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Tailored Post-Disaster Shelter Solutions

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ABSTRACT

In post-disaster emergency shelter aid, relief agencies and other actors with different backgrounds try to cooperate in a tremendously short time and under different circumstances, mostly under time and emotional pressure. Lives depend on the quality of aid and, specifically, on the quality of shelter aid in this case.

In this article we describe a research project that aims to contribute to the optimisation of post-disaster shelter aid by implementing a new approach in which the demands for shelters in a specific situation are methodically connected with available and innovative, sustainable shelter solutions. We perform experiments by computer simulations as well as building prototypes to investigate long-term solutions, shape and materialisation of the shelter. The conclusions will explain that trust of the users for optimal results in this approach is in addition to the key elements of data accuracy and data security.

Keywords: *post-disaster, shelters, shape, needs, solutions, tailored*

INTRODUCTION

In post-disaster emergency shelter aid, successful choice of shelter solutions depends on deep understanding of the needs; contexts of the needs; practical knowledge of the available solutions and smart strategies to optimally connect the disaster with the solution. A broad understanding of the available local and innovative solutions is in addition to accurate data gathering over the needs, the basic requirement for good decision making in design or selection of post-disaster shelters.

Post-disaster emergency shelter designers are, as any other designer, concerned with the ecological, social, cultural and spatial application of technologies to meet specific human needs after each disaster and in each location. The choice for an on-demand designed shelter contributes to an optimal post-disaster shelter relief process and sustainable post-disaster emergency shelters.

Regarding the total shelter solutions, when a suitable shelter is not available, an innovative design can be suggested.

MEETING THE STANDARDS

Standards are the framework to function in the hectic environment of post-disaster emergency aid. The first initiative for standardisation of sheltering process, the sphere (Project, 2003) was launched in 1997 by a group of humanitarian NGOs and the Red Cross and Red Crescent movement. They formulated a Humanitarian Charter and identified minimum standards to be attained in disaster assistance, in each of five sectors of aid: water supply and sanitation, nutrition, food aid, shelter and health services. This process led to the publication of the Sphere handbook in 2000.

The Sphere Project was to develop a common framework and improve accountability for humanitarian aid. The Sphere Project is continuously being updated and developed. The updates and information is shared via the sphere handbook publications and via the website www.sphereproject.org. As a consequence, the humanitarian community mostly uses Sphere standards. In some cases, Sphere indicators and standards have been dismissed, as in the case of Pakistan where it was decided that "Sphere standards will not be met" (2005, Iom/js –b/strategy-Internal working document).According to the IOM[1] working document, Shelter Cluster/Pakistan/ Post Earthquake Interim Emergency & Transitional Shelter Strategy, for logistics reasons, as well as the need for consultations with the affected populations,, *it is not possible to provide fully adequate, standards compliant temporary housing to all affected populations immediately'*.

Currently various guidelines for shelters are available. Each organisation has specific standards as the UNHCR handbook and the IFRC catalogue (Médecins Sans Frontières, 2002; Howard & Spice, 1989; IAPSO, 2012; ICRC/IFRC, 2002; UNHCR, 2002; UNHCR, 2009).

In the complex environment of post-disaster shelter relief, however, the task of creating optimal designs needs a systematic framework. The framework should take the following aspects into account:

- context-sensitivity
- crisis-sensitivity
- 'performance standard' paradigm

Performance standards lead to a flexible design environment that leaves room for flexible, sustainable shelter designs (Tafahomi, 2008).

Local building standards play a role in shelter aid for a longer period of time.

[1] *International Organization for Migration was designated as the cluster coordinator, as outlined within the IASC humanitarian reform process.*

On-Demand Sustainable Post-Disaster Emergency Shelters

Designing tailored post-disaster emergency shelters needs adaptive design thinking. The basic design must be flexible.

For this reason we developed a basic design for a sustainable shelter that can be adapted to each situation. A central column in the shelter can include additional part solutions as energy, water and sanitation.

Figure 1a and 1b illustrate two possible shapes of the designed shelters. The frame and the central column provide freedom for design and flexibility to create culturally accepted shapes for the shelters. This means more acceptance and longer use of the shelters, thus more sustainable shelters.

