TYRE_SPACE©
Elastic Building Frames Applied in Urban and Rural Environments

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ABSTRACT: The purpose of this research by design is to provide new ecological building frames made of whole disused tyres and by-products. This study focuses on the generation of geodesic and elastic frames and mainly its potential applications as dwellings, greenhouses and games. It also develops low technologies and smart insulation systems by using trashed whole tyres, rubber sheets, plastic straps and packaging or expanded foam. It has been carried out at Barcelona School of Architecture, Spain and also at the Faculty of Architecture and Fine Arts, NTNU, Norway. For further detail, visit www.tyrespace.com or www.prefabricate.org

Keywords: reuse of materials, low-tech building systems, elastic junk-frames, trashed tyres

1. INTRODUCTION

Current house building techniques in the Western world have to a large extent failed to incorporate knowledge of geometry that enables lightweight and durable constructions which can be produced at a fraction of the cost of conventional houses. The lack of innovation in this field can be attributed to the enormous economic interests that are tied to real estate. Challenging habitual conceptions in this area is seen as a risk not worth undertaking.

Figure 1: Landfills of trashed tyres.

However, the present situation creates considerable inequalities, where people with even average incomes cannot afford buying or renting a place to live in major cities and their suburbs. As a result, monoculture prevails and people with lower incomes are forced into the margins or into finding alternative solutions.

Making dwellings available for less money would reduce the need for high incomes in order to afford living. Concentrations of power limit person's access to land by the force of among other things the notion of ownership. Furthermore, the use of land is highly regulated. Living on, or under water, is a realistic alternative to living on land.

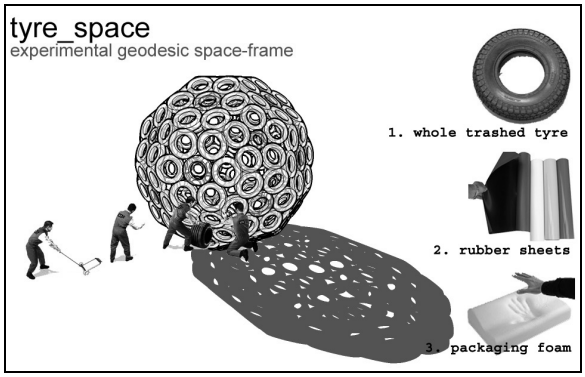

Figure 2: Initial space-frame concept of form and basic materials.

On another hand, a significant amount of tyres are not reused. New uses must be found for the valuable raw materials embodied in whole tyres and tyre shreds. Product designers have a unique role in creating a valuable product from a resource many would see as waste [1]. Many products in construction are made from old tyres, and even more can be developed (for instance, civil engineering's market, including landfill construction, and daily cover; tyre-derived fuel; crumb rubber manufacturing; retreading and reuse).

So, the purpose of this new research is to provide resources for ecological designers creating new

building frames or landscape products made of whole disused tyres and by-products.

This preliminary study provides information on the geodesic prototype and its structural, constructive and technical characteristics of the design system and mainly the potential applications as dwellings and urban games. It is also a design patent working with the unique properties of tyres, tyre shreds, and rubber sheets applied for urban environments.

2. EXPERIMENTAL DESIGN

The TYRE_SPACE© is initially conceived as a low tech prefab, compact rubber space that is both environmentally responsible and is available as an affordable waste product everywhere. It is a simple tyre-framed modular unit, consisting of pentagons and hexagons 'chunks' and simply a web.

The geodesic form consists of 6 or 7 trashed tyres, depending on the modular geometry, encircle each module. As result, we obtain a 'sphere' or domes, a sort of big football ball ready to be inhabited. It also appears to float above the ground, expressing its minimal environmental impact by touching the earth very lightly.

Figure 3: The geodesic tyre_space© is situated in arid context. It performs as shading device by providing a cooling.

The TYRE_SPACE© demonstrates the wise use of rubber components to fabricate lightweight spaces with an abstract frame. Tyres have many advantages as a structural material. And trashed tyres can be easily re-used and re-cycled at the end of a structure's life. In addition, a tyre does not warp or rot, and it is impervious to termite attack or another biological agents.

