PALLET HOUSING SYSTEM - PHS©

A potential wood-frame design applicable in different contexts

Cristian Suau [1]

[1] Visiting researcher at Innovative Design Unit, School of Architecture, Chalmers University of Technology, Sweden
Postdoctoral research fellow at Building Design Unit, School of Architecture, NTNU, Norway

ABSTRACT: This research on experimental housing design has initially been supported by the Ministry of Education, Spain (2003) and carried out at Chalmers University of Technology. It also has been registered as patent design in the Swedish patent and registration office. It constitutes a continuation of teaching experiences and previous studies on potential wooden architecture since 2001, by using disused or recycled pallet boards as wood-frame systems both in dwelling framing and mobile furniture. PHS© shows new possibilities for flexible housing systems easy to transport and assemble. Since 2004, an advanced research on potential wood architecture and PHS© project is taking place at the Faculty of Architecture and Fine Arts, NTNU, Norway.

Conference Topic: 6. Recycled architecture
Keywords: Experimental elementary dwellings - Lightweight timber construction - Pallets boards.

INTRODUCTION

Purchasing a house is one of the biggest expenses that a dweller ever invests. But, does it need to be costly? One field where costs can be reduced and where affordable building solutions are undergoing great experimentation is the domestic application of junk or disused materials. Also the search of new elementary dwellings is partly illustrated by the number of self-builder and designers who are making houses utilizing, for instance, tea-containers or reconditioned shipping boards, by readapting various materials under low-tech manufacturing. However, what is the “cutting edge” of eco-dwelling systems today? The PHS© project performs as an affordable housing structure based on pallet units capable of becoming an elemental dwelling. Also it provides thermal comfort by using passive techniques [1].

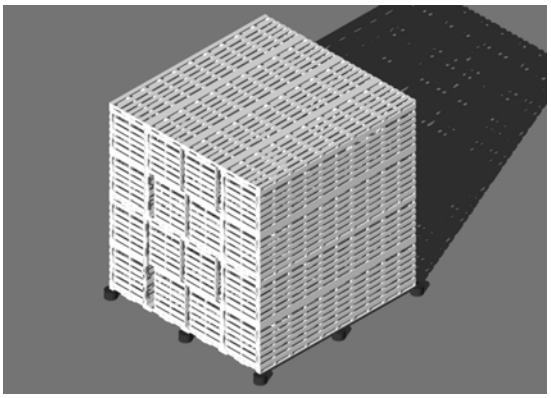

Figure 1: Rough 3D model of PHS© timber frame. The frame structure consists of Euro-pallet or US stringer boards, applicable in several contexts as roof, floors and wall framing and embraced mainly by plywood boards, tensile structures, etc. Source: Suau.

What should we design instead? Here, PHS© also appears as a manifesto of Elementarism against over-packaged architecture, exploring the use of delimited models as a strategy for freeing up unexpected trails of spatial production.

Thus this design process provides new flexibility and interoperability, by identifying potential obstacles; exploring possible architectures; looking at potential low-technologies and defining architectural models and guidelines. It is an open design system, involving several general parameters such as programmatic condition, climates, location, a flexible and lightweight structural frame and a cheap budget.

Inevitable, we may find specific design parameters in PHS©: flexible and collapsible plan (variable divisions of interior spaces and flexible furniture) and low technology construction. Basically, this study is focused on architectural, constructive and climatic tool design both to achieve simpler wood-frame constructive solutions -applicable both in buildings and furniture- using recyclable shipping pallet boards and also to generate an indoor thermal comfort by passive energy systems applied in experimental sheds located in cold, temperate and arid lands.

2. ASSUMPTIONS

1. Recycling of used wood materials for building and structural appliances formulates an innovative design process for elemental low-budget housing units and explores new technical applications and uses of timber framing panels in built and natural environments.

2. Simple passive techniques such as orientation, building shape, colours, materials changes in the skin, and shading devices can improve housing indoor comfort. However, the impact of these factors can vary according to specific climatic parameters and the occupancy in dwellings.

3. BUILDING EXPERIENCES AND DEVELOPMENT OF PHS© COMPONENTS

This structure system [2] is a hybrid based-panel construction of twin pallets (2 pallets boards of 800mm x 2400mm). Floor and roof framing are connected mainly by internal aside trimmers and at least one-deck side is covered with thin panel-type sheathing (mainly plywood or OSB boards, 2400mm x1200mm of 6mm thickness). Wall framing has the same modulation and side sheathing.

