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POTENTIAL FOR THE USE OF NOVEL ENVIRONMENTALLY FRIENDLY MATERIALS FOR CONSTRUCTION

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ABSTRACT

A peremptory survey of traditional architectures will show that they are dominated by local materials and constrained by local climates. However, historical changes have occurred in the usage of materials of construction that appear to be driven by social as well as climate and materials constraints. Social, climate and materials are factors that influence the uptake of newly developed materials such as for example agricultural waste in fibre cement composites. The usage of various materials and the factors that contribute is illustrated from the author's experience in Australia, Malaysia and the USA. It will be shown that the obvious factors such as competitive cost as well as social factors such as the social aspirations of the building owners, their ability to pay for particular types and construct and the way in which a particular construction method may imitate of traditional building styles are all factors that may influence the uptake of a novel building material.

INTRODUCTION

Traditional Architectures

A peremptory survey of traditional architectures will show that they are dominated by local materials and constrained by local climates. They are also constrained by expectations and the culture of the owners. Thus architecture in Europe and other cold wet climates populated by farmers is traditionally masonry. Masonry protects against the cold is appropriate for sedentary farmers and is long lasting. Masonry was traditionally constructed from unaltered local stone, earth and wood although with the advent of modern industrial manufacturing, local materials may be much modified. For example stone has been replaced by brick and concrete, wood has been replaced by steel and recently reinforced plastics.

By contrast in tropical wet climates farmers may construct less durable buildings because protection against cold is not so important and large quantities of plant materials are available for construction. Traditional buildings are constructed with rapid replacement in mind and durability is not so important. In such traditional areas therefore the need for replacement materials is minimal.

Traditional pastoralists and hunter gatherers by contrast are interested primarily in mobility to follow their herds or food sources and this is true wherever they live. Their buildings therefore are designed to provide appropriate protection for the climate and they may be designed either to be moved (tents or similar) or be disposable (igloos etc).

In recent centuries many traditional architectures have been disrupted by European colonialism, itself a consequence of the technological power and industrialisation of Europe. Thus the colonial movement has seen the transfer of traditional European architectures to countries such as Australia, South Africa, Brazil, and Malaysia etc. Because European culture has dominated in each place and the colonial masters have tended to import their traditional architecture, this architecture becomes the aspirational architecture for the colonial subjects seeking to emulate their rulers.

Industrialisation of Building Components

In return European architecture has been influenced by the architectures of the European colonies subjects with modifications to for the climate into which it has been introduced. For example, the veranda an invention of the Indian subcontinent, was introduced into Australia by British colonists and is very much part of what is now known as traditional Australian Architecture.

Superimposed over this migration of architectural forms has been the development of industrial building systems featuring mass production of building components. Industrialisation of building has essentially been a mechanisation of manufacture of components derived from the traditional building crafts and trades. Industrialisation is not a new phenomenon having been in existence in various forms for thousands of years but it has been a major force for change in building methods since the beginning of the 19th century but has been of much greater significance in the 20th and now 21st centuries.

Industrialisation may be characterised by standardisation of building components over larger and larger geographical areas. It has been driven by our increasingly efficient use of energy to drive machinery and by our increased ability to transport building materials economically over greater and greater distances. Thus the bricks that were used in the 18th century would have been made locally with local materials often on the construction site. They would probably have been moulded by hand and fired in a local kiln using local wood or coal as a fuel. Materials such as lime for mortar would also have been made on site from limestone or other materials such as shell fish shells. Timber would also have been felled and cut to size locally. Thus there was little pressure for standardisation beyond the local area and the because of the difficulties of transportation only relatively expensive and difficult to make components such as metal nails, locks, hinges, glass and the like would have been imported from elsewhere.

By the early 19th century more efficient methods of transport had been developed. For example the 18th century in Europe was a century of canal building which offered a means of transporting heavy materials such as brick over large distances. Technological changes afforded by inventions such as Portland Cement by Joseph Asphdin early in the 19th century provided a further impetus to change in building techniques. The use of powered machinery provided impetus to mass production of building components in large quantities and we see the rise of companies devoted to the manufacture of all sorts of different components and materials.

The improvements in transportation resulted in the interchange of materials and components all around the world. Thus it was common before the manufacture of cement commenced in Australia to import cement from Europe in barrels. Indeed the transport of building materials over incredibly long distances continues to this day and cement or cement clinker is routinely transported around the world from huge manufacturing plants typically located close to ports to places of high demand for the finished product where local manufacture is not possible because of lack of suitable raw materials or the local industry is not developed.

