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41st IAHS WORLD CONGRESS
Sustainability and Innovation for the Future
13-16th September 2016
Albufeira, Algarve, Portugal

WASTE IS MORE
WASTE REUSE IN ARCHITECTURE

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Keywords: Reuse, Waste, Sustainability, Architecture

Abstract *Studies about reusing waste materials in architecture have produced in recent times unexpected and very original results. Anyway, this is still an unexplored field, that could be prosperous in certain geographical contexts and economic conditions or limited to few experiences of experimentation in others. In both these contexts, the limits for the spread of building systems that reuses waste products are basically two: the first one belongs to the cultural sphere, the tradition and the difficulty of accepting ways of building and living radically alternative (unless they're not limited to academic experiences, temporary uses, or in any case, when they don't interfere with traditional living); the second one includes the absence of specific regulations and the need for certification of building components. It follows that structures built with waste will be very different, depending on the environment inclination to experimenting in this field. Temporary shelters, pavilions, installations, experimental prototypes, street furniture and equipment for parks are common examples wich testify the success of the reuse of waste almost everywhere, but just in few cases and few countries it is possible to see examples of efficient waste architetture (not temporary), such as residences, offices, restaurants, places of workship, sometimes built simply adding natural materials, typical of the geographical context (like earth, straw, bamboo), to waste.*
And since building, among the industrial activities, is the first for environmental impact, consumption of resources and territory, pollution and waste generation, it is also our task and our responsability, as architects, to take, where possible, new ways of investigation and experimentation on the theme of reuse.
The contribution analyzes the different approaches to this theme and the resulting currents of reuse in architecture, distinguished in: reuse for emergency, reuse for research and , reuse for ecological and environmental sensitivity, reuse for creativity.

1. INTRODUCTION

Construction industry is responsible for about one third of world energy consumption and 40% of material consumption, it generates 45% of air pollution [1] and, in Europe, it produces 50% of total waste [2].
Together with construction waste, even all other consumer goods which have exhausted their purposes and capabilities are put aside or trashed, due to necessity, obligation or merely desire, because they are no longer usable owing to inherent faults, decline, or dangerousness. Most of them are disposable goods, designed with planned obsolescence, always well preserved and protected by different packagings that ensure their safety from producer to consumer. This has provoked a exponential increasing of waste production, mostly hard to dispose (it concerns, for example, waste of electric and electronic equipment – WEEE).
Whichever it is the origin of waste, this is straight connected to the production process of the product, from extraction of raw material to its disposal.
There is, therefore, a close relationship between primary resources and energy consumption and waste production. Annual studies by *Global Footprint Network* association reveal a raw material and energy consumption nowadays almost double in relation to what the Earth itself could offer, at the expense of both poorest Countries, which have a lower influence on global analysis, and also future generations.

2. WHY REUSE?

In construction industry, all the phases of a building life cycle produce waste: from extraction, transport and processing of primary resources, to their transformation in raw materials and products to be packaged and carried in building site, their assembly and installation, use and maintenance, until the final disposal which, after the demolition, includes the removal, transport and disposal of waste materials and, where appropriate, their repurposing.
After the latter phase, based on waste potential, there are four different possible actions:

1. Reuse the item for the same previous function, if it preserves entirely its original features;
2. Recover some of its components and employ them again for the same previous use or for a comparable one;
3. Recycle materials and components, which go back again in the production process to get new products;
4. Thermal treatment, to recover energy.