	LIGHT PALLETS	MID-HEAVY PALLETS	HEAVY PALLETS
THICKNESS OF DECKS (T) IN MM	15 < T < 17	17 < T < 20	T > 20
LOAD CAPACITY	From 0 to 400 Kg	From 400 to 800 Kg	From 800 to 1500 Kg
USE	One-way pallets or shipping pallets	Limited one-way trip pallets	Multiple trip

Table I: Load capacity. There are different kinds of pallets: heavy pallets, mid-heavy pallets, and light pallets. They are distinguished by the thickness of the decks and their load capacity. The PHS© tests have utilized mainly mid-heavy pallets and light pallets.

After arise the whole frame, the final embracing and also exterior cladding is carried out by overlapping a structural sheathing, consisting of mainly plywood board with waterproof adhesive. The sheathing panels can be applied vertical and horizontally. Diagonal application of lumber sheathing can also be applied instead of. However, the angle cuts in the diagonal approach require more time and materials. If climatically the dwelling frame does not entirely covered by sheathing but perform as a vertical shading device (i.e.: PHS walls in the Atacama Desert); the bare pallets are embraced by standard metal connections or tensile bracing.

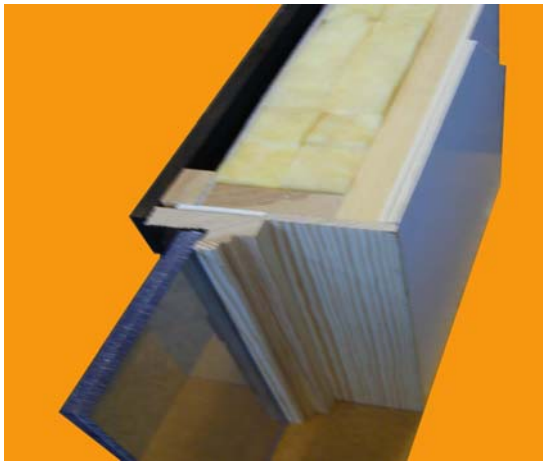

Figure 2: Constructive detail of **PHS© Wall** applied in the Scandinavian case. It consists of the following:
1. External sheathing panel. Structural sheathing based on plywood; waterproof treatment painted red or black. Load-sharing and bracing properties.
2. Wood-Frame: Euro-Pallet board (120cm x 80cm), filled with thermal insulation (100mm mineral wool board or wood-wool slab) and vapour barrier.
3. Internal sheathing panel. It is non structural. Thin plywood board, OSB or gypsum boards.
4. Openings: double glazed windows (low-E with air fill). Also can be applied poly-carbonate boards. Both with timber frame. Interior movable insulation added over solar windows at night to reduce heat loss. There are two types of windows combination: fixed and tilt- turn ones.

In terms of thermal insulation, its cavity between the top deck and the bottom deck is fully insulated. Depending on the climatic context and local feasibility, the types of insulation utilized in the cases are grouped into batts; rigid or semi-rigid (i.e.: mineral wool, wood-wool slab and expanded polystyrene). In terms of installations, the pallet cavity between deck-sides allows easily electric wiring, plumbing pipes and ventilating ducts.

Summarizing, fundaments of consists of:
1. Self-bracing by structural sheathing
2. Simple geometry for fitting-out and façade
3. Standard mechanical galvanised connectors (floor suspended and floor laid on top)

Figure 3: Structural test of PHS-F1© developed in my studio in Sweden. The whole structure consists of 8 Euro-pallet boards, collapsible and mobile. Its layout area is 80cm x 240cm. Source: Suau.

Due to its building features, the PHS© constitutes a semi-finished product consisting of a twin-board system, a wood-based board [3]. The principal components are the following:

A. PHS© Wall / Floor / Roof is a prefabricated twin board system based on ribbed slabs with structural plywood, OSB or the like in both deck-sides. They perform as bracing elements. It is filled in

with several insulation materials, depending on the climatic parameters.

B. PHS© box-section beams is a prefabricated system based on ribbed slabs with 3-ply core plywood, OSB or LVL panels as bracing elements. Also it can be a see-through structure (i.e.: clerestory in Scandinavian case study) with tensile bracing system or trimmers lapped over stringers.

C. PHS© shading devices. This is a bare framing wall based on pallet boards distributed along facades, painted according to the location and with metal plates and standard connections as bracing elements.

