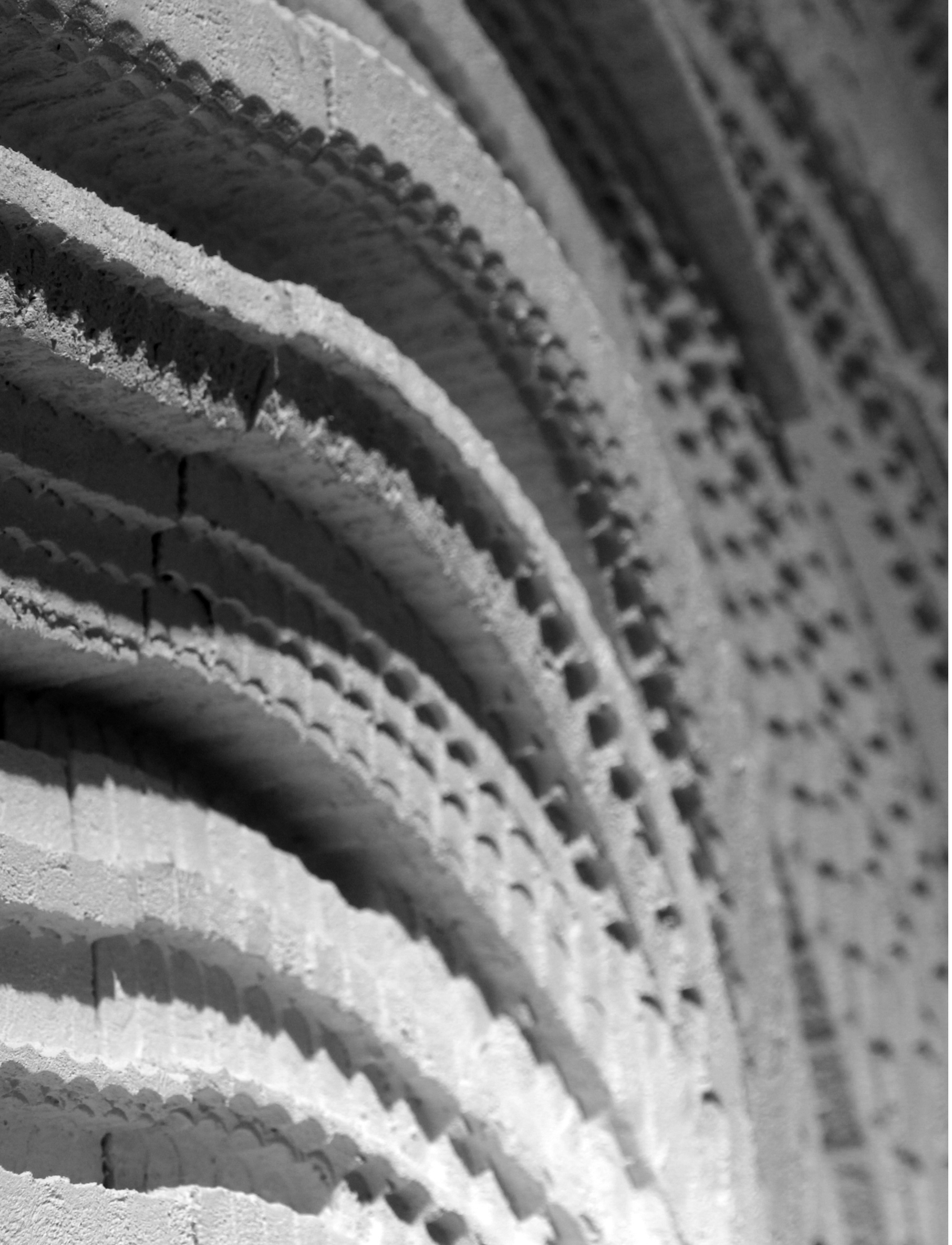

Synthetic Manufacturing

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1. INTRODUCTION

This paper will discuss three scaled prototypes that utilized the idea of how repurposed waste materi-als are sourced within the field of architecture, and the developmental nature of the design utility based on the parameters of repurposing within the underlying theme of "synthetic manufacturing." The basic use of these prototypes ranges from 1) an architectural modular developed as an attempt to address the issue of construction waste produced by demolished project sites for unskilled workers within developing countries; 2) an art installation piece that addresses overstocked and over-ordered materials and EPS foam, originally used for insulation, by contractors for an existing institutional construction project in Houston, Texas; and 3) an academic design-research project that was further pursued as an art installation sculpture, made for the HKSZ (Hong Kong Shen Zhen) Biennale, which uses localized wood materials, pre-fabricated through CNC and tried-and-tested to be constructed offsite to limit the onsite production, delivery, and man-power.