3. WHAT MAKES TYRE-SPACE© SPECIAL?

Why choose trashed whole tyres? The TYRE_SPACE© demonstrates the use of rubber components to fabricate lightweight spaces with an abstract frame. Tyres have many advantages as a structural material. And trashed tyres can be easily re-used and re-cycled at the end of a structure's life. In addition, a tyre does not warp or rot, and it is impervious to termite attack or another biological agents.

Each tyre-framed module is crowned by a shimmering opening in the middle that hovers above the inner space. The frame is eye-catching but dynamic and practical. It is designed to shade the living spaces, reflect radiant heat, and might support solar collectors or photovoltaic panels.

A single sphere or the like could be an emergency house, a vacational shed, a studio, a playground or a greenhouse. You can also combine two or more spheres to form a large residential or playground complex or an eco-village with corrals, patios and dwellings.

Figure 4: The TYRE_SPACE© team was running an intensive workshop on April 2006 at the IaaC, Barcelona, sponsored by NTNU. This collective experiment was focused on the generation of irregular shapes and elastic roofs. The advantage was that you do not require specific sizes but every single tyre is usable!

The internal layout is open and it can easily be configured to suit individual needs. And it will be possible to start with a single unit –either circular or hexagonal- and add a second or third module as occupants grow. This kicking ass design can be positioned to make the most of any site.

The orientation, the views of the surroundings, local wind patterns and approach from the street are all considered when locating the modules on a site. The inherent flexibility of the modular system allows views and sun to be manually controlled.

Because the TYRE_SPACE© is an off-site fabrication, disruption to the site is minimal – the only site works required are simple screw-pile foundations and utility connections. Solar panels and grey water treatment have been incorporated. And it can be easily removed, leaving practically no trace of its existence in the landscape.

4. ASSUMPTIONS AND METHODS

I. Rubber Junk. Use of whole trashed tyres as building and structural components formulate a pioneering design process for low-budget houses and explores straightforward techniques and uses of rubber framework in emergency and also recreational environments.

II. Passive Energy. Simple passive techniques such as orientation, building shape, colours, low-value materials, and shading devices can improve housing indoor comfort.

Nevertheless, the impact of these factors can vary according to specific climatic parameters and the occupancy.

About methods, this study has been oriented towards a research by design.

On one hand, structural and building solutions have initially been experimented off-site (models 1:1 scale) in order to demonstrate the feasibility and flexibility of tyre modules. Two notions rule this stage:

A. Smallness. Identifying potential architecture and elemental building systems by using disused tyres. Define basic principles in 3D CAAD models.

B. Prefabricating Process. Select building models, structures and smart skins required to satisfy functional and climatic requirements applied mainly in urban and natural contexts. Tyre_space© modules of have been tested.

On another hand, it is about how to improve indoor climate in geodesic dwellings. The preliminary designs have been compared with traditional analytical tools (i.e.: Givoni's bio-climatic chart and Mahoney tables) and solar diagrams.

Computer simulation indicates that indoor comfort conditions improve by using simple passive technique: use of lightweight insulation; shading devices; climatic adapted colours in the skin and orientation of openings as solar collectors or passive cooling devices.

5. PROPERTIES OF WHOLE TYRES

We summarize some characteristics of whole and processed trashed tyres intended to help designers invent new products based on tyre-frames.

For most practical purposes, tyres and tyre products function as homogeneous mixtures, but processing can impact physical characteristics as size and shape are altered and as reinforcing wire and fabric are removed [2].

Tyres look like one simple black mass, but they are actually a complex mixture of various types of rubber, carbon black and reinforcing wire/fabric in multiple sections of a tyre. Some features are:

A. Density. Tyres are slightly heavier than water and will sink in water unless entrapped air provides enough buoyancy to allow them to float. This generally occurs only with whole tyres or fine crumb rubber particles. However, tyres and tyre products are much lighter than soil or stone.

B. Durability. Tyre rubber contains carbon black, antioxidants, and UV stabilizers to enhance resistance to wear, chemical decomposition, and sunlight, respectively. Strength is enhanced by reinforcing wire and fabric (like nylon or polyester).

C. Humidity Absorption. Tyres and shreds can trap water on the surface and in irregular contours, but they are relatively impervious to actual absorption. Various studies indicate maximum moisture absorption of 2-3%.

