WASTE RECYCLING AND PARAMETRIC DESIGN: VIABILITY AND APPLICATION IN EMERGENCY TEMPORARY BUILDINGS AND HUMANITARIAN ASSISTANCE

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ABSTRACT

This paper aims to study three realities: on one side, products from waste and recycling; on the other hand, the use of parametric design defining construction elements; and finally, temporary buildings.
The analysis of these three realities is done in order to obtain models and forms of intervention that respond effectively to emergencies and humanitarian assistance.
The research incorporates modes of social participation, economic and constructive strategies towards the valorisation of temporary constructions executed in such situations.
Another objective of the research is the model formulation "HomoUs" which incorporates and adapts to the real needs of emergency and humanitarian assistance the analysis made in temporary projects and modular, lightweight and convertible architectures.
The study covers the analysis of the products used, the geometric definition of the set, the connecting elements, the scheme of operation, actions and stresses required, and mode of execution and implementation.
The choice of case studies are made based on the materials used and the connecting elements, the dimensions of the assembly and the geometry used for application in modular "type constructions", taking as reference the human scale.
The proposal "HomoUs" expresses the results of the analysis of projects studied and proposed model for use in emergencies and humanitarian assistance.
Social aspects economic, organizational, implementation and evaluation strategies are added to the environmental aspects in the use of recycled and waste, and the use of parametric design.

Keywords: waste, recycling, parametric design, construction, humanitarian assistance.

1.- Introduction

The humanitarian and emergency assistance is a reality in many parts of the world geography. These kinds of situations are found in areas of social exclusion, war zones, in areas that have suffered natural disasters or seismic movements, or in areas that have been defined as a disaster area and are inhabited

The social reality of these situations requires our participation in improving their health and environmental conditions, well as in its organizational structure within the territory and the landscape in which they develop.

The scarcity of resources and products must be overcome with the contribution of strategies to optimize the resources available and incorporate inclusion measures.

Waste management, recovery of waste and recycling are observed determinants for use in such situations.

The importance of waste management is manifested also in the abundant regulations, and whose European reference the Directive 2008/98 / EC of the European Parliament and of the Council of November 19, on waste [1]; at national level, Law 11/2012, of 19 December, on urgent measures for the environment [2], Law 11/2012, of 19 December, on urgent measures for the environment [3], or the Order MAM / 304/2002, of February 8, by which published recovery operations and disposal of waste and the European waste list [4].

Resource optimization is a major factor. The geometry and parametric design give answer to this objective.

Waste, recycling, geometry and parametric design are defined as the basics of building types and models that respond to the needs of emergency or humanitarian assistance.

The analysis of projects for emergency architectures, modular, lightweight, convertible, and of products from waste and recycling make possible the formulation of proposals for this type of services.

Shigeru Ban develops designs for these needs in Port au Prince (Haiti, 2010), Kaynasli (Turkey, 2000) and Bhuj (India, 2001); Felix Escrig Pallares performs projects and proposals of modular, lightweight and convertible architectures; And Roberto Narváez Rodríguez and Andrés Martín Pastor define the "Caterpillar" project using parametric design and collaboration of students.

The research paper describes criteria and principles -obtained the result of analysis of projects and products- for the definition of essential elements that are part of the proposed architectures emergency or humanitarian assistance.

The proposals "HomoUs 1.0" and "HomoUs 2.0" materialize the determinations of research.

2. Object

The object of study is projects and architectures temporary, modular, lightweight, portable, that used parametric design and incorporating products from waste and recycled for use in construction of temporary nature, in emergency or humanitarian assistance.

3. Justification

The justification of the research is focused on human and environmental dimension for studying:

- Answers to space needs in emergency humanitarian assistance or using waste and recycled products,
- Proposals for new modes of intervention, making possible and feasible another type of architecture and construction.

- The formulation of types and construction systems applied to the realities of study.

4. Objectives

The development of the research is directed towards achieving the following objectives:

- The development of models and building systems that respond to spatial needs in emergency and humanitarian assistance, using recycled waste products and parametric design systems.
- The inclusion of measures of valuation, participation, and social inclusion in the execution of buildings intended for these services.
- The formulation of proposed "HomoUs" to answer the needs described above.

5. Hypothesis

To achieve the above objectives the following hypotheses are proposed:

- Is it possible, from the analysis of projects of ephemeral architecture and product from waste and recycling, the formulation of models and building systems that respond to the needs described?
- Is it possible to specify criteria and principles that define the mode of intervention in emergency or humanitarian assistance?
- Is it possible to define types and constructive models that attend to the space needs of these situations and realities?

