Building real buildings with cardboard

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In partnership with: www.cardboardschool.co.uk

Cottrell and Vermeulen Architects	Architect
Westborough School	Client
Essex Tube Winding Ltd	Manufacturers of card tubes
Paper Marc	Manufacturers of paper and board
Quinton and Kaines	Manufacturers of panel products
C G Franklin	Building Contractor
Dept of the Environment, Transport and the Regions	Government Sponsor

Introduction - why build with cardboard

Cardboard is a material with an image problem. People think of it as a disposable, short life packaging material with poor properties. In reality it can perform very well over an extended period if it is designed correctly and treated properly. Perhaps most importantly from an environmental and sustainability point of view it is also made from a waste product for which there are few alternative uses - paper. This makes efforts to find appropriate construction uses of cardboard appealing in environmental terms, as well as offering an interesting challenge.

There are already several common uses of cardboard in construction, and more still in the furniture sector. A large proportion of internal doors are filled with a cardboard honey-comb, covered with a thin laminate. Tubes are used for column forming because they are cheap and available in large numbers. This not only reduces cost compared to other sorts of form work, but can save time as well. Tubes are also being used to help the process of pile driving. Panel products are widely used in temporary and Exhibition structures.

Cardboard dominates the packaging industry, because of its low cost, but also its ability to give enough protection to the object being packaged. There is no need for greater strength for breakfast cereal boxes; these products normally reach us in good condition so it is clearly doing its job. But by coating cardboard it is possible to use it for transporting frozen fish. Perhaps most striking where a vast quantity of liquid is transported in cardboard boxes lined with aluminium and plastic.

What these examples show is that like any other material, cardboard, when engineered correctly, can do the job it is asked to do.

Figure 1:Card beam under two man test load!

Environmental issues

The process of paper and cardboard production is interesting from an environmental point of view, and has often generated debate. All of the materials involved are relatively cheap and bulky, so that transportation is a key issue for consideration. However fundamentally, using cardboard products must help to find a secure market for the waste paper that is otherwise finding its way into landfill sites.

Worldwide the annual use of paper and board is about 300 million tonnes, and this requires a lot of trees. The card industry is one of the largest users of post consumer waste paper.

The issues to consider in terms of paper recycling are the collection and movement of the material, and any waste products removed in the process. These wastes are both solids, like plastics or any stray metal, and liquids, including any inks or water repellents. The energy balance of recycling also deserves checking, as if it is carried out sufficiently inefficiently it might be less energy intensive to use new trees instead.

Overall I am confident that wider appropriate use of cardboard in construction will have a positive impact on the environment.

What has been done before

The largest number of cardboard buildings have been designed by the Japanese architect Shigeru Ban, most recently the very large gridshell for the Japanese pavilion at the Hannover Expo. However, in my opinion, the most important work he has done has been in emergency shelters. These have been used in Africa and more recently in Turkey following the earthquake there, and have been based on cardboard tubes.

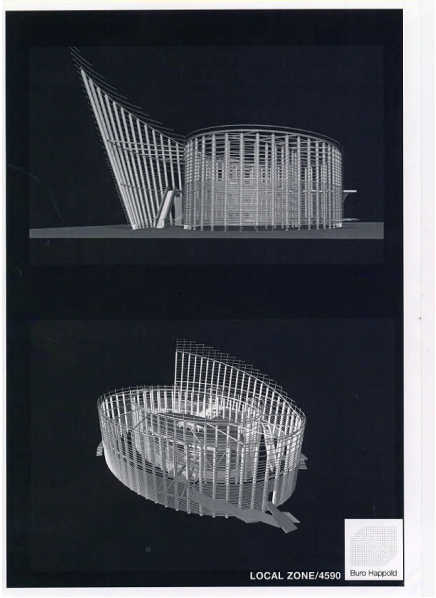

Figure 2: Local Zone in the Millennium Dome

Buro Happold has experience of large scale construction with cardboard, with three important projects being the Local Zone (also called Shared Ground) in the Millennium Dome, the Japanese Pavilion for the in the garden of MOMA (Museum of Modern Art) in New York. All three of these examples involved the architect Shigeru Ban again, although others were also involved.