The greater is the designer's attention to building's and material's life cycle, the more appropriate will be his choices.
Reusing waste material is really favorable for different reasons, both environmental and economical: it extends the product's life; it encourages creativity and "non conventional" choices; it reduces waste; it distributes the item's production costs along a wider period; it reduces and sometimes avoids raw material and energy consumption, necessary for a new item's production; the reused item is less expensive than a new one. Except for obvious advantages, reusing has also some limits: first of all, it is not possible to reuse indiscriminately all discarded items, because of need, hygiene or health; secondly, sometimes it could be economically or ecologically disadvantageous, because reusing an

item could require more expensive procedures than producing a new one.
It is possible to reuse a product in different ways, in relation to the features of the product itself, for example its ergonomics, its material and its deterioration level. Generally, there are five different types of reuse [3]:

1. Exact Reuse: the item is used without any kind of intervention for the same function it had previously;
2. Appropriate Reuse: the item is used without any changing, but to fulfill a new function;
3. Minimal Changings Reuse: item is lightly alterated before its reuse;
4. Material's Reuse: the item is dismantled with the aim to reuse the material whose it is made;
5. Component's Reuse: the item is dismantled with the aim to pick and reuse its pieces.

3. REUSING WASTE IN ARCHITECTURE

In architecture, reuse could have a double meaning: it is possible, in fact, on one hand to reuse a building or an abandoned place, which already became waste itself and, on the other hand, reuse material and products from construction or other industries which, once became garbage, could be part of a new structure. If reusing architectural parts and components has always been a custom, specially in the past, reusing waste from other industries seems to be a new trend, proved by numerous buildings all over the world.
In Italy, a multitude of reused waste in architecture come from building demolition. In other countries and contexts, garbage originated from daily activities (as plastic bottles, aluminium cans, newspapers) or from transport and industry sector (as wooden pallets, reels, galvanized drums) at the end of their life cycle become non conventional building materials for façades and permanent or temporary structures, such as houses, schools, parks, pavillions. Waste items are chosen in relation to its material, its shape, the composition or decomposition possibility, the standardisation, its abundance or availability.

Figure 1. Three different reuses of plastic bottles in architecture: *Plastic bottle house* in Nigeria (a), *Morimoto restaurant* in New York (b), *Vegetable nursery house* in Vietnam (c).

Depending on the needs and construction techniques used, then, the same type of waste can assume different functions in the new construction. Plastic bottles, for example, are one of the most common waste around the world. If filled with sand, overlapped and blocked with clay, they can take the same function of the bricks in a masonry structure, ensuring good performance in terms of thermal insulation and, despite appearances, even a good reaction to the earthquakes. The same object can also be reused as filler element, or take advantage of the ability to spread the light to create elegant backlit walls, and transparency for greenhouses.

3.1 Reuse for emergency

In case of economic insecurity situations or after environmental catastrophes, reuse waste for emergency shelter and basic services seems a conscious decision, sometimes inevitable. It is a common solution for those who have no other materials to build their own home and decide to do it themselves, using what the street or the landfill offer. Most of the time the final product consists of a shack, a makeshift refuge uncertainly healthy and aesthetically pleasing. However, the results can sometimes be extraordinary, veritable tourist attractions, such as the Buddhist temple *Wat Pa Maha Kaew Chedi*, nearby Bangkok, Thailand: its particular structure is entirely made up by 1.5 million of glass bottles recovered and used as transparent bricks. Every part of the temple was built by monks who live there. The use of glass bottles as a building material has been for them a surprisingly interesting solution, thanks to the material's permeability to natural light and ease of maintenance.

Figure 2. *Wat Pa Maha Kaew Chedi temple* in Thailand.

The emergency dwelling theme is always current because it concernes many areas and stakeholders. ONG, designers, researchers are constantly testing new high-performance, sustainable solutions and frequently the waste has been instrumental in the design and construction of housing systems used to host people in need, wherever there is lack of materials and resources.
Examples of how reusing the waste may be fruitful in emergency situations are offered by the japanese architect Shigeru Ban and its *Paper Log Houses*. Beer boxes filled with

sandbags, debris, recycled paper are the building materials used by the designer for its emergency homes, built to aid the victims of disasters or natural calamities [4].
Old tires filled with earth, placed in staggered rows as heavy bricks, up the wall structure of a school built by ARCÒ group on the Gaza Strip, territory distinguished by the delicate balance and subjected to highly restrictive environmental and political constraints, including the desertic climate, the rigid laws according to which building is forbidden to Palestinians; the need to build in a simple and fast way, even in the absence of skilled workers; the use of local materials; the minimum financial resources.