D. Standard connections and joints (Gang-nail punched metal plate fastener / Wood screws in floors, walls and roof / Ordinary round wire nails in floors, walls and roof). Also perforated sheet metal plates (rafter-purl in anchor / joist hanger for web beam); prefabricated bases (cast in / height-adjustable dowelled) and special connectors (wires and turnbuckles for V-tensile bracing).

4. METHOD

This study has been oriented towards a research by design. On one hand, spatial, structural and building solutions have initially been experimented on site (models 1:1 scale) in order to demonstrate the feasibility and flexibility of PHS© modules.

Two movable devices have been tested: **PHS-F1** and **PHS-F2**. The first one is an operative working cabin made by 8 Euro-pallet boards and it is a foldable system (See figure 4). The second model is a 4-seats couch with a foldable cover of plywood board. By assuming that disused pallet boards were donations or free fares and excluding handwork hours and tools, I might estimate that construction budgets of PHS-F1 and PHS-F1 were both 165 and 43 euros each. The items included in calculation were standard connections and joints, paints, blinds and wheels.

Figure 4: Constructive test of PHS-F1© developed in Sweden. After several simulations, the adopted connector system is based on galvanised gang-nail punched metal plate fastener; wood screws and round wire nails. The roof is supported by a tensile V-bracing. Also the collapsible system requires both lateral roll blinds and a folding light arm and desk made by recycled MDF boards. Source: Suau.

On another hand, about how to improve indoor climate in the PHS© dwellings, the preliminary designs has been first compared with traditional analytical tools (i.e.: Givoni's bio-climatic chart and Mahoney tables) and solar diagrams. Climatically computer simulations (mainly, DEROB-LTH [4]) indicates that indoor comfort conditions may be improved in elemental dwellings, by using simple passive technique: use of disposed, disused, recyclable wooden materials; appropriate insulation materials; wood-frame shading devices; climate-adapted colours in facades and orientation of openings as solar collectors.

5. DESIGN GUIDELINE FOR PHS© MODELS

The Pallet Housing System© (PHS**)** is applied in three housing units which formulate an entire life cycle model combining traditional and new techniques by recycling timber shipping boards with lightweight insulation materials in 3 different climatic contexts: Scandinavia (Gothenburg city and Västra Götaland); the Mediterranean landscape (Barcelona city) and a remote location in the coast of the Atacama Desert .

5.1. PHS© Scandinavia case
Sweden, Västra Götaland, Gothenburg
Geographic location: 57° 42´N 11° 58´E

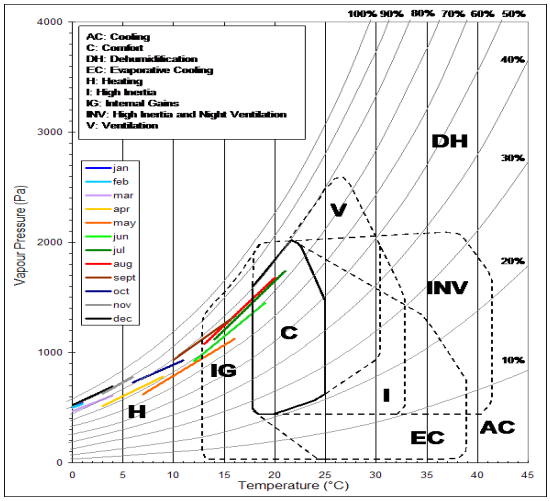

Table II: Bioclimatic data of Gothenburg city, according to Givoni's diagram. Source: M. Müller [5].

1. Form. The dwelling is a cubic compact shape (plan layout based on 6 times 8 pallets) facing South. It has an attic as sleeping area naturally well-lit. Its envelope is well-insulated (see figure 2) and its framing is based on Euro-pallet size. The main floor contains sanitary services facing north and a flexible multifunctional area with mobile furniture. The roof is flat with a slight slope and is covered by a grass layer.

The Direct Gain Systems (DGS) is both the south-glazed façade and a clerestory which perform as an efficient solar collector [6]. The clerestory is a

horizontal opening projecting up from the roof plane. In winter, it admits extra-direct sunlight and co-operate when there is a solar blockage of the south wall by nearby obstructions. This bare beam performs as shading device during summertime.

2. Solar orientation. It is the main factor during winter. Large or medium-size plus double/triple-glazed openings facing south are the most suitable. During wintertime, mobile insulation is recommended to reduce night-time heat losses.

3. Ventilation. Prevailing southern winds along the year keep an average speed of 4 m/sec. Low rate of ventilation is required.