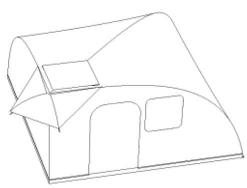


Figure 1a

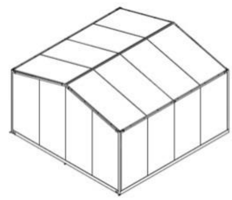


Figure 1b

Figure 1a and 1b: Usage of local materials, energy and cost effective designs are the consequences of this approach

Total Concept

The design contains a central column that is a part of the construction, the construction and the skin including the floor.

Depending on the needs and the available solutions the elements of the central column will be chosen. Sanitation, heating and cooking facilities can be included in the column. There are various options for the skin and the construction. Two examples are:

A Rapid response: lightweight emergency solution with flexible tubes as construction and lightweight fabric (Figure 1a). The flexible elements can be replaced by aluminium profiles or locally available materials for long-term usage.

B Transitional solution: with construction profiles and the possibility of filling the surface with panels and extra accessories with the locally available materials (Figure 1b).

As the central column provides flexible components, tailored solutions for each post-disaster situation can be offered. Figure 2 illustrates the position of the column in the shelter.

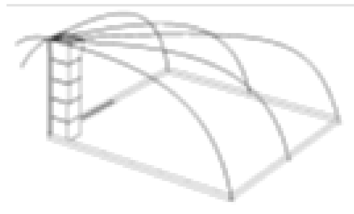


Figure 2: The position of the column in the shelter construction

Based on the evidence gathered with respect to needs and solutions, the tailored advice for shelter solutions can be provided. The advice can be materialised with this shelter design approach. This approach will lead to more sustainable and tailored shelter solutions that meet the needs of the beneficiaries the most (Figure 3).

An optimum can be calculated and presented in diagrams as shown in Figure 4 a and b.

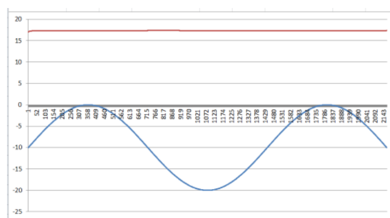


Figure 3: Realising constant inside temperature in various outside conditions (source template Tonny Grimberg, Saxion)

To meet the specific needs of the beneficiaries after each disaster, the shelters need an integral design. Water, sanitation and energy can be included in the shelter advice. Figure 4a illustrates the design for the central water and sanitation unit, developed in this research project.

An energy unit that can be adapted to the needs in each situation and meet the maintenance criteria is being investigated currently. Figure 4b illustrates the basic mobile energy unit that is developed and tested. We need to keep in mind that the choice of water, sanitation and energy facilities is made by shelter experts by connecting the evidence on needs, location and solutions and presenting the possible solutions that meet the needs of the beneficiaries the most, for each situation.

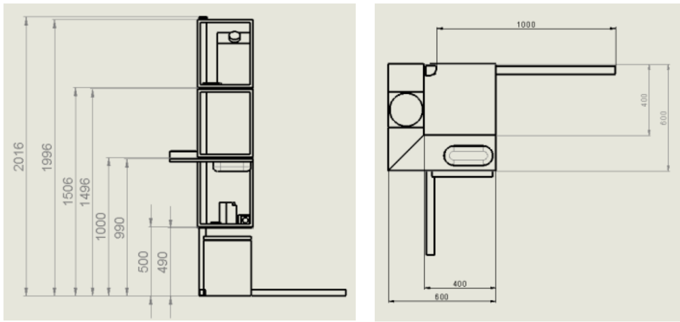


Figure 4a: The central column can include energy, water and sanitation units

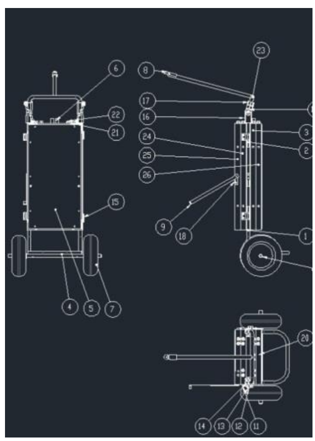


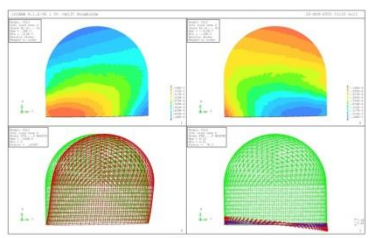
Figure 4b: The energy section can be delivered as a separate unit (Johan Kok, industrialdesign.nl)

Regarding energy provision, the provided shelters are to be based on the long-term effects of the usage of timber with the resulting deforestation, versus durable energy sources as solar energy; there is also the issue of fire sensitivity when using kerosene versus the usage of alternative energy sources that are currently less cost effective and need maintenance and technical know-how. The latter can mean educating the local population and growing the local economy.