Our project

One of the features of most of the previous examples is that they are short lifetime buildings. At Westborough school we wanted to develop something more modest in terms of size, but with a longer useful life.

The Westborough school, near Southend to the East of London, is a large school for the under 11s, with over 700 pupils. The project is for an 'after school club', which also provides toilets for the playground, and a general purpose space for the school.

Our current design thinking is shown in the two images below. The intention is to make an interesting building, so that people have further reason to take note of it. Its form reflects the nature of cardboard, in particular the corrugated nature of the South facing wall. The main approach is to use 50 mm thick honeycomb card built up in three layers to make a complete wall or roof panel. These are timber edged to aid jointing. Across the centre there is a wooden truss, necessary to span the width of the building. This is supported by cardboard tubes; other tubes support the roof on the side with the large windows.


Figure 3: Internal view from design concept

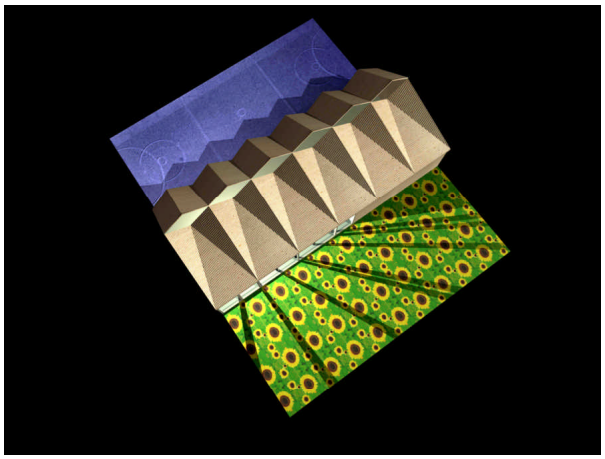

Figure 4: Aerial view of design concept

Dealing with fire and water and other hazards

Water

When you talk with people about building with card, they nearly always ask something like, 'Won't it get soggy when it rains?' The answer is of course yes - unless you do something to stop it. In this case we have opted for a 'belt and two sets of braces approach', we do not have time to test options.

First we are treating the card with a water repellent chemical, to prevent the card absorbing moisture from the air, and to allow it to survive any accidental wetting. This chemical is removed in the re-pulping process, so allows recycling, although in an ideal world it would be avoided.

Secondly, each panel is coated with a plastic layer, to keep moist air or liquid water out. This coating is also removed by the pulping process.

Finally, on both the inner and outer faces of the panel, there will be a protective top layer. On the outside this will serve as a rain-screen or tile, and on the inside as a pin-board for the classroom. This outer layer may well need to be replaced every few years, as it will bear the brunt of footballs on the outside, and whatever the children are doing on the inside!

Fire

Although cardboard obviously does burn, it is actually very similar to wood in its fire performance. This means that it tends to char on the surface, and therefore although it is damaged, it does not contribute significantly either to the heat of the fire nor to the spread of flame. Hence, in this case at least, the issue of fire is not as critical as might be expected.

Other hazards

The description of the panel system covered the approach to natural wear and tear with the outer and inner layers. The outer layer is not fully specified yet, but will also need to be tough enough to discourage deliberate damage. However the school does not have a problem with vandalism so this aspect does not need to be excessive.

In other locations there could be more of a problem with vermin of various types. Care is needed in the detailing to make it difficult for any to gain access. We can learn from the straw building community in this respect.

Conclusion: Environmental impacts

One particular benefit of using honeycomb cardboard as the main structural component, is that it provides good insulation at the same time. Calculations show that the panel structure we plan to use has a U value of around 0.3 W/m^2 and this is sufficient to exceed the UK building regulations.

In setting out on the project, we set ourselves the target of achieving 90% recyclability, and 90% recycled material input. It is important to emphasise that the need to deliver a viable building supersedes those targets, but we are still confident we will be close to achieving this through the use of so much card.

Everything in sustainable construction involves some compromise, and we are comfortable with where this project is taking us - but believe others could go further.