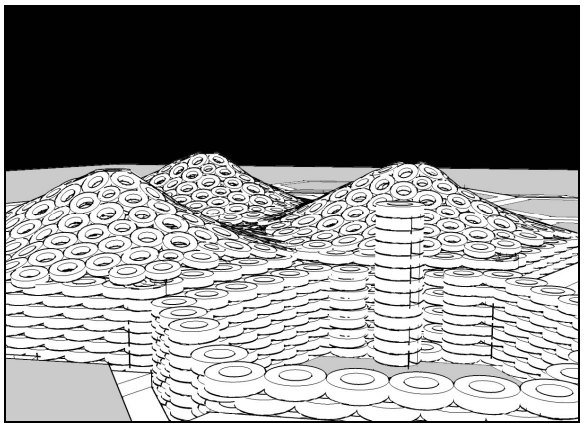

Figure 5: Building detail of a web car tyre dwelling. The roof adapts to the landscape crating a new morphology. Tyres can recreates artificial landscape by using the colonising strategy of camouflage.

D. Thermal Insulation. Rubber is a poor thermal conductor, conversely providing a better thermal insulator than soil or aggregate. Thermal conductivity depends on particle size, reinforcing wire content, compaction, moisture content, ambient temperature, and other variables.

E. Temperature Tolerance. Tyre rubber is capable of withstanding a full range of ambient temperature extremes without undergoing permanent property change. Some properties—like flexibility—change as a function of temperature, but this change is reversible and repeatable.

F. Energy Content. Tyres are made from oil and gas. As a result, they have energy content greater than coal, making them thermally suitable for use in many tire-derived fuel applications in the manufacture of cement, paper and power.

G. Flammability. Tyre shreds have a reported flash point of 305º C, higher than some other materials used for architectural purposes such as wood, paper, foam, and fabric.

H. Colour. Passenger tyres are predominantly black. Colour can be an important performance characteristic. In addition, tyre can be coloured by mixing with some types of paint.

This has been fully demonstrated in coloured applications where durability has been shown to depend on the paint, not the rubber substrate.

6. ENVIRONMENTAL FEATURES OF TYRE_SPACE© DWELLINGS

• The outer skin is as expected dark and it absorbs radiant heat during the cold months. In summer, there are some controlled openings that allow natural air currents that passively cool the building
• Light insulation fills the cavities of the tyres and gaps with packaging foam, expanded foam or the like.
• To collect water for toilet flushing and the garden, there is a rainwater tank always located outside.
• The floor plan allows natural cross ventilation by reusing washing machines' doors as windows.
• The appropriate use of colour in the outer layer performs climatically well. For instance, if the volume

is situated in a hot-humid context, it must be painted white to reflect summer overheating.
• Electricity is generated by solar photovoltaic panels set up on the top. Also solar hot water collectors could be installed on the roof to heat water.

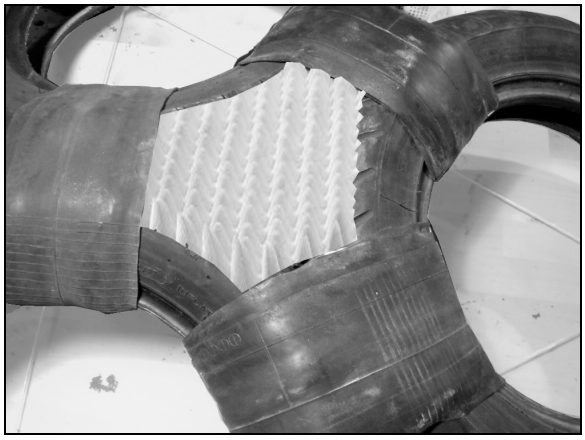

Figure 6: In geodesic models, light insulation is applied in the cavities of the tyres and gaps with packaging foam or expanded polystyrene.

7. WHAT ARE THE DIFFERENCES BETWEEN TYRE_SPACE© AND EARTHSHIP DESIGNS

Tyre_Space©	**Earthship** [3]
Whole and roof skin	Applicable only in walls
Space-frame	Wall frame
Textile	Block
Elastic (deformable)	Static (rigid)
Released trashed tyre	Hidden trash tyre
Whole building solution	Partial system
Strapping joints	Compact mud mortar
Lightweight	Heavy

8. TYRE_SPACE© DWELLINGS

The TYRE_SPACE© DWELLINGS are rubber buildings for making low cost houses of variable sizes for any number of persons. It consists of movable housing modules that can form different configurations on land, on water and under water. The system allows for a diversity of materials as well as changes and adaptations.

