
- The wall paper tubes when being 4cm in diameters became too weak as it was 2.5m in length so we put the bracing bares in the long direction and we put the

curved piece of wood in the wall unit mid length this to strengthen the panel and to protect the tube from being buckled.

Conclusion

In order to build a paper tube structure one must take into account the following few points:

- The material is available and need not special skills, as the structure has appropriate constructional system. The building can easily be built and it is inexpensive material. However, the proposed structure was expensive due to the first time to build with such material (paper tubes) there was some waste of the material after the experimental work.
- Using Paper tubes in the roofs (making the roof from paper tubes panel) is unpractical as the panels are quite heavy on the whole panels when compared with the tent roof supported by paper tube truss.
- Paper tube structural is good example for emergency structures as it provides the structure with the criteria of almost like permanent structure characteristic. Paper tubes can be easily manufactured and processed in Variety off sizes, lengths, thickness and diameters. It is quite strong material but in used in small diameters (4 cm diameter, 0.5 cm thick) into two rows it became not as strong as big size tubes (more than 10 cm diameter), and more than 1 cm thick.
- The application of paper tube construction was not only innovative but also very practical often with very pleasing cost effective and aesthetics results.

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