4. Materials. Due to the climatic chart, the dwelling mostly requires heating and internal gain. Thermal insulation and exterior dark colours (high absorptance and high emittance, over 80%) must be utilized in order to gain a comfortable indoor climate.

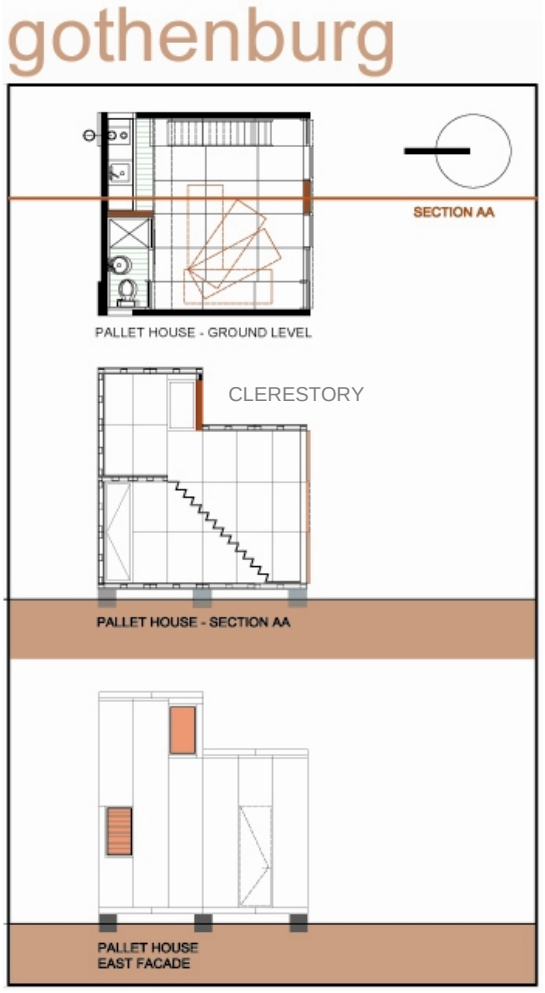

Figure 5: Plan, section and side façade of PHS© Scandinavian case. Location: Landvetter.

5.2. PHS© Mediterranean case
Spain, Catalonia, Barcelona
Geographic location: 41º22'N 4º12'E

In this case study, a passive cooling and heating system are required along the year. Nevertheless, we may find an important comfort zone between May and September.

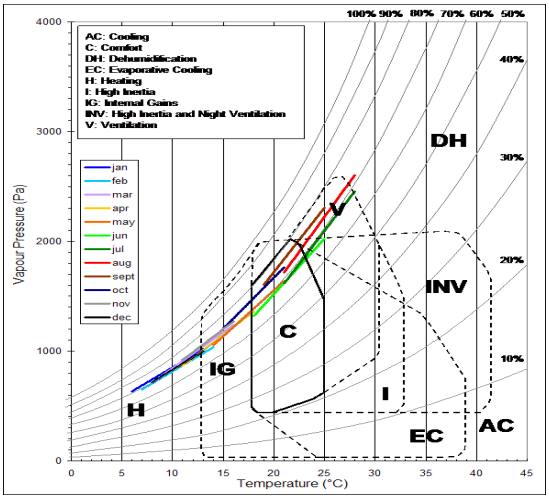

Table III: Bioclimatic data of Barcelona city, according to Givoni's diagram. Source: M. Müller