Shigeru Ban performs reflections related to scenario set:

> "[…] *Can we incorporate the creativity of architects to provide higher quality to emergency architecture and to improve the lives of its occupants?* […]" [5].
>
> […] *What would happen if architects working in network sharing solutions to tackle more efficiently solve problems systematically repeated in different parts of the world?* […]" [6].

6. Methodology

To address the problem to answer to space needs in emergency or humanitarian assistance is necessary ask questions to narrow and define the search.

The first questions we ask are directed toward, What? and Why?:

- What we want to build? What requirements must be met?

The following questions are directed towards, Who?:

- Who project the construction? Who made the constructive elements? Who perform the construction?

We continue with questions like, How? With what?:

- How do we made the construction? What means? What products we use? How to organize / develop work?

Type questions, When?:

- When we define the elements of the project? When we checked the dimensions of the elements? When we made the elements? What chronological sequence assembly / performance continue to?

We need to search for answers:

- Analysis of ephemeral architecture projects.
- Analysis of the use of waste and recycled products in lightweight, flexible, modular and portable buildings.
- Analysis of elements and projects that are defined by parametric design.

The analysis and case study is directed towards the establishment and development of criteria and principles for application in construction projects and temporary emergency or humanitarian assistance.

The development of standards and principles enables the development of proposals and alternative type models that respond to the needs expressed.

7. Case Study

To obtain models and criteria for intervention is performed in the first place the analysis of projects flexible, modular and portable architecture, composed of simple elements and simple joints.

Auditorium outdoor of Alameda of Jaen (Félix Escrig and Sánchez) [7] using coupled arches dropdown (fig. 1)

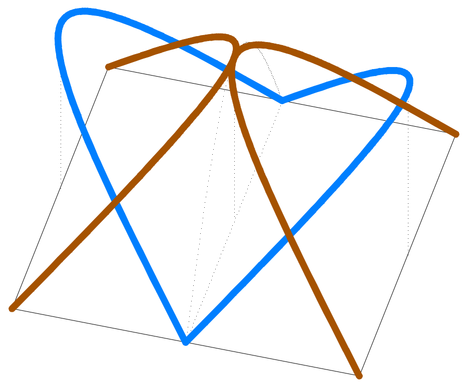

Fig. 1 “Schematic structure of four coupled arches (Félix Escrig y Sánchez)”.
Drawing: The author

The structural system allows variations in the elements, using mated pairs structure (Fig. 2), or by variations coupled isosceles trapezoids (Fig. 3).

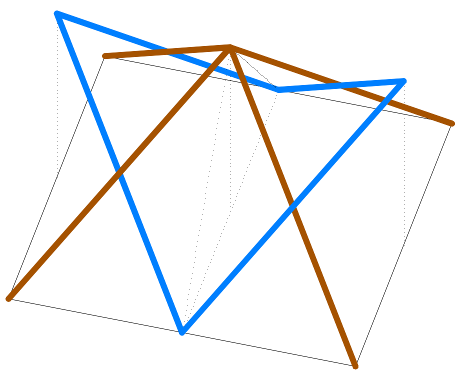

Fig. 2 “Structure of coupled pairs”. Source: The author.

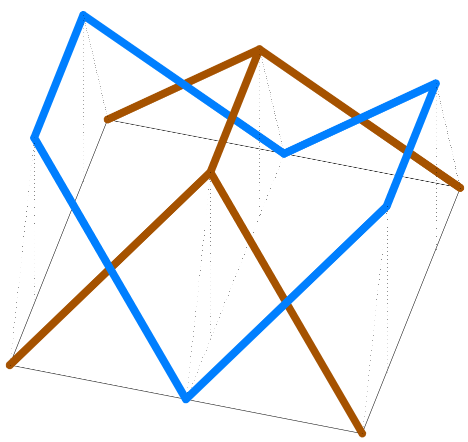

Fig. 3 “Structure of coupled isosceles trapezoids”. Source: The author.

Both structures allow easy implementation of the project and its adaptation to the geometry of space available, following the functioning of the structure of coupled arches.
Within the emergency architectural projects highlights the structure of cardboard tubes, wood joining knots and ropes that Shigeru Ban performed for the community of Tabarre (Port au Prince, Haiti, 2010) [8]. Structure (Fig. 4) enables easy mounting by the users of the project.

