CARDBOARD IN ARCHITECTURE

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1. ABSTRACT

Corrugated cardboard is increasingly being used in a wide range of modern applications, including printing, packaging, and aviation, as well as the construction of various indoor elements such as furniture and doors. Corrugated cardboard has numerous advantages as a structural building product. It has very good isolative (thermal and acoustic) properties, is easily recyclable, and can be processed, in addition to being a relatively low-cost material utilizing clean energy sources. Corrugated cardboard, on the other hand, has a high degree of structural strength and stiffness as a construction material. Despite these proven advantages, corrugated cardboard's popularity as a building material has remained relatively steady over time, owing to its perceived limitations. Its susceptibility to ultra-violet light and various chemicals, as well as its vulnerability to moisture, burning, and temperature change, are among its weaknesses. Many of these problems are currently being studied and evaluated by experts in the area. Corrugated cardboard also needs substantial improvement in order to conform to current design paradigms in its architectural quest for universal acceptance as a building material.

2. INTRODUCTION

Paper and cardboard, in different types, are commonly used in a wide range of modern applications, from packaging and food to cable manufacturing, aviation, and indoor elements like doors and furniture. The key benefits of paper and how to use it byproducts include its low cost, high recyclability, and low environmental impact.

Paper and cardboard have been shown to have significant structural strength, stability, and stiffness as compared to other traditional building materials. Limitations, on the other hand, include its susceptibility to humidity, heat, chemicals, and ultraviolet light. Researchers in the field of paper technology are currently investigating temperature fluctuations and other factors.

Despite its shown structural ability and high degree of versatility in construction, demolition, and disposal, the few current applications in which cardboard has played a significant role in building construction have not been developed or

thoroughly investigated pursued beyond the prototype level.

Furthermore, these previous implementations were mainly ephemeral in nature and did not completely leverage cardboard's noted building physics benefits. A systematic study of previous cardboard implementations, with an emphasis on structural considerations and physical defects, is a crucial first step to be able to explore the exciting possibilities further cardboard's architectural ability.

2.1. ARCHITECTURAL BACKGROUND: CARDBOARD BUILDINGS

A review of previous cardboard applications in architecture must begin with the first attempts during WWII. The 1944 House1 was the first known building made entirely of cardboard, and it was built in the same year, followed by a period of slow growth in the area.

Figure 1 - 1944 House

The slow adoption of cardboard was due to a lack of research and development into its flaws, such as its susceptibility to water, fire, and other factors, as well as limited manufacturing and assembly options redevelopment. Following these early trials, a number of architects, including Buckminster Fuller in the 1950s and, more recently, Japanese architect Shigeru Ban, have gradually influenced the development of cardboard's use in architecture.

The introduction of other new alternative building materials delayed cardboard's growth as a viable building material even further. Plastic and Formica, a plastic laminate, had become common replacement building materials by the late 1950s. By the 1970s, a new alternative, polycarbonate, had been introduced as a lower-cost, but durable and waterproof, option.

In recent years, academics have become more interested in cardboard construction science. ETH Zurich, the Architectural Association in the United Kingdom, and TU Delft (Faculty of Architecture, Building Technology, and the chair of Design Constructions) in the Netherlands have all conducted experimental and theoretical research into cardboard as a viable building material.

2.2. CHARACTERISTICS OF CORRUGATED CARDBOARD

Paper with a density greater than 200 g/cm3 is generally accepted as cardboard. Corrugated cardboard is a stiff, strong, and light-weight material made up of three liner layers of brown craft paper, a type of paper which is resistant to tearing, splitting and bursting, and is produced by using the craft process of pulping wood chips. Composed of ply liners and a corrugating flute layer, corrugated cardboard is produced in a variety of Flute sizes. Ply weights between 115g/m2 and 350g/m2 while corrugating flute weights around 112-180g/m2. Today, the vast majority of corrugated cardboard is used by the packaging industry, but it is also used for advertising board, various furniture applications, and the interior core of doors. Corrugated cardboard can be classified by several different defining characteristics, including: construction, flute size, burst strength, edge crush strength, flat crush strength, basis weights of its components, surface treatments, impregnation, printing and coatings. In the initial stages of the corrugation process during the production of the paper pulp, paper ply, and flute, cardboard’s mechanical and physical properties can be altered and adjusted.

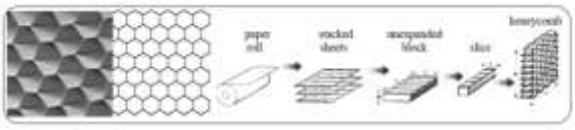

Figure 2 -Traditional honeycomb cardboard production by expansion.