Figure 3. *Tire School* in Gaza.

The tires filled with earth, together with the easy availability of raw materials and the fast implementation, are characterized by the high thermal and static performances. The strongly compacted earth ensures stability and resistance to compressive stresses, ensuring a the same time a high thermal inertia. The external clay plastering protects the rubber to sunlight, avoids tire deterioration and the release of harmful substances.
Furthermore, in Nigeria the NGO DARE has handled the cleaning of Kaduna region, heavily polluted by non-biodegradable waste, such as plastic, solving at the same time another hard question: the lack of housing. This is the reason why the organization decided to build a sustainable house using plastic bottles as a building material. For the structure, bottles were filled with sand, linked together by an intricate system of strings and blocked with a mixture of cement and earth. The colored caps of the bottles were left on the facade to create a dinamic chromatic effect. The result is a fireproof and bulletproof building, surprisingly resistant to earthquakes and comfortable throughout the whole year.

3.2 Reuse for research

This branch includes all the institutional and private initiatives, based on the study of the potential of waste materials and aimed to researching and testing new solutions and technologies for the construction industry. One of the forerunners in the field of research was the tycoon Alfred Heineken, who has created a bottle of beer that, when empty, could be used as a building material.

The project was managed by the designer John Habraken, who transformed the traditional bottle of beer in a glass block: *WOBO* (WOrld BOttle). The product was obviously designed in every way as a bottle of beer but, lying on his side, it became a self-locking brick. Despite the good intentions, only two housing prototypes were built with these glass bricks in the '70, both assembled at Heineken headquarters, in the Netherlands.

Figure 4. Heineken WOBO.

Auburn University, in Alabama, for sure is one of the most active institution in research. Here started, in 1993, the *Rural Studio* program, founded by Samuel Mockbee. It is a kind of laboratory/workshop that combines social needs and academic testing through the making of low-cost structures designed and built by student teams, for example the *Corrugated cardboard pod*, a home made of compacted cardboard bales, stabilized with wax, and the *Lions park playscape*, a multifunctional recreational platform which consists of 55 galvanized drums and colored tubes where children can run, hide, jump, climb, ride a swing, play with "sound tubes".

Figure 5. *Corrugated Cardboard Pod* (a) and *Lions Park Playscape* (b).

One particularly interesting research was carried out at the Polytechnic Institute of Tomar in Portugal. It concerns the use of waste from the production of beer (malt and corn grits) as an alternative to the use of polystyrene in the production of bricks: added in a percentage of 5% to the rest of the raw materials, they are able to enhance the insulating properties of the brick, reducing the heat loss of 28%.
Moreover, the designer Dave Hakkens has pioneered a new way to reuse plastic avoiding chemical processes and assembling special machines capable of smashing bottles, cans and containers for the manufacture of new objects and furniture; while in France, the reuse and recycle of old mattresses is emerging as an economic and environmental fruitful activity, providing excellent materials for the construction and the automotive industry, leading to lower production of waste while providing a great resource.

3.3 Reuse for ecological and environmental sensitivity

Thoughts on a more environmental friendly lifestyle, closer to the reduction of consumption and waste of resources, materials and energy are the basis of this type of reuse. The site becomes a real experimentation and self-building workshop, where all kinds of techniques and materials are used: cardboard, bottles, cans, wooden elements, caps, windows, tires, newspapers, umbrellas, street signs, even animal bones.

Figure 6. Two houses by Phoenix Commotion: *Bone House* (a) and *Sign House* (b).

Each of these objects assumes a new function and its own qualities are used to best advantage to give not just good performance characteristics, but also a particular and unique aesthetic value to the final construction: it is the case, for example, of *Phoenix Commotion* company buildings, founded by Texan Dan Phillips, who realizes all kind of dwellings made up by 80% recycled materials, including those mentioned above.
The first trash homes originated from ecological sensitivity were born in the 70's from pioneering experience: this is the period in which the first Earthships were built in America by architect Michael Reynolds [5].
These are houses made by earth and all kinds of waste, including tires, glass bottles and cans, provided with passive systems of energy production and water recovery. Reynolds and his *Earthship Biotecture* team's researches have produced, in over 40 years, hundreds

of "Radically Sustainable Buildings" and they still guarantee, to those who are interested, the opportunity to build their own sustainable home, providing detailed instructions for its building.