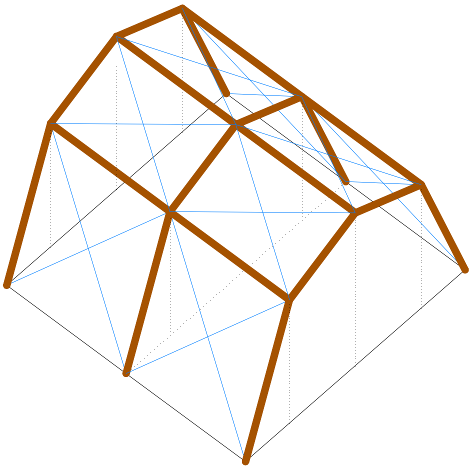

Fig 4 “Schematic structure for the community of Tabarre (Port au Prince) designed by Shigeru Ban”. Drawing: The Author.

For the project to Kaynasli (Turkey, 2000) of Shigeru Ban [9] used cardboard tubes applying transparent polyurethane waterproofing layer and introducing thermally insulating paper inside the tubes. The foundation is performed reusing cases of beer or soft drinks. In figure (Fig. 5) the project outline is drawn.

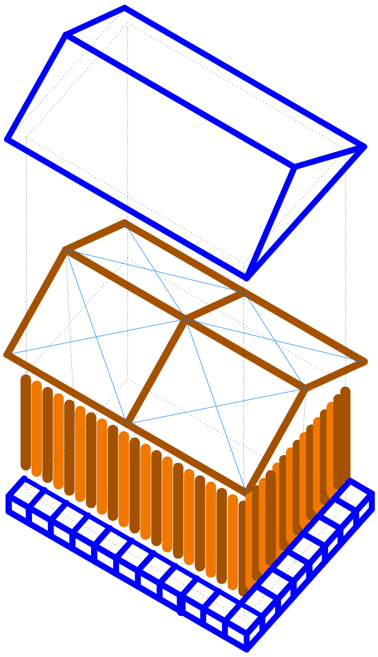

Figure 5 “Schematic structure of Paper Tub loghouses
Kaynasli (Turkey, 2000) designed by Shigeru Ban”. Drawing: The Author.

In the Paper Studio project (2003), Shigeru Ban humanizes the architecture and adds aesthetic expression [10]. The structure is based on barrel vault generated by grid cardboard tubes Fig (6).

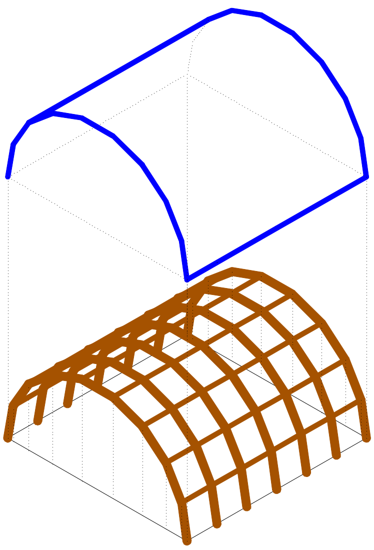

Fig. 6 “Schematic structure of Paper Studio in Fujisawa (Japan) designed by Shigeru Ban”. Drawing: The Author.

The Caterpillar project [11] uses simple materials based on geometry, assembly rigidity is obtained by the sum of all its elements (Fig. 7)

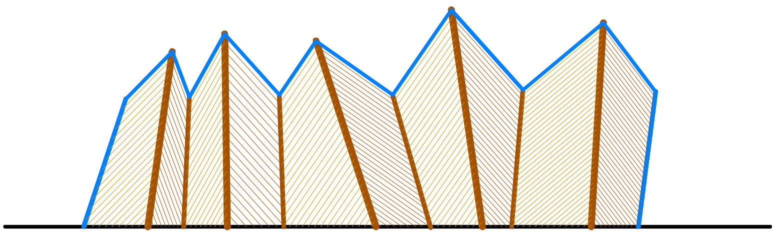

Fig.7 “Schematic structure of the "Caterpillar"
Roberto Narváez Rodríguez and Andrés Martín Pastor”. Drawing: The Author.

In connection with the application of parametric design underline the projects using recycled products and pre-recycled in Table 1:

Name of project	Author	Product recycling / pre-recycling
P.F.1.	WORK.AC	Cardboard concrete formwork tubes [12]
Pached	Tom Pawlofsky, Instructor	Corrugated cardboard [13]
Cardborigami	Tina Hovsepian	Cardboard [14]
Pallet Canopy	Digital Arts Center	Pallets [15]
Pipe Furniture	Sebastien Wierinck	Polyethylene from recycled bottles [16]
Table Cloth	Ball Nogues Studio	Tables and stools with no two of the tables alike [17]
Stand para Metropolis	Urban A&O	Plate white 100% recycled polyethylene (UHMWPE) [18]

Table 1 “Projects with parametric design using recycled products”.