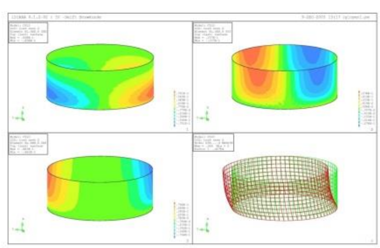
Shape, Performance and Acceptance

Regarding the shape of the shelter, cultural and local parameters are to be taken into account. The performance of the shelter keeping in mind variables such as climate and local recurring hazards are decisive factors in post-disaster shelters. We demonstrate this fact with a computer simulation in an earthquake sensitive area. We started with the simulation of the effects of an earthquake on different spatial shapes: a cuboid (7x7 m, 3 m high) with a flat roof, a cylinder (8 m diameter) with a flat roof, and a cylinder (8 m diameter) with a coned roof (height: 3 m). All have a surface of about 50 m2. A wall thickness of 300 mm was chosen. These measurements would make an acceptable shelter for a family of four. The used element is CQ 40S, a curved shell. The material-specifications of the clay are: E = 5000 N/mm2, Poisson 0.2, Specific gravity 2000 kg / m3.

The simulations were conducted using the DIANA program, a software tool for calculating loads[2]. The simulations were carried out with the assumption that the horizontal charges as a result of an earthquake are equal to the own weight as charge. The torsion has not been simulated since in earthquakes torsion is negligible compared to tension and deformation, which are the main reasons that buildings collapse as a result of earthquake. Figure 6 is an illustration of examples in calculations of the tension and deformation in a cylbol, an open cylinder and a cuboid.



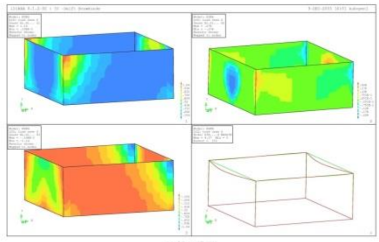
Cylbol: Earthquake g = 1: maximum tension +0,273



Open cylinder horizontally charged g = 1, maximum tension +0.08, 0.02 mm

We found that the most tension occurs at the sharp edges, and the minimum tension and deformation occurs in the cylinder. When the cylbol and the cuboid with flat roof are compared, the former shows less deformation as a result of horizontal loads. The preliminary conclusion is that the open cylinder will get considerably less tension and deformations in comparison with the open cuboid, and that the cylbol can handle the highest charges.

[2] With thanks to Gerrie Hobbelman



Open cuboid, horizontally charged g = 1, maximum tension +1.14, 4.57 mm

Figure 5: The corners in a cube are the weakest place in an earthquake. Additional strengthening is needed. A dome shape does not have this weakness.

Based on the findings of this experiment we can conclude that a cylbol that has no sharp connecting lines between the walls and the roof is the most optimal shape for a shelter in earthquake sensitive areas. However the shape of a shelter is not determined only by the constructive calculations.

The cultural acceptance of the ideal shaped cylbol has been shown not to be optimal in many cases, such as the polyurethane dome-shaped shelters in Nicaragua.

Earthquake strips can be used, for example, to reinforce the joining walls, and material amelioration can result in a higher resistance to collapse.

The shape of a shelter is defined by the local and cultural factors, the available technologies and the available materials.

CASE STUDY INNOVATIVE SHELTERS, KIVI NIRIA- 2007-2008

Engineers Without Borders, The Netherlands, initiated a workshop for designing innovative shelters for Dorcas[3] in 2007–2008. After the brainstorm sessions, the framework for the designs was formulated. Measurements, construction and the materialisation were the key questions.

