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## LIGHT SHELTERS: USE OF REFLECTIVE INSULATIONS IN EMERGENCY ARCHITECTURE

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#### ABSTRACT

The purpose of this paper is to discuss a technology combination between easy assembling shelter and reflective insulation, starting from emergency needs of displaced people. Shelter means by definition 'a habitable covered living space, providing a secure, healthy living environment with privacy and dignity to the groups, families, and individuals residing within it' (T. Corsellis, A. Vitale). Materials like cardboard, aluminum guarantee the covered living space, giving privacy feelings needed for traumatized people after disaster. The lightweight, flexibility, recyclability of these materials offer an effective answer to this need presenting fast assembly structures. In combination with these materials, to provide healthy living environment, different projects involve the use of reflective insulations. Exploiting the reflective properties of these components can be possible to increase the technological performance ensuring lightness, space saving and easy installation.

The paper started studying the shelter state of art by different case studies, where reflective materials are used to improve thermal performance. 'Ape Tau' by Atelier 2, after Aquila's Earthquake, is one of these projects, in particular for the use of thermo-reflective materials. This analysis is accompanied by 'Paperboard Shelter Workshop' practice, held on October the 4th, in Lecco. It was inside the current Academic Network for Disaster Resilience to Optimize Educational Development (ANDROID) and from 'Cardboard Shelter Workshop' Professor Toshihiko Suzuki experience, after Fukushima Earthquake. Students have gained awareness of the emergency requirements issues, with a small units construction, made of cardboard, useful to

0146-6518/03/183-192 2014 Copyright©2014 IAHS understand the meaning of handle spaces and easy fitting. The result is a technological design view where healthy and space performance is combined to guarantee psychological and physical safety to displaced people. The observation of reflective technology in this extreme context can be useful for civil application as a future development too.

Key words: technology, emergency, healthy, flexibility, reflective.

## **Introduction**

Some 373 are the disaster in 2010, which are killed over 296,800 people, and affecting nearly 208 million others. Totally, in the last twelve years 2.9 billion are the people damaged and 1.2 million killed by catastrophe. Moreover, many of the world's mega-cities, with more than 10 million of citizen, are located in the most dangerous areas subject to natural disasters, where combination between human system and natural hazard are the reason of catastrophes.

In the post-disaster activities it is possible recognise three major phases: Response and Relief (0-35 days), Recovery (days to months) and Reconstruction (months to years). In the second phase people returns to relatively normal conditions, not the true normality, and the main activities include moving the population from emergency location to tolerable housing. In this temporary housing, normally call 'Shelter', the basic services as water, sanitation, nutrition and public health (including psychological) are provided as soon as possible. They are, particularly, part of the process covering the spectrum from immediate emergency and the reconstruction, where individual's houses are reconstructed or a durable solution is found.

The problem in this internal phase is that temporary solutions become, often, permanent without the appropriate requirement. For this reason is important that the cultural, social and economic norms of the specific disaster-affected societies, must be reflected in shelter and, therefore the design are based to rapid and cost effective solution can also be culturally acceptable to the populations. In principle with this reflections it is important to design shelter remember this important key points:

- Lightweight. An easy assembly and transport shelter allow to be faster in the construction phase and to answer to emergency situation.
- Resistance. The reconstruction can take years, or decades, and transitional shelter needs to be designed to potentially last as long as the permanent solution is achieved.

- Ductility. The best designs allow the household to upgrade or incorporate the shelter materials into the permanent reconstruction. Allow the family to return to their home because they are mobile and flexible, or both.
- Practicality. To minimize the distance from former and future homes and minimize the duration of displacement, allowing people to better maintain their livelihoods and protect their land, property, and possessions.
- Modular. To create a sense of community among displaced families at the temporary settlement(s) helps to avoid conflicts and discontent.
- According with culture. Degree of acceptability and ownership by displaced communities determines a successful outcome of a transitional shelter program coordinated with population's participation and with local needs and customs taken into consideration.

To answer to this needs the design explore the lightweight material as a thermoreflective multi-layer insulation for their high thermal feature in a flexible way. It is an innovation originally developed by aerospace suits, and it became a viable lightweight way to reduce energy consumption and thereby improve comfort and save on energy bills. The features of these materials are totally in agreement with shelter parameters, in this way thermal, psychological and construction performance are ensuring by this lightweight, resistance, ductile, practical, modular system.