Table 2 summarizes the joining elements used in projects that use parametric design.

Name of project	Author	Products and joining means
Chromatex.me	SOFTlab	Clips [19]
Corefab-Nubik	Ammar Eloueini. AEDS	Plastic ties [20]
Moma PS1 Canopy	nARCHITECTS	Green bamboo, freshly cut, for the design and unions [21]
ICD/ITKE Pavilion	Achim Menges and & Kippers	Friction between elements [22]

Tabla 2 “Products and joining means in projects that use parametric design”.

Table 3 summarizes other types of products used in the general configuration of projects:

Name of project	Author	Product used in the general configuration
Swissbau Pavilion	ETH Zurich	Wood conglomerate boxes [23]
THE SEQUENTIAL WALL	Gramazio & Kohler ETH Zurich	Wooden slats [24]
THE RIPPLE WALL	Digital arts center. University of North Carolina at Cahrlotte	Plywood board [25]
WINNIPEG SKATE SHELTERS	Patkau architects. Winnipeg. Manitoba. Canada	Wood veneer [26]
TRONDHEIM CAMERA OBSCURA	Norwegian Univertity of science and technology Trondheim. Norway	Fir planks standard length [27]
Croatian pavilion-venice biennale	Leo Modrcin et ali	Steel bars [28]

Table 3 “Products used in parametric architecture projects”.

Other recycled products that enable its application in this type of project, are summarized in Table 4, have been taken from the *Guide materials for sustainable construction writing content* [29].

Sustainable products
Oriented strand board OSB sandwich panel OSB + cork + tongue-and-groove Fiber board of wood and cement or magnesite Chipboard from tetra brick Fiber board of wood and magnesite Glulam Poplar wood laminate Forest timber from sustainable management Fir timber

Table 4 “Sustainable products”.

Alternatively recycled wood products is plate 100% recycled and recyclable plastic, elaborated with polyethylene mixture and recycled and recyclable polypropylene [30].

9. Results

The results of the analyzes of the projects studied are specified in two main aspects:

- Criteria and principles.

- Proposals "HomoUs 1.0" and "HomoUs 2.0" models

9.1.- Criteria and principles

For the realization of the criteria and principles we take as reference some of the reflections of Shigeru Ban. Making contributions to universal solutions and global application.

- *Optimization* of resources. It is essential the choice of product / material for the design process. "[…] *I use an existing material differently from the usual and thereby I attempt to find him a new meaning* […]" [31].
- Economy -*Low-COST*-, "less is more", fewer resources and more results. "[…] *The use of humble materials, work with what is at hand* […]" [32].
- The *Temporal Dimension* of projects depends on the social respond. "[…] *The life of a building in fact depends on if people want or do not keep it* […]" [33].
- Simplicity in construction -*Low-Tech*- looking for local solutions. "[…] *Avoid very sophisticated details* […]" [34].
- Looking for nearby materials -*The existing*- adaptation and optimization of resources. "[…] *Find a new use of everyday materials* […]" [35].
- The linking of "form and function", structural design and geometry. "[…] *I am interested in the structure and material as process, not as a result* […]" [36].
- Commitment to the environment. The project should refer to the principles expressed by Michael Braungart and William McDonougn in *Cradle to cradle, redesigning the way we do things*, [37] improving the concepts of "reduce, reuse, recycle".
- Architecture, participation and social commitment. The project must transcend construction, involving and participating as many people. "[…] *Usually, I work with students, and they are strongly influenced* […]" [38]; "[…] *Buildings can be constructed by students, everyone is invited to participate, even children* […]" [39].
- *Flexibility* is a key factor for durability of construction, enabling adaptation to the needs and functions of its users.

The criteria and principles from the analysis of the projects are specified in the following sections:

In relation to products that conform the project:

- Be trained by inexpensive recyclable and worthless / financial compensation in case of being dismantled by outsiders, thereby preventing theft and damage to buildings materials.
- Be able to be assembled and joined with simple and economic elements.
- Being light and in case of fall have little risk to people.
- The products must have certificates proving their sustainability.

In relation to performance:

- Must be able to collaborate in the execution of the work persons to whom it is intended construction.
- Ability to perform transformations and adaptations as the project is done. Versatility solutions
- Easy handling during execution of the work, people can collaborate without qualification.
- Ability to use the products as auxiliary elements in developing works

In relation to design:

- Using a small number of products and materials.
- The geometry construction provides stability and functionality to project. Form and function.