Figure 7. The exterior (a) and the interior (b) view of an *Earthship*.

This type of choice implies for those involved in the design and construction of structures like these a continuous review of its own work: an example could be *Welpeloo house* by Superuse Studio, in The Netherlands. The designers said: "*The waste materials provided a continuous stream of new incentives to develop and refine the design. New shapes and innovative construction methods were needed to incorporate the found materials*" [6]. The single family house was, in fact, built using up to 70% recycled and reused materials, coming from maximum 15 kilometers of the site boundaries. The main structure is made of steel rods from an old textile machine. Since the exact nature of the steel was not known, structural elements were evaluated and designed taking in account a boundary stress condition.

Figure 8. *Welpeloo House* in Enschede, The Netherlands.

The particularity of the villa lies in its façade, made with the remains of 1000 reels, hot impregnated to be more resistent to atmospheric agents, vertically arranged, with horizontal steel bands which scan the rhythm. Windows are made with glass coming from

a nearby factory, insulation consist of waste polystyrene from a nearby camper manufacturer. Inside, old billboards are reused for the white kitchen surfaces and most of the furniture, the structure of the halogen lights consist of old broken umbrellas.

3.4 Reuse for creativity

The creative reuse comes from gaming and from aesthetic and functional testing of waste materials. In this field, the importance of waste materials lies in their shape, their color and modularity, in order to create experimental housing, prototypes, pavillions, artistic and architectural installations, exhibition spaces. The results are heterogeneous, they generally tend to unchange the element, trying to enrich its performances and to increase its durability [7]. This category includes many of the trials involving the use of aggregate or individual shipping containers, esteemed for their resistant structure, easily transportable and modular. Some of the most important exemples are: *Cove Park*, a centre for established artists situated on the west coast of Scotland, which consists of 9 shipping containers transformed into housing units in close contact with the surrounding nature; the *Freitag Flagship store* in Zurich, by Spillmann Echsle architects, made by seventeen containers assembled with metallic elements; *Space Box* by Mart de Jong, a shipping container modular system used for the construction of university campuses; the *Papertainer Museum* and the *Nomadic Museum* by the aforementioned architect Shigeru Ban, two itinerant structures made of cargo containers and recycled paper tubes.

Figure 9. Container architectures: *Freitag Flagship store* in Zurich (a) and *Papertainer Museum* (b).

Like shipping containers, even the pallets recently have been used for those approaches to creative reuse. The advantages of pallets are various: availability, standardization, the physical and mechanical characteristics, modularity, affordability. The *Palettenpavillion* is a temporary pavillion 18 meters long and 6 high, built with 1300 pallets; the *Pallettenhaus*, designed by Austrian students Gregor Pils and Andreas Claus Schnetzer, is a prototype house composed by 800 dry assembled pallets and glass wool panels insulation; *Infiniski Manifesto house* by James and Mau architects uses the pallets as cladding, insulation and shielding of shipping containers, which are the dwelling structure.

Figure 10. Pallet atchitectures: *Palettenpavillion*, Berlin (a) and *Infiniski Manifesto House*, Curcavì (b).

4. CONCLUSIONS

In the perspective of environmental protection, resource conservation and sustainable development, architecture plays a key role, which has its fulfillment in the sustainability of the design.
The multitude of examples using construction systems specifically designed for the reuse of waste shows that what we often consider "waste" just because it has exhausted its original task, in fact, if re-used with intelligence and creativity, can become a great resource.
The "waste architectures", are often labeled as "poor" architectures and sometimes they are not considered architectures at all. The study and research in this field, however, can open ways now unexplored to potential of a responsible and sustainable architecture.

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