# Thermal Reflective Multi-Layers System (TRMLS)

The TRMLS is composed by numerous thin membranes made up different materials. The definition of system comes from the need to lying the multilayers element inside two air gap of 20 mm thick per one, to improve thermal performance.

In fact, as shown by the measurement with guarded hot plates apparatus and the hot box, there are lower thermal resistance values where such air cavities are not present. In the hot box apparatus, where are cavities are existing the R value are approximately 1.5 to just above  $2.0 \text{ m}^2\text{K/W}$ , whilst in the guarded hot plates apparatus, without air cavities, R value is between 0.47 and 0.60 m<sup>2</sup>K/W. There is, moreover, a different between the presence of air movement in this layer. National Physical Laboratory, farther, studied the changed between TRMS performance with non-ventilated and ventilated air cavities, on the cold side of roof construction, and the result was an U-Value 9% higher in the case of ventilated layers. The performance of system, therefor, can be increasing with non-ventilated air gap.

The numbers of layers change depending to the materials and to the thermal performance requirements. In general, reflective films are separated by wadding layer, foam layer, polythene film, and bubble films sewn together to form a thin insulating blanket. It can be three to five times thinner than traditional insulation (including air

spaces) but performs to the same level and does not support the nesting of rodents because of its minimal thickness. These features ensure less damage in case of earthquake for the thickness and consequent lightweight of building envelope. The chosen materials are ordinarily non-irritant fibres, non-asthmatic and non-allergenic. For these reasons no protective clothing or equipment is necessary during the assembly and the insulation does not weaken over time become more easer in emergency contest. Installation is, furthermore, easy for the flexibility of multilayer materials sold in light rolls, easy to transport and to cut. The system is usually built with wood frame following foil dimension and limiting air infiltration.



Figure 1 : Thermal-reflective multi-layer system.

This technology allows to reduce energy consumption, for heating and cooling, saving of up to 50% for the building occupier and reducing greenhouse gas emissions for the environment, contributing to 40% reduction of global housing requirements.



Figure 2 : Thermal-reflective system performance in winter time and summer time.

## Heat Transfer

TRMS works creating a barrier against the transmission of cold or heat through walls, floors or roofs. The heat is kept inside the construction during winter and rejected outside during summer. Three are the types of heat that affect a building: radiation, convection, and conduction. This insulation system takes advantage of all three, ensuring efficient operation of the same according with chancing state.

- Radiation: TRMLS external reflective foils insulation are extremely effective at reflecting infrared radiation back towards the source of heat (heating systems in the winter, and solar radiation in the summer). Each internal reflective foil acts as an additional barrier to thermal transfer by radiation. The amount of energy emitted from a surface, however, depends also on its surface temperature and above all depends on the value of the long-wave emissivity  $\varepsilon$ . Aluminium foil in the external side of TRMLS with approximately the low emissivity of  $\varepsilon \approx 0.1$  can considerably reduce the amount of heat transfer through the product, reflecting most of the incident radiation energy (up to 97%).
- Convection: TRMLS layers reduce thermal loss limiting the cold air infiltration in the winter, and warm air infiltration in the summer.
- Conduction: heat transfer via physical contact between solids, liquids or gases. TRMLS layers separators with low density (wadding and foam) between the aluminium foils create insulating air gaps, which are also barriers against conduction (same principle as double glazing). To ensure this reaction outside the multi-foil insulation is installed between 2 air gaps, which not allow the materials to be in contact with the surface to be insulated. This part of the system significantly reduces thermal transfer by conduction. Within the multilayer insulation there is a very little conduction occurs given that the foils are separated by materials which create small air gaps which act as barriers to conduction.

TRMLS is waterproof in case water penetrates the roof area, furthermore, its thermal performance prevents any internal condensation.

## Case Study

## Ape Tau kindergarten, Aquila, Italy

Atelier 2 (Gallotti and Imperadori Associates) in collaboration with Politecnico di Milano (Professor Marco Imperadori) and Manufacturers Association of Mantova 'A regola d'arte' (Luigi Masotto) are the developers of this Ape Tau project. The kindergarten was built for charity purpose in Aquila, Italy, after 2009 earthquake.