- The construction must have aesthetic values and be integrated into the landscape.

In relation to environmental criteria:

- The construction must be able to be recycled or reused once it has served its time function.
- Construction can prolong your life easily with proper maintenance and replacement of parts or damaged items.
- The use of concrete and steel should be avoided.

9.2.- Proposed Model "Homos 1.0"

The proposal “HomoUs 1.0”, adapts and improves the concepts contained in the project for the community of Tabarre (Port au Prince) and Paper Studio in Fujisawa (Japan), designed by Shigeru Ban.

The proposal “HomoUs 1.0” provides the improvement in thermal performance of the projects identified by the incorporation of air layer contained between two fabric layers. A fabric layer forms the outer cover and another layer constitutes the inner cover construction.

The structure of “HomoUs 1.0” project, can be formed from recycled cardboard tubes or pipes recycled tubes, forming stereo bar confer stability to the assembly and make possible the arrangement of the textile fabric layers.

The lateral surfaces of the joint make possible the incorporation of two textile covered, outdoor and indoor. The lateral geometry allows the expansion of the array surface with the addition of new modules.

Figure 8 shows the proposed "HomoUs 1.0", being the top of the scheme the outer cover; the intermediate part corresponds to the structure of stereo bars; and bottom is interior textile cover.

The module surface is 12 m^2 in the inside and 14.40 m^2 on the outside, forming rectangles of 6 x 2 x 2 meters and 7.20 meters respectively.

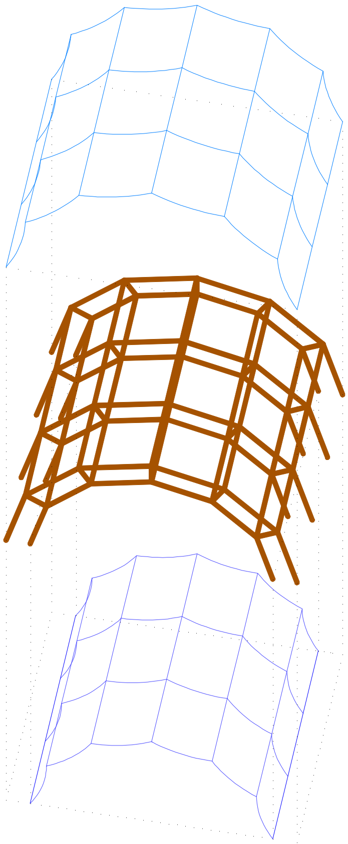

Fig.8 "HomoUs 1.0". Project scheme. Source: The author

9.3.- Proposed Model "HomoUs 2.0"

The proposal “HomoUs 2.0”, is based on the use of geometry.

The project takes as a reference "Caterpillar" project, “HomoUs 2.0” having a unique structural module.

The geometry of HomUs 2.0 makes possible the use of sheets of recycled products as plywood panels or sheets of recycled plastic.

The union of the elements is performed by cable ties and plywood sheets or sheets of recycled plastic and screws.

The module covers an area of 3.85 m2; having 3.70 meters in larger and 2.45 meters in the lower dimension; module width is 1.25 meters. The greatest height is 3.70 meters and the lowest is 2.45 meters.

Figure 9 shows the model schema of “HomoUs 2.0” proyect.

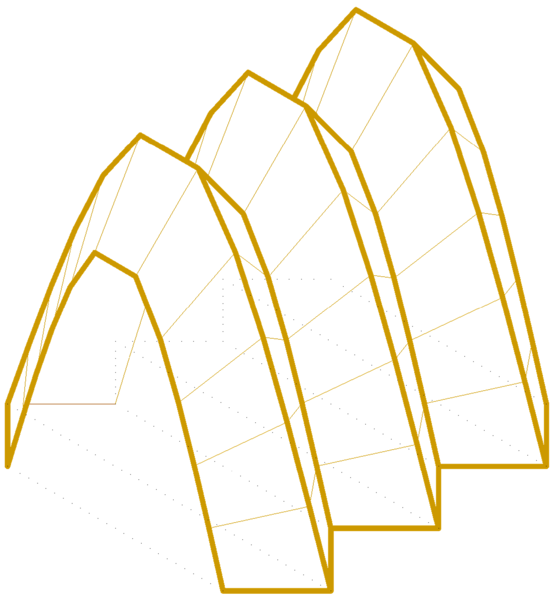

Fig.9 "HomoUs 2.0". Project scheme. Source: The author

The criteria, principles and proposals, summarized the research work, having as purpose to provide solutions to situations of temporary emergency or humanitarian assistance.

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