Each of these projects investigates the range of developing processes of computational design-research and the parallel intentions of diversion within the construction, repurpose, and demolition processes inherent to the production of architectural design. All three case studies utilize and appro-priate construction waste and consider the repercussions of the construction waste within a novel form of fabrication and processing for the built environment. Incorporating the three Rs (reduce, reuse, and recycle) into construction, renovation, and demolition waste management creates a closed-loop manu-facturing and purchasing cycle. This significantly reduces the need to extract raw materials, reduces the amount of materials going to landfill sites, and reduces the life-cycle costs of buildings and build-ing materials.

2. BASIS OF DEVELOPMENT

According to the United States Environmental Protection Agency for Region 8, the qualifying basis of construction and demolition materials is as follows:

> *Construction and demolition (C&D) materials consist of the debris generated during the construc-tion, renovation, and demolition of buildings, roads, and bridges. C&D materials often contain bulky, heavy materials,*

such as concrete, wood, metals, glass, and salvaged building components. Reducing and recycling C&D materials conserves natural resources and landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall build-ing project expenses through avoided purchase/disposal costs.

In recent years, numerous efforts have been underway to reduce the environmental impacts of con-struction and demolition projects. EPA Region 8 helps promote and facilitate the recycling and re-use of these materials by providing useful information and grants, tools, and resources.

Given the basis of the classification of what materials qualify as construction and demolition materi-als, the following projects were researched and developed according to the nature of the use and need. Most importantly, each prototype and design-research project dived into the computational aspects, in both high-tech and low-tech opportunities, and investigated the fundamental requirements, computa-tional rigour, and intrinsic opportunistic possibilities of computational tooling in both analogue and digital testing as a means of understanding the material opportunity provided as a CRD material, while looking upon the use of the material as a hybridized retainer for the larger development of the premise.

3. RESILIENT MODULAR SYSTEMS V.1

Resilient Modular System (RMS) is a continued collaborative academic project that is working to-ward a regional grant approval. RMS is a multidisciplinary research proposal to forge the synergy and efforts between three different colleges/departments within the University of Houston: the College of Architecture, Department of Industrial Engineering, and Department of Material Studies and Engi-neering. The topics and fields of research will include, but will not be limited to: Architecture/Design, Industrial Engineering and Prototyping (Digital/Analogue), Patents, and the Material Sciences. Within the larger understanding of the design-research, all conducted research will require a high level of computational science and bioengineering support. Each collaborator/faculty member is a key asset to the development of this project and is an expert within his or her respective field.

The division of research and development included the following: Professor Wendy W. Fok (Archi-tecture/Design/Prototyping), two graduate students assistants, Jose Aguilar and Megan Hartensteiner (Prototyping), Professor Ali Kamrani (Patent/Industrial Engineering/Modular design aspects for form and fit analysis), and Professor Ramanan Krishnamoorti (Material Sciences/Bio-related engi-neering). The developmental nature of RMS was to conduct design-research into a modular system that could be applied as an urban intervention within the context of temporary and permanent settings.

Using both eco-intelligent architectural design objectives, the knowledge and technique of manipulat-ing sustainable materials ultimately pursues a positive impact on the planet as a growth opportunity and engenders a focus on enhancing benefits (not only reducing costs) through its decision-making and actions—taking an approach of optimization rather than minimization. This project can under-stand the perspective of "people, planet and profit" as expansionist and enabling leadership through the achievement of advanced success metrics. For example, the concept of effective design of prod-ucts and services should move beyond typical measures of quality—cost, performance, and aesthet-ics—to integrate and apply additional objectives addressing the environment and social responsibility.