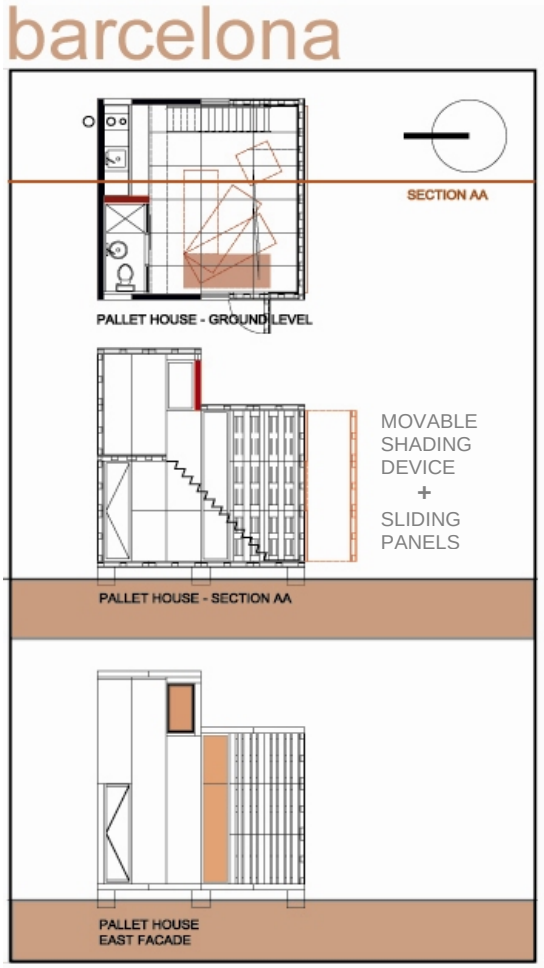

Figure 6: Plan, section and side elevation of PHS© Barcelona case. The south façade contains a movable shading device and sliding opaque panels, providing privacy. Source: Suau.

1. Form. The dwelling is a cubic compact shape facing south, based on a framing system and mobile shading device. Layout plan is 6 times 8 Euro-pallets.

Its array contains kitchen and bathroom buffers facing north plus flexible social area. The roof is flat with minimum slope, well-insulated and has an exterior sand layer (low-absorption properties).

During summertime, the dwelling is cooled by natural cross ventilation through shaded and glazed mobile panels. Thus, it keeps a lower temperature.

2. Solar orientation. It is the main factor. Mobile openings facing south, but also east and west, is the most suitable way. During wintertime, double-glazed and medium-size openings may minimize cooling. During summertime, pallet shading devices as movable exterior framing may reduce overheating.

3. Ventilation. By existing prevailing southern winds during hotter seasons and western winds during cooler ones, the house requires mobile shutters both to regulate solar radiation. Interior two-glazed sliding panels prevent excessive airflows during windy season and avoid thermal loss.

4. Materials. Basically in this context, the envelope needs both light thermal insulation and thermal storage capacity. A combined system of outer light thermal insulation based on wood-wool slabs is purposed in walls and roof sections. Exterior light colours are highly recommended.

Figure 7: Rendering of PHS© Mediterranean case, outskirts of Barcelona (nearby Cerdanyola). The structure consists of a Euro-pallet frame, based on 120cm times 80cm each board. It is oriented to south and has double skill. The outer envelope towards south is a whitened shading device. Source: Suau.

5.3. PHS© Atacama case
Chile, Tarapacá, Iquique

Geographic location: 20° 12' S - 70° 11' W
The bioclimatic chart of Iquique city may be found by reviewing "The Pallet House" paper, PLEA 2003.

For dwelling in semi-arid lands, cooling is the most important agent along the year, but in cool season certain heating is required for additional internal gains.

1. Form. In comparison to the previous pallet house model developed in 2002, the new house has been shrunk and the stringer pallet has been integrated both as framing system and shading device. The upper roof is a well-insulated floating cover with vertical mobile shading devices facing south and north. The upper level contains the sleeping area and adjacent verandas. The building is cooled by cross ventilation. Thus, it keeps a lower temperature during daytime. The roof is also flat with minimum slope, well-insulated and has an exterior sand layer with low-absorptance properties.

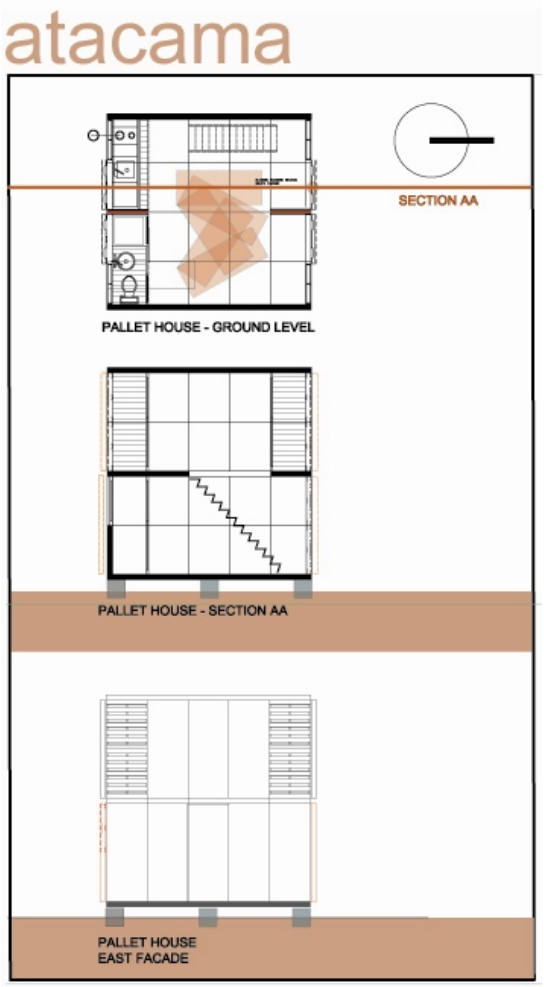

Figure 8: Plan, section and side elevation of PHS© Atacama case, coast of Iquique, Chile. Source: Suau.