The double meaning of the name 'APE TAU' are refer to the ability of organizing and knowledge of the way of living in a community, as a hive (APE means bee), and the positive symbol of peace represented by the shape of the structure, which recall Saint Francis Croce (symbol of rebirth and union). The building is organized in three principal part: the central body hosts services as restrooms, kitchen and deposits, two lateral portion, both connected with the central one, hosting classrooms. It is

characterized by a fast construction, high seismic, acoustic, thermal and fireprevention performances through an experimental dry multi-layered envelope.



Figure 3 : From left: Ape Tau plant, Ape Tau external view.

Seismic performance, according to the Italian Design Standards (D.M. 14.01.2008 - NTC), are ensure by the principal and the secondary bearing structures, by glue-laminated beams, in the central body, and by galvanized steel profiles in the lateral one.

The central body structure is designed to resist also to general horizontal actions, and the horizontal loads design is based upon the structure remaining essentially elastic due the lack of knowledge on the ductility of the glulam structure. In the lateral bodies the bearing structure is shaped in a semi-circular frame, protected by nano-ceramic anticorrosion systems to guarantee a complete protection and high durability.



Figures 4 : From left: Ape Tau wood and steel structure; Elycop sandwich panels; Aluzink galvanized steel ventilated skin details.

The secondary structure loaded by the sandwich panels is 70 mm thick with a radius of 3.30 m. The overlapping panels guarantee water and wind tightness and protect all the connections of vertical façades, in some cases, with the additional use of polyurethane foam. Aluzink ventilated skin of galvanized steel is applied on the top of sandwich polyurethane panels. These elements are coloured like a bee (black and yellow) because the ventilation layer between it and the corrugated sandwich panels improves summer comfort, and it reminds the bee concept.

#### Light Shelters

### Envelope Thermal Performance

The advanced components of this building is the envelope, a combination of innovative materials as a TRMLS, the result is a building elements with a U-value of  $0.18 \text{ W/m}^2\text{K}$ . In the dry assembled packet the thermo reflective system is collocated in a central position between: external corrugated coated steel sheet, air gap (approximately 5 cm), sandwich polyurethane panel (70mm thick) outwards and mineral wool insulation of density 100 kg/m<sup>3</sup> (10 mm thick), flexible self-supporting Aluzink structure, mineral wool insulation of density 70 kg/m<sup>3</sup> (40 mm thick), polyester panels insulation of 20 kg/m3 (30 mm thick), gypsum board panel with vapour barrier (12.5 mm thick), mineral wool insulation of density 20 kg/m<sup>3</sup> (20 mm thick), inner acoustic perforated special gypsum board air cleaning (12.5 mm thick) inwards.



Figures 5 : From left: Ape Tau section; TRML installations.

The thermal-reflective insulation product consists of 14 components: 2 external reflective films with reinforcing mesh, 4 sheep wool wadding layers, 4 foam layers and 4 internal aluminium reflective films. This product has been placed for the first time on internal face and the result is an incrementing of envelope technological performance.

This pioneering solution associated with a ventilated shell reduces the amount of heat that building absorbs in hot weather conditions. Solar radiation is reflected by the covering and the ventilated air gap, achieving considerable reduction in terms of air conditioning. The result is a sensible saving in terms of energy.

## TRMS Performance

Annual energy consumption of the kindergarten is equal to  $17 \text{ kWh/m}^2$ , according to the Casa Clima procedure, the Agency base in Bolzano, which certifies the comfort and energy efficiency of the Italian buildings. The contribution of this system was significant to rich this result, through the action of irradiation exerted towards the internal and external environment, allowed by its strategic central position inside the

various components of envelope. The heat performance of radiation, conduction and convention combined with outward layer protect the building to external heating. Combination between TRMS and internal layers (different types of mineral wool and polyester panels insulation), conversely, allows preserving the internal temperature without dispersions.

### International Paperboard Shelter Workshop

Second case study is the international Paperboard Shelter Workshop, held on October the 4th, in Lecco. Aims of the workshop was to raises awareness on to the design of flexible and modular emergency housing units through the use of recycled cardboard, showing and discussing different technologies and sustainable solutions applied to a multifunctional building.