Substitution of Manufactured Materials for Traditional Building Materials

The late 19th century saw the rise of a new phenomenon – new industrial building materials. These materials substituted for the traditional materials and exploited the new technologies in steel, concrete and other materials that had been resulted from the scientific advances of that time. Advances in the ability to manufacture materials to specific properties and advances in engineering knowledge truly produced a revolution in construction of large public structures such as bridges, canals, docks, municipal and private buildings. The new industrial building materials included reinforced concrete, rolled steel sections, cast iron structures etc etc. Not only was the development of these materials of significance but the increasing understanding of their interactions also allowed the manufacture of larger components and structures previously impossible because of the limitations of traditional materials now became possible.

As our understanding of materials increased, other trends became apparent. One such was the development of standardisation and the later 19th century saw the first development of standards to ensure that materials made in one region were similar in their properties to materials made in other regions. This was driven by the ability to transport materials over large distances and the need to ensure uniform performance when used in similar fashions.

Another trend was the deliberate development of substitutes for traditional building materials. One such example was the development of asbestos-cement as a substitute for roofing slates. Its development combines the use of strong fibres of asbestos to reinforce a brittle material viz. cement using a new industrial technology for the automated manufacture of paper. The resulting material was manufactured as a flat sheet and cut into pieces approximately the size of a traditional roofing slate. The asbestos-cement slates were applied and used in the building structure in exactly the same way as the true slate roofing with the advantage that they were and are all the same size, and uniform in their properties facilitating their installation into the building. Asbestos cement slates have the further advantage that they are light in weight and thus can be transported easily. Furthermore they are not dependent on local sources of slate and since asbestos is a minor component in their composition, asbestos can be transported to their place of manufacture which can be located wherever there is a local cement supply within easy reach. Low manufacturing and low transport cost are also factors in their attractiveness to consumer and for example asbestos cement slates it was attractive to import them into Australia in part because of this. Demand for these materials was such that it became attractive to manufacture them locally and the James Hardie Company has become successful in Australia and around the world because of this.

Trends in Housing

Australia

Prior to European settlement there was little evidence of permanent dwellings in Australia. Recently however, there have been discoveries in Victoria of what appear to be the remains of permanent stone villages associated with comprehensive structures to divert river water and trap fish. This however is rare and the indigenous hunter gatherer cultures moved around their traditional hunting areas in a perpetual “walkabout” following seasonal food sources. Their encampments therefore reflected this lifestyle which was characterised by temporary structures made from local materials.

The construction of permanent buildings commenced with European settlement from the United Kingdom in the late 18th century. The earliest permanent government buildings housing the colony governor were constructed from local stone bound together with lime mortar made from burnt sea shells. They were probably roofed with a bark thatch made by laying overlapping pieces of bark on unshaped wooden rafters. The floor was most likely to be compacted earth and the clay for this may be mixed with cow dung and lime to consolidate and make it amenable to trowelling to smooth it. Because of the remoteness of the colony from Europe the first buildings were rather primitive and did not include glazing and the like.

The other buildings of a reasonably permanent nature were built using a technique called “wattle and daub”. Thin branches are woven into flat walls and plastered with mud. Again such structures were probably roofed with bark thatch and had dirt floors. One of the oldest surviving European buildings in Australia is a stone cottage with a slate roof that was built in 1816.

WATTLE AND DAUB CONSTRUCTION

A common method of construction that survives to this day in some places is the slab hut. This was constructed from slabs that had been split from tree trunks. The slabs are embedded in the ground side by side to form the walls of the hut and tied together along their tops with a wooden top plate. A pitched wooden roof structure is placed over the top and thatched with bark. The structure would also have windows inserted in the walls and commonly a kitchen would be constructed separately with a stove and fireplace constructed of stonework. Where such structures exist today, it is common for modern construction materials and components to have been added to the structure and it will be found that factory made windows, doors and other modern features have been added. In many cases the underlying structure may be so disguised that it is almost impossible to determine its origin.

SLAB HUT

SLAB HUT INTERIOR

With the advent of saw mills and saw milling machinery during the 19th century masonry construction was supplemented with framed wooden construction. In the northern Australia where the climate is hot this became the most common method of housing construction and many houses were built in a very characteristic style called the “Queenslander”. This house is characterised by being raised on high (1.5m or more) wooden piles called stumps because they were formed from pieces of naturally shaped tree literally tree stumps. Typically the house will be surrounded with verandas providing shade to the outside walls and windows. The wooden frame of the house will be clad with wooden planks and will often have a corrugated iron roof. There will usually be fairly large windows opening to provide good ventilation and the ceilings will be around 3m high. The “Queenslander” house is designed for the hot climates. In the southern cooler states wooden framed and clad houses were also common but were usually set on low wooden or brick foundations. There they are designated weatherboard houses. Weatherboard houses were cheaper to construct than masonry houses and were therefore considered inferior to the masonry house. In many parts of Australia they comprised the houses of the poorer sections of the population.