The TYRE_SPACE© DWELLINGS are tyre-modular, can be scaled up and down, and expand and grow together with other systems into small communities. For instances, the TYRE_SPACE© DWELLINGS can be built onto rooftops of existing buildings. The modules can be mounted on wheels to become mobile or be connected to form floating constructions [4].

Most functions will be built into walls, and furniture, household equipment etc. will be provided by movable elements that change functions during the day. Supply modules (i.e.: service buffer) can also be mounted on the outside of the main modules.

The TYRE_SPACE© DWELLINGS are either geodesic or stretchy forms and are able to reflect changes in life, i.e. people moving in and out, the arrival of children, etc, as it is easy to add to the construction in stages. If people want to live together they can simply let their dwellings grow together, likewise, it is easy to separate modules and move them if desirable.

Figure 7: In web model, Light prototype made by whole tyres is connected by straps. This pattern and usability has been experimented as an elastic tissue for rooftops.

The TYRE_SPACE© DWELLINGS in themselves do not define a social constellation, but only provide the basic equipment so that persons can configure their own social setting. The present version of the system is made of discarded whole passenger tyres and can be constructed by strapping tyres.

9. CONSTRUCTION SYSTEM

The TYRE_SPACE© DWELLINGS consist of equal-sized units inscribed in a geodesic or web form.

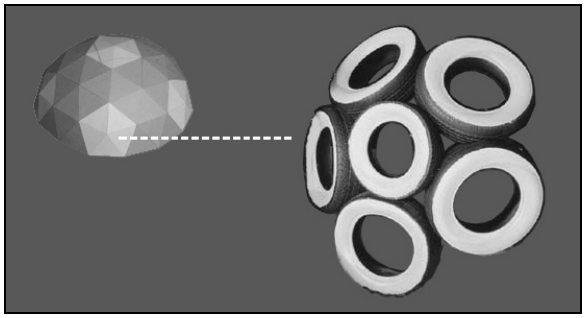

Figure 8: Geodesic form. Pentagons and hexagons will fill space when combined. They can also be joined with a variety of shapes into numerous combinations.

In the case of geodesic frame, pentagons and hexagons are built off-site. To provide stiffness in each tyre you must reinforce it with an inner metal ring; otherwise, it will loose its initial geometry. Unfortunately, it requires accuracy in the building execution: to provide stiffness, it depends on the

tyres' size and the strength of the inside tyre reinforcement.

In the case of web frame, it is a sort of free tissue, which does not need building accuracy. It means that the construction needs neither further reinforcement nor specific sizes as the geodesic model. It is more fickle and its works mainly as roof.

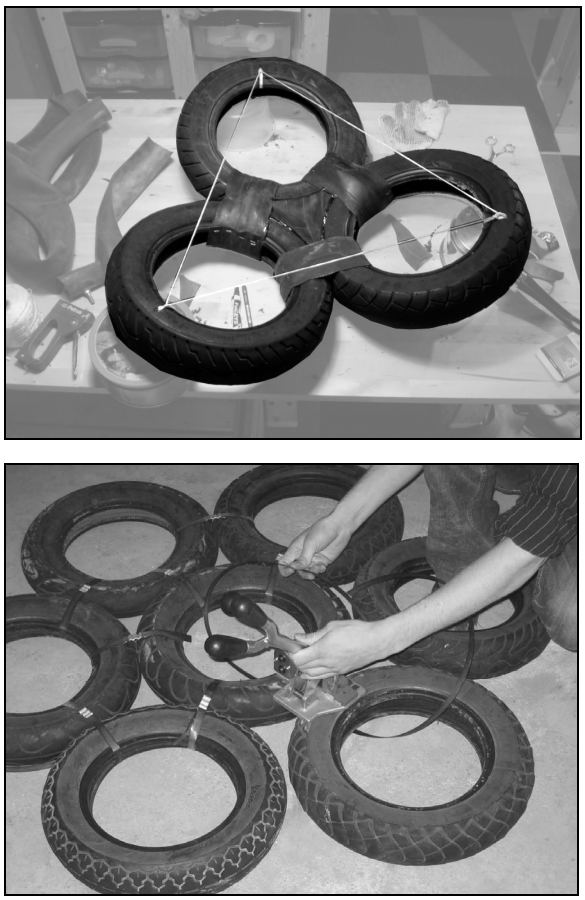

Figure 9: Comparative assembly solutions. The above image the initial test using rubber stripes as joints. The inferior image shows experimentations by using plastic straps instead of rubber ones. It is a reliable connector.