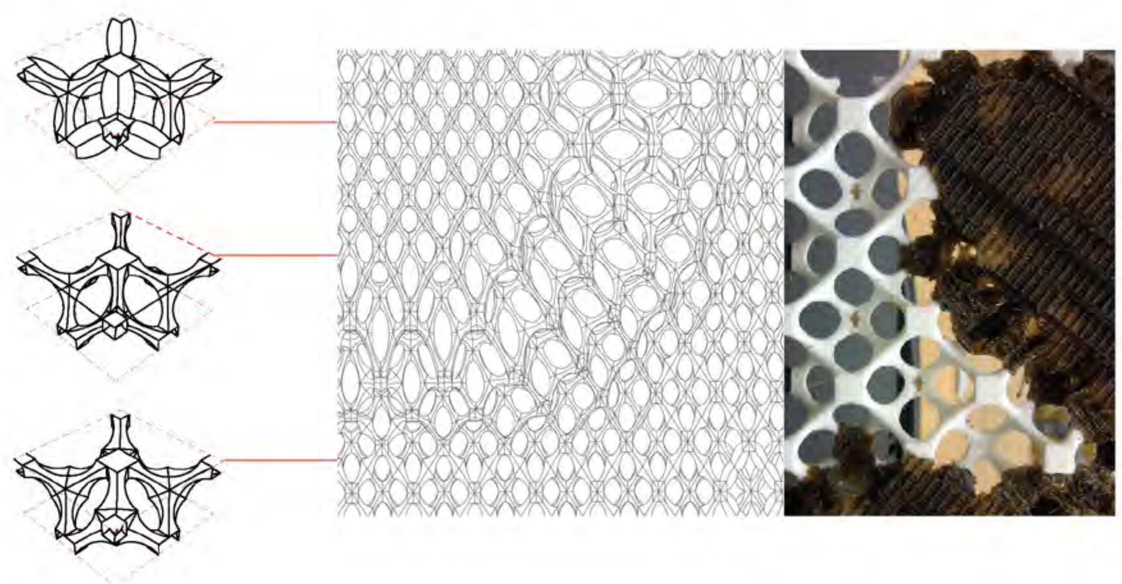

Figure 1: Scale, iteration, and tessellation of the RMS Modular

Through both digital and analogue (physical) prototyping in both architectural and design scales, and migrating the opportunity of a full-cycle cradle-to-cradle design process into a Design-Fabrication project—with real-world contextual testing and use of both repurposed construction waste and biode-gradable materials (specifically, biodegradable soy-based polyurethanes, ceramic fillers, and compo-site plastics)—RMS (temporal + structural) is to find a dualistic opportunity into sourcing ecological solutions of constructing temporary structures within the built environment in locations of need.

The idea of the RMS (temporal) is the ability of it to become an ecological and resilient modular con-struct for the built environment that could be subsequently dissolved, yet, in an effort of full-cycle de-sign, also contribute to nourishing the natural landscape.

The temporary proposal is that one of these structures could be possibly constructed as a retaining wall system similar to the ones that are seen along the side of the highway or a landslide retention wall. The composite within the mixture of this will consist of ceramic filler, broken-down glass, and biodegradable plastic as the main composite material. The process of this works as follows: 1) A landslide retaining wall is constructed with the RMS module; 2) due to exposure and UV-tested breakdown, the biodegradable plastic comes to the end-life; and 3) the plastic degrades and dissolves. Since the plastic is made with a mixture of ceramic filler, when the plastic dissolves, 4) the ceramic filler will be left, and since the ceramic filler itself retains moisture, 5) when the ceramic filler is de-posited into the soil, it will provide itself as a form of nourishment for plantation and development for agricultural growth.

The primary material research for the RMS (temporal) ephemeral structure will be based on agricul-tural or soy-based biodegradable polymers that have been in research since the late 90s and have been improved, bought out, and carried forward by some of the world's largest companies, like food and agricultural giant Cargill, who in 2008 spent over $22 million USD on developing a method to re-search and use polyols that can replace petroleum-based chemicals. The most effective method is to blend soy protein plastic with biodegradable polymer to form soy protein-based biodegradable plastic, and forming the material with the method of extrusion and injection-molding to form useable pieces of plastic. Therefore, using the same traditional methods of constructing plastics, the same design fab-ricated parts would be used for applying similar 'thermoforming' or 'vacuum'-forming techniques in-to constructing the prototypes.

While the secondary research for the RMS (structural) will be research for repurposing construction waste as a mixture for the remediation of the structural testing and joint detailing, the same modular structure will be utilized to further innovate on studying the structural form/fix/analysis of the RMS (structural) modular.