- Mechanical Behavior: Due to the characteristics of cellulose fibers and the bonds between them, paper has high tension strength, outperforming the strength of its compressive strength in both cross machine direction (CD) and machine direction (MD).
- Moisture Resistance: One major limitation of cardboard is that it becomes extremely weak when confronted with humidity or direct water, causing dimensional changes, distortion and reduced strength
- Acoustic Insulation Properties: Due to its low mass, acoustical qualities are not measurable for a single sheet of paper. However, extensive layering of corrugated cardboard has been shown to provide significant acoustical insulation.
- Thermal Insulation Properties: Cellulose fibers, the primary material used in cardboard production, are commonly used because of their low thermal conductivity in diverse industries, and are known to have strong isolative properties.
- Fire Resistance: Untreated plain paper has no fire resistant qualities. However, paper boards containing heavy stocks of paper pulp exhibit some fire resistant characteristics, similar to untreated timber.
- Biological Attacks: As with other wood and byproducts, paper and cardboard are sensitive to attacks by rodents, fungi and other bacterial development under certain conditions.
- Toxicity: Despite the fact that cellulose fiber is derived from a natural resource, under certain conditions recycled paper byproducts can exhibit toxicity as a result of chemicals, bleaching agents, adhesives and inks used during production process.
- Odor: Paper and cardboard do not release any odors but remain sensitive to foreign odors.

2.3. TECHNICAL BENEFITS OF CORRUGATED CARDBOARD IN CONSTRUCTION –

- Efficiencies gained from the multi-functional characteristics of corrugated cardboard: corrugated cardboard building components provide thermal and acoustical insulation, structural strength, and ease of recyclability-dismantling.
- Efficiencies gained in construction site organization: Prefabricated cardboard-based building elements allow for quick, simple, inexpensive manufacturing, and also minimize time spent on the construction site.
- Efficiencies gained by decreasing the number of building materials: Traditionally in construction, the exterior of the building's skin is separated into multiple mono-functional layers, resulting in needless complication and associated costs. Cardboard, in contrast, can alone satisfy all the functions of a building's exterior skin, thereby eliminating the costs of multi-layering.

2.4. CASE STUDIES-

Case study -1

PAPER CONCERT HALL

- ❑ The aim was to construct a paper concert hall which is easy to assemble and durable, for an early resumption of musical activities in the city.
- ❑ He has designed an elliptical hall inserted in a square 25-m x 25-m building covered by a lowered pyramid
- ❑ The main hall will house 230-seats.
- ❑ The main materials are heavy cardboard tubes and sandbags.
- ❑ The project was a challenge for the acoustician because of the unusual technical context, the shape of the hall and the materials used.

- The walls of the auditorium are made of heavy cardboard drums, recuperated from print paper rolls.

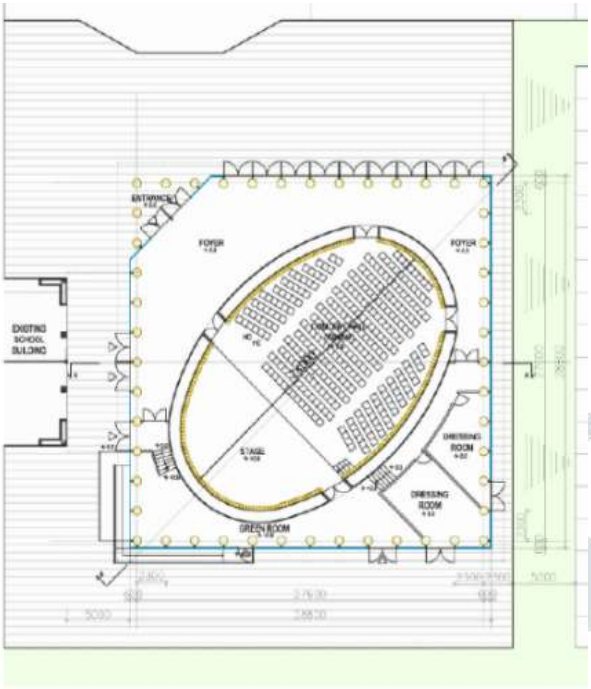

Figure 3- Plan of L'aquila concert hall

Case Study-2

PAPER CHURCH KOBE

The plan (10 x 15m) is enclosed within a skin of corrugated, polycarbonate sheeting. Within this, 58 paper tubes (325mm in diameter, 14.8mm thick, and 5m high), were placed in an elliptical pattern. The eclipse is based on those in Bernini's church designs, and the space between the eclipse and the outer edge of rectangular-shaped site formed a corridor and provided lateral support. At the entrance to the eclipse, the spacing of the paper tubes was widened, and the facade fully glazed to form a continuous, unified space between the interior and exterior. This church was disassembled in June 2005 and all the materials were sent to a city in Taiwan.

Figure 4- Paper Church Kobe

3. RESULT-

This study provides a close examination of the technical, social and environmental impact on the positioning of corrugated cardboard building industry. Using a top down approach, it gives a basic understanding of the research, development and implementation for innovative materials and techniques in the construction sector. The main results can be divided into the corrugated cardboard research level, the implementative strategy level, and the innovation management level.

4. CONCLUSION

People have tried for almost 150 years to use paper and its derivatives as building materials. Different approaches have been taken over the course of time. Since machine production of paper was invented in the late eighteenth century, the material has been recognized as a cheap substitute for existing construction materials – particularly for wood. The invention and popularization of new products in the papermaking industry, such as corrugated cardboard, paperboard and honeycomb panels, have encouraged architects and engineers to experiment with new structural and material solutions. In the 1980s, Shigeru Ban introduced paper tubes as building components, and it soon became the most popular paper-based product used in architectural structures.

Thanks to its light weight, low price and ease of production, and also thanks to its sustainable properties and rather ephemeral character,

designers are now more likely to use paper in several main categories.

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