2. Solar orientation. Computer simulation indicates that solar orientation is the primal factor. Openings facing north-south are the most suitable arrangement. During wintertime, simple type of double-glazed windows may minimize cooling. During summertime, the action of shading devices made by bare pallet framing may reduce overheating specially during afternoon.

3. Ventilation. Prevailing southern winds (speed of 3.6 m/sec) are canalized and regulated throughout the verandas. The shaded space under the floating roof is cooled through manual control of sliding shading devices and windows.

4. Materials. Due to the climate does not show extreme changes of temperature (short thermal variation between summer and winter), light materials

may be utilized in order to obtain a comfortable indoor climate. Nevertheless, thermal insulation and light colour (high emittance, 85-95%) are recommended specially in the exterior floating roof and walls because it absorbs the most solar radiation during summer.

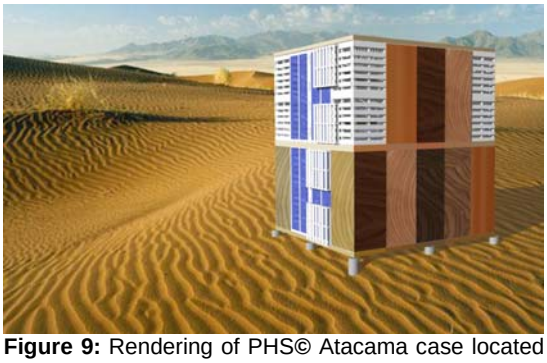

Figure 9: Rendering of PHS© Atacama case located outside the urban limit of Iquique. Source: Suau.

6. CONCLUSION

PHS© design is an accidental research by design. It began from a playful combination and assemblage of residual boards without a specific goal to be a wood-frame housing system, with a particular human scale. Within this exploratory process, these operations engendered an elemental system for a cheap, mobile and flexible living. Here, PHS© design proposes the development of variable and interchangeable elements of construction: exterior walls; interior walls and mobile furniture, capable to define temporary spaces and new uses well-adapted to user needs and climatic variations.

Figure10: Framing of PHS© Pallfriggebod in Sweden. This elemental dwelling can be raised in any plot not exceeding the layout plan 10 m^2. Source: Suau.

Programmatically, PHS© design shows the possibilities for versatile and creative uses offered by shipping boards applied in experimental or temporary dwellings that can be assembled or disassembled, foldable, refillable and the like. It poses the notion of PHS© as interchangeable *packs*, where an architectural understanding of these products may achieve a change in new usage patterns or in the expectations about its radical appearance beyond the conventional realms of construction market.

The cases above mentioned have a remarkable adaptability, both in response to changing climatic conditions and to foster elementary wood-framed sheds, uncomplicated, cheaper and 'greener'. Finally, PHS© has recently been registered in PRV, the Swedish Patent and Registration Office.

7. ACKNOWLEDGEMENT

First, I express thanks to the permanent support of the Spanish Ministry of Education and Science (MECD), who have given me the possibility to carry out this study and consequently enrich my academic experience in new research centers. This experience has not only covered theoretical field but also develop a tactile and hand-made exploration into wood.

The Innovative Design Unit at Chalmers University of Technology has given me a keen umbrella. Above all, I wish to highlight the critical and provocative reflections of my supervisor, Henric Benesch. Apart from him, I must express thanks to James Silverman, British photographer, and his intuitive way to document my PHS© handwork in our studio in Gothenburg.

Finally, I thank the cooperation of anonymous Pallet supporters. We may find them anywhere. Mainly, these disused panels belong to no-one or have an extreme low cost and lie in corners nearby supermarkets or ware stores and, of course, in factories or port areas.

8. REFERENCES

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[2] Pallet is a rigid horizontal platform of minimum height compatible with handling by pallet trucks, and/or forklift trucks. The Pallet acts as a unit load base and is constructed from different materials, primarily wood. There are different types of pallets such as 4 way entries and 2 way entries, and various styles such as stringer and block pallets (Euro-pallet).

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