Figure 2: Dualistic research approach of RMS

4. GEO-COGNITION

GEO-COGNITION is based on the geometric concepts of projective geometry (duality principal) and the convergence theory, and the fusion of the four main geographic locations that had the most signif-icant impact within the artist's career and life. The supervening confluences, which occur through transitional developments between the cities, are formalized by utilizing a form of projective geome-try and attach themselves within an underlying cognitive geometrics theory.

The confluences of the cities, through its linearity and dynamics, are representations of both duration-al and formal natures of the transitions. These factors are carefully developed and linked to the artist's respective influences and the relative time spent within the period of that city, resulting in the dynam-ic effects which transition between the axioms of the different skylines and planes. Formally speak-ing, the different skylines merge (converge) from one into another, creating a morphogenesis between the planes.

Projective Geometry is the branch of geometry dealing with the properties and invariants of geometric figures under projection. In older literature, projective geometry is sometimes called "higher geome-try," "geometry of position," or "descriptive geometry" (Cremona 1960, v-vi). The most amazing re-sult arising in projective geometry is the duality principle, which states that a duality exists between theorems such as Pascal's

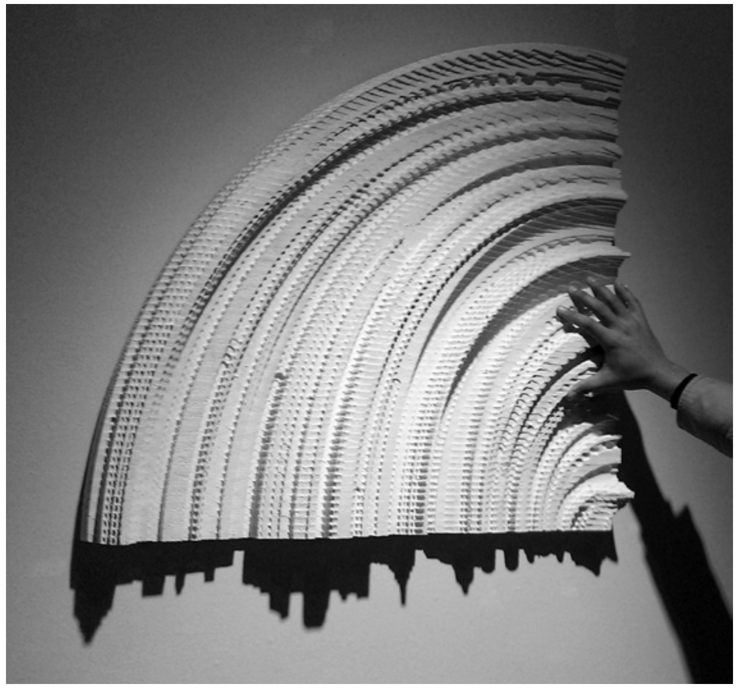

Figure 3: Singular modular example of the GEO-COGNITION installation
*Note: Shadows produce Cityscape

theorem and Brianchon's theorem which allows one to be instantly trans-formed into the other. More generally, all the propositions in projective geometry occur in dual pairs, which have the property that, starting from either proposition of a pair, the other can be immediately inferred by interchanging the parts played by the words "point" and "line."

The material exploration of GEO-COGNITION was made possible by utilizing the by-product of an architectural construction site. Facts show that most U.S. construction sites and construction managers overstock on more than 30% of building materials for construction. Over 70 million tonnes (155 000 million pounds) of waste is produced in the construction industry each year. This amounts to 55 lbs. per week for every person, about four times the rate of household waste production.

The EPS DOW insulation foam used to CNC mill, produce, and fabricate GEO-COGNITION was made possible through donations from an actual construction site (a commercial building on the cam-pus of the University of Houston), whereby the site manager offered us the overstocked material.

Through reusing the overstocked insulation material, it provided us (the artist) complimentary materi-als for production, while also lessening the waste creation and dumping cost for the contractor. This type of cradle-to-cradle/grave approach to design allows an innovation of creation, and amalgamation between art and architecture. Different material explorations, including the use of HIPS and MDF, and several prototypes, were made before finalising on the EPS DOW insulation.

5. TETRA V2

Tetra V2 is an urban sculptural installation created for the HKSZ (Hong Kong Shen Zhen) Biennale 2012 that provided evidence of offsite production (four days of CNC and production work), and less than eight (five) hours of on-site installation, with the assistance of three workers.