### Workshop Experience

The 'Paperboard Shelter Workshop' has stimulated students awareness of the issues of emergency planning, with a small units construction, it will be flexible, modular and designed with reused materials from cardboard. The workshop activity will consist of a whole day and involves students from: Politecnico di Milano, Università di Palermo, Kogakuin University Tokyo, Singapore Polytechnic, Universitas Indonesia Jakarta, ESPE; all was participants of the 'Premio Compasso Volante' competition.

Each of 8 international group, composed by student of different nationality, had designed and had performed, full scale, a post-disaster shelter or first need unit. The shelters was made entirely of cardboard, like the Kogakuin University experience, which, under the direction of Professor Toshihiko Suzuki and Yuki Sugihara, has made this practice after the disaster in Fukushima. As an example, during the workshop had been possible to observe a real prototype of this project, kindly brought for the occasion by the Professor Toshihiko Suzuki and Yuki Sugihara. The students had realized the unit following their creativity, obviously, they had to remember the sensitivity of the subject and the principal needs that people have after a disaster emergency, as a necessity of a private space. The choose of paperboard are from the versatility and functional of this material as well as ecological, flexible, lightweight and easy find.



Figure 8 : From left: Winner project; international collaboration.

## Workshop Contribution

It is possible to find different examples of paperboard use in the contemporary architecture, but the result for the students was to analyse the concept of volume and private space, giving a personal interpretation, recalling also the theme of self-construction, particularly significant in areas affected by natural disasters. With this experience they had the opportunity to analyse this concept showing the importance of easy assembling, collaboration between different culture and the importance to have lightweight, flexible material to project.

### Conclusion

The combination of Ape Tau project and Paperboard Shelter Workshop show the importance to lightweight materials inside emergency architecture.

In the first case high thermal performance, with equivalent  $\lambda$  of 0.04 W/mK, allows to have a building system able to ensure internal comfort to the user. In parallel the construction can be easy to assembly and to transport. This material are, farther, particular resistance to answer emergency and safety condition in disaster area ensuring ductile feature, to be integrated in future permanent construction, and modular design to increase the sense of community trough different solution.

In the second experience this property are showing by a practical exercise where importance of collaboration and flexible material are the key for simple, exhaustive design to answer to displaced people needs.

Combination of these phases suggests the integration of these materials inside the emergency architecture. Paperboard are already use in this field but, combination with TRMS can increase is thermal performance allowing the maintaining of is malleable, ecological materials, ensuring all the shelter parameters necessary for a good final design and thermal comfort.

The use of TRMS technologies in extreme design is useful to understand and improve application of this innovative material inside construction, increasing his insertion inside civil architecture. The micro-architectures as a shelter, in fact, allow the use and study of new technologies with more control for the limited size of the systems.

### References

- 1. Tiemperik, M.J.; Hasselaar, E. Reflective Multi Foil Insulation for Buildings: A Review, in Energy and Buildings, No.568, (2013), pp.233-243.
- 2. Yonetani, M.; Holladay, S. Global Estimates 2011: People Displaced by Natural Hazard-Induced Disasters, IDCM, NRC (2012).
- 3. Learning from Megadisasters, The world bank/GFDRR, (2012).
- Pasztory, Z.; Peralta, P.N.; Peszlen, I. Multi-Layer Heat Insulation System for Frame Construction Buildings, in Energy and Buildings, No.43, (2011), pp.713-717.
- 5. Earthquake Reconstruction, The world bank/GFDRR (2011).
- 6. Uvsløkk,S.; Arnesen, H. Thermal Insulation Performance of Reflective Material Layers in Well Insulated Timber Frame Structures, Proceedings of the 8thSymposium on Building Physics in the Nordic Countries, 2008.
- 7. Seriacaroupin, J.; Miranville, F; Braga, D.; Duran, M. Experimental Evaluation of the Thermal Performance of Building Roof Including Multireflective Radiant Barrier, in HEFAT, paper number SJ7, (2007).
- 8. Corseillis, T.; Vitale, A. Transitional Settlement, Displaced People, University of Cambridge, Shelter Project, Oxfam, 2005.