Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 180 (2017) 1110 – 1120

Procedia Engineering

www.elsevier.com/locate/procedia

International High- Performance Built Environment Conference – A Sustainable Built Environment Conference 2016 Series (SBE16), iHBE 2016

# Architecture for refugees, resilience shelter project: A case study using recycled skis

Graziano Salvalai[a,]*, Marco Imperadori[a], Federico Lumina[a], Elisa Mutti[a], Ilaria Polese[a]

[a]*Politecnico di Milano – ABC department, Via G.Ponzio, 20133 Milano, Italy*

**Abstract**

In emergency and post-disaster situations one of the hardest issues to deal with regards the means and materials suitable to build temporary and livable shelter. In this prospective, the following work analyze the potentiality (from technological, thermal and structural point of view) of a lightweight shelter skin composed by recycled skis, covered by a textile envelope coupled with thermal reflective multilayer insulation able to provide high-quality thermal comfort. This solution addresses different purposes: recycling high technology material, construction speed, lightness and low embodied energy. As skis are constituted by different layers of high-performances materials, that are also difficult to dismiss, their reuse reduce the $CO_2$ emissions and the amount of wasted material. In collaboration with the University of Grenoble, some laboratory tests have been carried out in order to investigate the mechanical properties of skis and design durable and resistant structure. The morphology of proposed shelter comes from the archetype of the Mongolian Yurt, modelled and adapted to improve energetic performances: a detailed building model has been used to perform dynamic building energy simulation. The structure is composed by 130 pair of skis with different lengths and characterized by a circular basement (6 meters of diameter) divided in 24 concentric sectors that constitute the structural axis, where are located pillars and beams made by coupling different combinations of skis. Externally two orders of circular hoops help to absorb the loads coming from the covering, and between the pillars are placed two bracing elements. At the center of the circumference a steel pillar supports the flat-roof window. A real-scale prototype has been developed in order to verify the assumptions made during the design phases. The shelter is now built and used in a humanitarian mission in Guinea Bissau.



Peer-review under responsibility of the organizing committee iHBE 2016

*Keywords:* Post-disaster insulation; reflective multilayer insulation; ski shelter; recycling material.

* Corresponding author. Tel.: +39 0341 488791; fax: +39-02-2399-6013.
*E-mail address:* graziano.salvalai@polimi.it



Peer-review under responsibility of the organizing committee iHBE 2016
doi:10.1016/j.proeng.2017.04.271

## 1. Introduction

Many disasters exist, whether caused by natural or by human factors [1]. In the world, during the 2015, the total number of people affected by natural disasters are approximately 103 million (222.000 in Europe) [2]. In emergencies context, it is important to provide shelters to protect the population ensuring technological and psychological safety [3-4]. The massive refugee crisis that has dominated the news over the last and current year has resulted in a displaced population spread across many countries in Europe, as well as a shortage of affordable and quick-to-construct shelters. The scope of the challenge suggests the tradeoffs that arise when designing and implementing a large-scale shelter solution: how to create quick and easy buildings that are more solids and dependable than simple tents, with adequate comfort conditions. Several scientific researches concerning emergency post disaster shelter are available in literature dealing with the technological design, the adaptability and versatility of different solutions [5,9]. Only few publications focused on the reuse of recycled materials for shelter construction. The purpose of this work is to investigate the re-use of high-tech recycled materials improving thermal comfort, reducing the energy consumption with an easy assembly installation. Starting from the Ski Dome project, a geodesic dome entirely built with skis [10-11] developed by a team of researcher of the University Joseph Fourier of Grenoble, the presented work analyze the potentiality of a lightweight shelter composed by recycled skis, covered by a textile multilayer envelope. The skis are high-tech materials made up by several layers: steel plates, plastics and resins that confer high resistance and good ductility, the analysis concerning the amount of skis disposed on the Alpine Area shows approximately 1.500 tons of skis fallen into disuse every year. However, their recycle is very difficult due to the proper layers composition, the reuse option is, therefore, the achievable option. A temporary emergency shelter, called “Ski Shelter” made up by used skis and covered by a lightweight envelope composed by thermal-reflective-multilayer insulation and PVC (polyvinyl chloride) sheet, has been studied, and built in a real scale. The joint between skis has been tested, from the structural point of view, with experimental tests. The first tent prototype has been donated to the Missionaries Oblates of Mary Immaculate and it now operating in the Republic of Guinea Bissau.

**Nomenclature**

| | |
|---|---|
| R | Thermal resistance [$m^2K/W$] |
| MLI | Multi-Layer Insulator |
| PVC | Polyvinyl Chloride |
| ACH | Air Change Hour |
| ORT | Operative Room Temperature |

### *1.1. Analysis of the disposal skis*

In Northern Italy, the Alpine Skiing is a popular sport, the main equipment consist on skis and poles that after some season must be disposed because of delamination, splinters, cracks or other reasons. The material composition of the skis is particularly complex and they cannot be recycled easily by deconstruction: the making-up materials of a typical alpine ski are assembled in a sandwich panel, perfectly bonded together and hardly disassembled (Fig.1a). In order to get the alpine ski life-cycle data a reference ski was taken into account, which weighs 1,8 kg divided as follows: the 35% of the weight is represented by the angular steel blades, 20% by the wood core, 10% by the surface foil. The remaining 35% is mostly represented by adhesives, foams and by rubber elements [12]. Regarding the disposal, the companies take just the metal parts out, after that, the remains is shredded and burned in incinerators producing $CO_2$ emission. Considering the different manufactory steps the ski’s production involves a big amount of energy. The environmental impact produced by a single ski can be achieved by calculating the energy spent for each stage: processing, manufacturing, distributing, using and disposing at its end.

The Fig.1 b shows the specific profile of the Alpine Ski: the first two life cycle stages, namely raw material and manufacture, contribute most to the overall energy consumption. The distribution scenario or the use stage contribute little to the environmental impact of the product. Italy has more than 250 ski areas, with a huge amount of