The intention of the Tetra V2 computational process was developed through Rhino as an overall pro-cedure to expedite the installation process by devising an off-site pre-fabrication, manufactured, and construction system, using localised and repurposed MDF materials within the region of Hong Kong. The installation was developed as an academic project at the Chinese University of Hong Kong for a summer 2011 studio, which was subsequently furthered as an installation commission for the Hong Kong Shen Zhen Biennale. The larger intention of the piece was to understand the load bearing mate-rials of repurposed wood materials, and understanding the manufacturing process of the CNC for offsite assembly. The design of the efficiency for offsite transportability and onsite construction, therefore, became a key asset into the umbrella premise of designing the sculpture itself.

Given the minimal budget and constraints of the design itself, the continuous production of utilizing the CNC in an innovative flat-cut 2-axis process, rather than the typical 3-axis production, made this structure an assembly project rather than an innovation of the tooling itself. Each arm of the tetra-pod is composed of two pieces of 2-axis flat-cut MDF, whereby each tetra-pod itself is composed of six arms, and each pod is comprised of twelve pieces. The ability to construct a three-dimensional struc-ture is therefore played into both the computational tooling of the piece, and the innovation of the as-sembly.

The construction and demolition of the piece was, therefore, an innovation of repurposed materials; however, the hybridized approach of offsite assembly and onsite installation also expedited the de-installation of the structure. It also led to the ease of transportability of the piece, which later became part of the permanent collection of the BGCA Foundation in Sai Kung, Hong Kong.

6. PERFORMATIVE CRITERIA

The goal of these prototypes and design-research projects is to deliver a performative criteria and in-centive for continued effort into generating material appreciation, and a conscious approach to the continued discussion of generated waste production and management within the construction industry. While a large part of the debate is to better fulfil full-cycle design and cradle-to-cradle full loop de-velopment, in the case of the RMS, the larger discussion is to provide a model of research that allows the cradle-to-end result of construction waste being repurposed rather than disposed. All three in-stances functionally outsource to the utilitarian approach to further the results of the architectural state of the material, and transpose the traditional expectations of the end-result of the produced product or design—by creating a viable and creative method to the end product.