Functionality, construction and materialisation, with an accent on usage of local materials, were decided to be the basic priorities. Day lighting, artificial lighting, cooking and sanitation were seen as part of functionality. Cooking in a semi-interior environment can keep the mosquitoes away and the fuel smoke will not be produced inside the shelter.

[3] An NGO based in the Netherlands

The measurements of the shelter depend on the function of the shelter, the constructive possibilities and the users' requirements. As in this project these parameters were open, the following assumptions are to be made: 2*3 m or is it too small; is combining small units to create a bigger space a good idea? A modular system can be a solution to this question. Should sanitary facilities be outside? The shape is a cube (it is easier to combine rectangular units) with a slight roof angle for rain drainage.

One or more modules of 2x3 m and a clear height of 2 m was chosen; the location and the standards were not known. In terms of materials, the following was considered for the walls: clay (treated with linseed) as a coating on the inflatable (temporary) moulds; straw; sandbags. For the roof, the following variations were considered: bamboo (as a temporary template); bottles.
The final prototype (size 30x20x25 cm) was a model of a clay house as a coating on an inflatable (and thus reusable) mould. This is natural clay and pieces of rope used as reinforcement.

Prototype 2 was made of sandbags with a roof made of empty plastic bottles.

In this experiment, the local clay quality and the importance of the knowledge of the proportion of used clay and straw became clear. The knowledge of the quality of locally available materials and preparedness to ameliorate this quality became clear at this stage as the engineers searched for the right kind of clay in the area and for the right mixture which would not collapse easily.

The initiating engineers did not have easy access to the standards and the requirements of the users. The design choices were made based on common sense and logic, from the thinking perspective of a western engineer.

Such decisions as 'cooking is to be in a semi-interior environment that will keep the mosquitoes away and keep fuel smoke away from the internal shelter', can be the right decision in certain locations. The heat produced by cooking, however, can be used as heating in cold climates. In addition, alternative cooking methods such as solar cooking are to be investigated.

The inflatable mould did not take and sprung a leak while the clay was drying. High quality for the mould is required which means higher costs.

Lightweight empty plastic bottles, seemingly of no value in the western world, may be used for transport and storage of water after a disaster and are tremendously valuable.

This experiment is an example of how innovative post-disaster shelter designs are initiated, including the dilemmas, choices and the need for a systematic framework. The concept had to be developed within a period of six months, after which an open-day is planned. As location parameters, cultural parameters and clear standards were lacking, assumption for the measurements and needs are being made by the engineers group. The chosen concepts were sandbags and the inflatable structure. As the sandbags concept seemed 'less innovative' (previously realised and documented in 2006, design like you give a damn), the inflatable mould was chosen as a working template. The available materials and the usage were the basic criteria in the development process. The question was raised as to how to implement usage of the local materials as a priority, since it was not known where the shelter was to be built. A shelter that is suitable for any location has to be adapted to different local parameters such as climatic aspects and hazards, as wind, rain, snow and earthquake.

The designer group chose the following solutions:

'No floors will be made in the shelter. The floor was of stamped earth. The openings required in the walls for admitting daylight depended on the location. Artificial lighting was an option as well as satellite dishes and TVs. Cooking to be (semi) inside as the smoke would repel mosquitoes. The materials to be used are: empty bottles, adobe (earthen materials), stone, empty jerry cans, hay, inflatable construction (which will be used as a mould)'.

The accent in this approach was on the construction and material specifications. The measurements of the shelter depended on the constructive possibilities and the users' requirements, as well as the function of the shelter. The engineers wondered if a 2 m * 3 m room was sufficient or if that was too small; was it a good idea to combine small units to create a bigger space? The combination glasshouse construction and shrinking foil, inflatable construction, adobe and shrinking plastic foil are examples of examined solutions. The sanitary facilities will be outside. The shape of the shelter is a cube as, according to the designers, it is easier to combine rectangular units. Drainage in the roof for capturing rain is desirable.

Knowledge of the quality of locally available materials and preparedness to ameliorate this quality became clear at this stage as the engineers searched for the right kind of clay in the area and for the right mixture which would not collapse easily.

Figure 6 is an overview of the realised prototypes using bottles, sandbags and clay in combination with an inflatable mould.