The strength is a combination of the tyre's stability and the space-frame that occurs once these are assembled -strapped or bolted- along the edges.

The frame consists of whole tyres and the infill materials are lightweight; they can vary, but durability, strength and low cost are crucial parameters that have to be balanced. The outer skin and insulation properties might be the combination of rubber film and insulating and weatherproof foam layer.

10. FAMILIAR DWELLING

Let's describe an example. The geodesic version of a TYRE_SPACE© DWELLINGS contains very simple equipment for living.

However, a familiar dwelling consisting of three modules combined would allow for separating functions as follows:

A. Eating dome

It consists of the kitchen area, including micro-greenhouse with hydroponics systems for supplementing daily household with lettuce, tomatoes, etc. Floating TYRE_SPACE© DWELLINGS can have their own fish farms, chicken farms and floating gardens attached outdoors.

B. Sanitary dome

This module contains the toilet and shower made with disused petrol barrels. In addition, all wet appliances such as water drain and supply and hot water tanks can be brought together here.

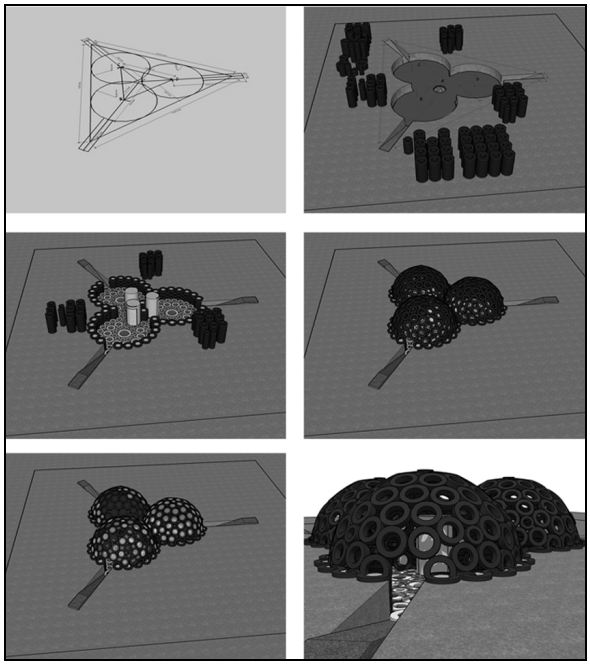

Figure 10: Building process of geodesic familiar dwelling geodesic. Prefab elements provide bathrooms and kitchen. Bubble spaces are poly-functional areas.

For offshore living, tanks for water storage and wastewater can also be installed. All tanks can be mounted on the outside to save space. Grey water can be led to the micro-greenhouse and purified by the plants. A micro-desalination plant can be installed for deriving drinking water from seawater. The toilet can be a compost toilet that uses no water.

C. Resting dome

It is a unit for sleeping as well as for relaxation and social activities during daytime. Movable furniture serves as sofas, beds, and tables according to needs.

Flexible screens can divide the space to create privacy if wanted. In addition, smaller modules of various shapes can be attached, if there is a need for more space, e.g. extra rooms, storage, etc.

11. CONCLUSION

Design is living a massive change. Prefabricated low-tech dwellings by using tyres perform as smart systems capable of being or becoming visionary frame-spaces.

In order to consider the potential impact of this tyre-architecture, we should rethink the following questions: What should we design instead? What type of minimum dwellings might we achieve?

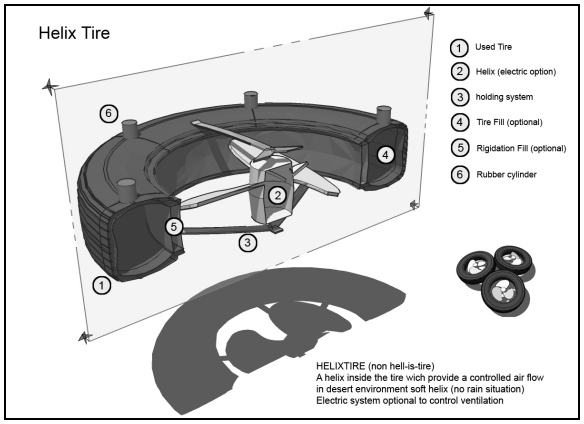

Figure 11: A low-passive energy supplier could be installed in the cavity of each tyre. So, they are consisting of for example micro-funs (see figure 11), solar panels or solar heating skins, etc.