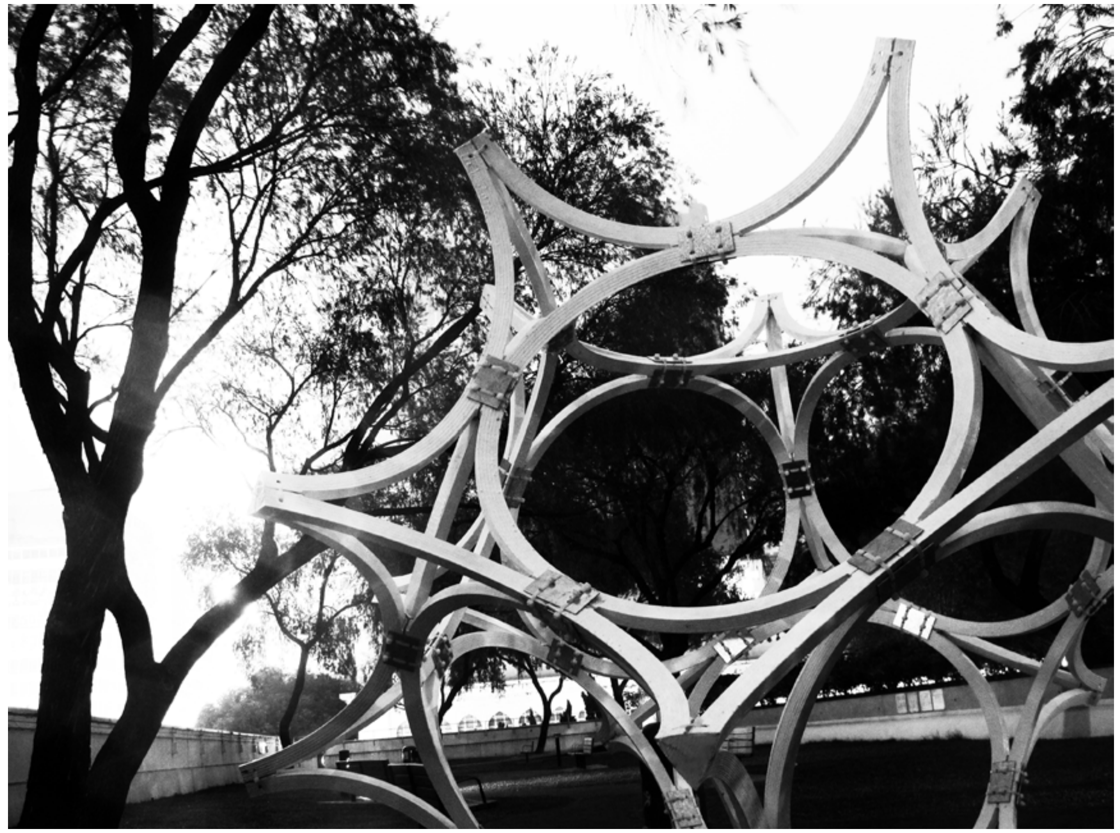

Figure 4: Onsite installation of the Tetra V2 at the HKSZ Biennale

The current environmental crisis and diminished natural resources have challenged the practice of ar-chitecture to rethink its outdated processes of design and construction. New processes that act as full regenerative cycle systems are replacing existing wasteful construction models. The scope of this work focuses on the understanding and development of minimal surfaces, specifically of those that are triply periodic (i.e., periodic in three directions) as an efficient modular building component fabri-cated out of high-content recycle/salvaged construction solid waste. Each building component will be designed utilizing computational generative strategies to find the most optimal performance. Rapid prototyping and digital fabrication methods will be utilized in order to find efficient and economical modular structure systems that perform at three levels: structurally, environmentally, and socio-economically.

7. CONCLUSION

The diversion of construction, renovation, and demolition (CRD) waste from landfill sites is an issue that has been gaining attention within both the public and private sectors. Surveys have indicated that as much as one third of the 20 million tonnes of solid waste from municipal waste streams is generat-ed by construction, renovation, and demolition activities. Many of our landfill sites are reaching ca-pacity. In addition, CRD waste is sometimes illegally dumped or burned, causing land, air and water pollution. The increasing costs of disposal are ultimately reflected in project costs, as contractors must incorporate anticipated disposal costs in their bid costing. Realities such as these emphasize the need for initiatives that focus on reducing and diverting as much waste as possible from CRD activities.

With the rise of computer-aided technology, the vast amount of rapid prototyping tools prompts de-signers to question how our visions of objectivity diverge into the tendency to push and understand the limits of different material properties to further the development of architectural design. The premise of this research proposal is to achieve speculative studies within a project framework, which will be presented through a quad-fold process of design-research, fabrication-construction, exhibition-publication, and international distribution (including patents).

Design—the larger function of the term inclusive of Research and Development of Applied Sciences, Engineering, Technology and Architecture—today could perhaps be described as the relational equa-tions mediated by digital techniques assisted with production and knowledge of fabrication. Like many fields in the modern culture, it strives to be truly integrated wherein the designer can move seamlessly from concept to production in a single, contained process.

The much larger discussion is less about how the demolition technique is developed, however; it is about the greater control of the material that is processed, where demolished materials are reused. Part of the problematic debate within the construction, renovation, and demolition argument originates from the structural integrity of reused materials, and the incentives provided by the localised govern-ments for the repurposing of the materials. Whether computational techniques are required as a means to further the research, computation should, however, be viewed as a means to test and further the po-tential for opportunistic developments, rather than purely as a means to digitize the technique of building.

According to the United States Environmental Protection Agency, a large part of the initiatives for re-purposing materials within the field of construction are dedicated to reduction and reuse. Rather than looking into the means of solely researching with the ongoing problems that end-materials produce, perhaps the larger research and development goal should be to look into potential re-establishment of the materials into cradle-to-end results, which produce a larger effect—whether cultural, social, or economical—on the societies, which architecture and construction place an importance on.

ENDNOTE

Reduction

Techniques for reducing the amount of material used in construction without any harmful consequences to the structure are still being developed. One of the best debris reduction techniques, Advanced Framing, can greatly reduce the amount of lumber used in wood framing for houses.

Reducing the amount of C&D materials disposed of in landfills or combustion facilities provides numerous benefits.

- Less waste can lead to fewer disposal facilities, potentially reducing associated environmental issues including me-thane gas emissions which contribute to global climate change.
- Reducing, reusing, and recycling C&D materials offsets the need to extract and consume virgin resources, which also reduces greenhouse gas emissions.
- Deconstruction and selective demolition methods divert large amounts of materials from disposal and provide business opportunities within the local community.
- Recovered materials can be donated to qualified 501(c)(3) charities, resulting in a tax benefit.

Source: United States Environmental Protection Agency

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IMAGE CREDITS

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