This experiment did not result in a design for post-disaster shelters in general. However the lessons learned can be implemented in various projects. We learn from this experiment that the requirements for a post-disaster shelter are to be defined and that, for solid decision making, accurate data on the disaster and the users and a framework are needed. In this manner the motivations for decisions may be realised. Choice of materials and shape depended on local parameters and performance criteria. The measurements of a shelter needed to be defined. Standards such as shelter standards, Sphere standards and local standards may be useful tools. However performance standards lead to direct choice of solutions that perform best for each solution. As relief and development projects often are realised by volunteers, the need for a central knowledge bank, where gained experiences and available knowledge can be shared and archived, becomes clear in this experiment.

Figure 6: The prototypes

CONCLUSIONS AND FUTURE RESEARCH

Our research indicates that a lightweight reinforced dome-shaped adobe shelter has optimal earthquake resistant properties. Such a low-cost shelter will be applicable on many sites where adobe is locally available; if in a desert area, the amount of water required can be reduced by adding chemicals to the clay. Production with controlled quality requires a fast method of testing the clay on site and of improving its quality, matching the optimal needed reinforcement, and a fast calculation method for the thickness of the walls. These methods may be the subject of future research. At the moment a decision support system (DSS) is being developed by the author, which can be used for training the construction workers and which states the required performance of the clay when used under certain conditions, the available local adobe quality and the available solutions for optimizing the clay quality.

Illustration of the process

If disaster …..
And
If damage repair desired
Then process:

Figure 7 illustrates phases1, 2, 3, 4 and 5.

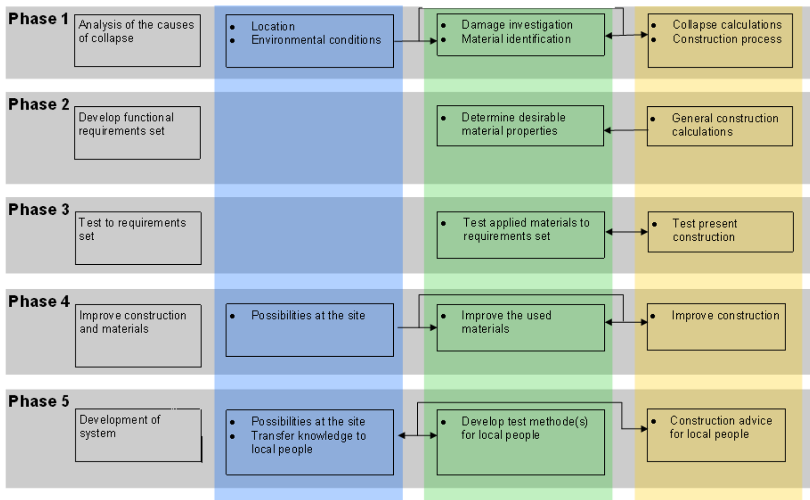


Figure 7: Material amelioration

This paper presents the effect of preparedness to eliminate the effects of a disaster. In long-term construction after a disaster this knowledge is of enormous impact. However in providing shelter aid in the immediate phase after a disaster, this knowledge cannot be used. Awareness of preparedness can be integrated in the shelter relief activities after a disaster, to prevent repeating the damage when a disaster reoccurs.

In each case data accuracy, data security and the trust of the users are the key elements in the implementation of this process. The gathered knowledge and the experiences, including learned lessons from less optimal solutions, are the key elements for learning purposes and for training construction workers.

Examples as the earthquake in 2010 in Haiti show that building collapse has been the main cause of fatalities and injuries after earthquakes. From the expert evaluations we can conclude that educating construction workers in the field is the first step to improve the quality of shelters and rebuilding better after disasters.

According to Guiteau Jean-Pierre, executive director, Haitian National Red Cross Society, it is important to create a sustainable approach to disaster recovery. According to shelter experts such as Ted Fellow Peter Haas (AIDG)[4], education plays a vital role in the capability to build sustainable homes after a disaster.

[4] Appropriate Infrastructure Development Group

Haiti for example was not a natural disaster according to Haas (2013). It was a disaster of engineering. The buildings in Haiti were not built according to the rules that are applicable in earthquake hazard areas. This was a result of a lack of education in building safe homes. The DSS that is being developed can contribute to the education of local building construction workers and shelter experts in the field.

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