A. Workshop: Searching for a Rubber Web

A recent research workshop was carried out in Barcelona on April 2006. Two institutions and a student group from NTNU, Norway, facilitated the necessary infrastructure and financial support to carry out new empirical tests.

The initial design assumption of the geodesic with strapping connector failed! It requires additional stiffness to bear itself such as metal rings inside the whole tyre. Nevertheless the only use of strapping system showed a fascinating capability to build up random tissue structures. Information about this work can be found at www.prefabricate.org

The potential lies in the construction of a rubber mesh, which creates a random tissue. 100% of the tyres can be used no matter their specific dimensions.

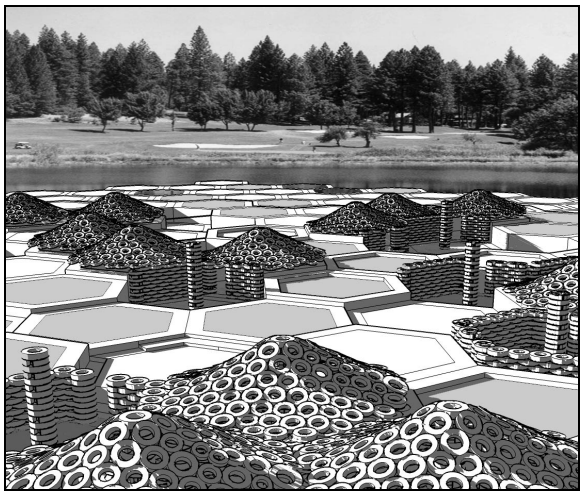

Figure 12: TYRE_SPACE as Eco-village. Layout of tyre hexagons forms a limitless pattern for patios and dwellings. Then a tyre web covers each unit. Finally a central column made by tyres bears the mesh.

B. Versatile Rubber Frame

The tyre web is a stretchy system, immensely cheap and clever low-tech manufacturing, which use pneumatic junk as material and packaging bending as union. If form follows the material, what will be the shape of new this junk-frame? How can it conceive a universal dwelling pattern? The tyre web consists of tyres connected by packaging straps. If insulation is necessary you can spread foam in cavities and on surface.

The result is a hybrid structural system consisting of hexagonal tyre walls -forming patios and roofed spaces- and a tyre roof supported on a central tyre-made column: a Mongolian tent.

Therefore, these elastic forms should provide scalability, flexibility and interoperability to release maximal potentiality and free up unexpected trails of housing production. TYRE_SPACE© is available at www.tyrespace.com and also at www.prefabricate.org

12. ACKNOWLEDGEMENT

First, we express thanks to the Barcelona School of Architecture (ETSAB) and AGAUR, whose have given the possibility to carry out this case study and thus enrich the investigation in several research centers. This experience has not only been covered theoretically but it has also been developed as a pedagogic exploration of rubber waste as frame systems at the Institut d'Arquitectura Avanzada de Catalunya. Above all, we wish to highlight the collaboration of two aassociated architect researchers: Inés Barata and Carmelo Zappulla.

We also wish to thank the fruitful debate on trashed tyres carried out on March 2006 at the International Workshop "Minimum Prefab Systems" at the School of Architecture, University of Ljubljana and sponsored by Socrates Programme.

Finally, we show gratitude to the NTNU students who carried out the research workshop *'Minimum Prefab'*, 2006; where we led and opened up new reflections on experimental dwelling by using junk-frames.

13. REFERENCES

[1] Ed Paschich & Paula Hendricks,"The Tire House". Sunstone press, New Mexico, 1995.

[2] Robert W. Wassmer, "Changing Tires," Resource Recycling, 2002, p.21.

[3] Housing construction is a unique application for whole tyres. One example is the Earthship Biotexture of Taos, USA. Builders stack tyres to form walls, and then pack them with earth. Finally, they install a vapour barrier and apply stucco and paint. The challenges with this application are seismic, and they use too few tyres compared to the number generated in the state. See www.earthship.org

[4] www.tyrespace.com