QUEENSLANDER STYLE HOUSES

In the twentieth century two variations on the wooden framed house were recognised – the brick veneer house and the fibro house. In these houses the construction method is basically the same as the weatherboard house – a wooden frame is set on foundations and the house is constructed around the frame. The fibro house is clad with asbestos cement (or more recently with Cellulose cement) sheets while the brick veneer house is clad with a single skin of bricks in imitation of the more expensive double brick or solid masonry.

The earliest fibro houses were clad is flat asbestos cement sheets with the joints between the sheets covered by a cover strip. A development of this construction style is to cut the asbestos cement sheets into strips and overlap them in imitation of wooden weatherboards. This technique has been used for some time but it does not give the impression of weatherboards because weatherboards are usually considerably thicker than fibre cement. A recent development has been to produce thickened fibre cement and shape it to more truly imitate weatherboards.

FIBRO HOUSE

MODERN BRICK VENEER HOUSE

In Australia currently there is a hierarchy of preference in building styles that is as follows

1. Framed house with flat fibre cement cladding
2. Framed house with planked fibre cement cladding
3. Framed house with brick veneer cladding
4. Double brick or masonry constructed house

The preference hierarchy reflects the construction costs of the various styles. At one time brick veneer was considered an inferior method of construction but it is true to say that this is now the most common method of construction in most of the major Australian cities. Of course it is also true to say that there is considerable variation in the costs of construction in different parts of the country due to local factors that determine the preferred methods of construction. Thus in Sydney with its hilly topography it is less common to use slab on ground construction whereas Perth is built on coastal sand dunes that favour slab on ground construction. Furthermore while it is possible to classify housing in this way there is mixing of the features of one type of house with another and desirable features are found in more than one style.

There are other more recent trends in housing. With increasing affluence, the standard of housing has increased and in recent times there has been a trend to construct larger and larger houses whatever the style. This has been coupled with a decrease in the lot size due to population growth of the major cities and lack of available space (at least where the majority of people wish to live).

Malaysia

Trends of housing in Malaysia have followed a surprisingly similar patter to than in Australia. The aboriginal inhabitants of the Malay peninsula constructed houses made from local plant materials. Wall would be woven from palm fronds and bamboo and other straight branched plants were use as poles to support the structure. Indeed it is still possible to see houses made in this way today.

Traditional Malay architecture was wooden framed with sawn plank cladding. It is surprisingly similar to the architectural forms of “Queenslander” house of tropical Australia but of course the details are different. Malay houses have an elevated open structure with wide verandas and flow through ventilation. They range is size from single family dwellings to large palaces occupied by the regional rulers such as the Sultan’s palace at Melaka.


TRADITIONAL MALAY KAMPONG (VILLAGE) HOUSE

MALAYSIAN SHOP HOUSES AND STREET

There are of course traditions of masonry construction in other parts of Asia that would have influenced the locals. However, these do not seem to have been common and it may have been that the unstable soils and the high rainfall in the region that makes masonry more difficult to construct, militated against that form of construction.

The Europeans introduced their own masonry based architectures into their colonies such as the Dutch and Portuguese colonies in Melaka and British colonies in Penang. The colonial architecture of the Europeans was also influenced by the need to protect themselves against the locals who were often quite hostile to their presence and this would have affected their preference for masonry in their buildings. The advent of long term British Colonialism in the 19th century and 20th centuries saw the construction of domestic housing for the colonial officials. For the most part this was also masonry in the European tradition but adapted to the hot climate with features such as high ceilings, verandas for shade and good ventilation.

The post World War 2 period in Malaysia saw the demise of the traditional wooden architecture and the rise of masonry. This has also been influenced starting in the pre-war period by the migration into the region of large numbers of Chinese tin and gold miners having their own tradition of masonry. Many of the Chinese who remained after the minerals ran out became merchants and traders and it is probable that masonry was their preferred construction material because of the need to protect their goods and livelihood.


MODERN MALAYSIAN STREET AND MASONRY HOUSING

As a result of these social trends the preferred construction material in Malaysia today is masonry. The typical house is a one or two storey row house, constructed on a concrete slab, with light concrete frames and suspended concrete floors. The frame will be in-filled with low grade ceramic brick and plastered with cement based render inside and out. The house will usually be covered with concrete or ceramic roofing tiles on a wooden frame. Housing of this type is complemented by multistorey apartment buildings in the major cities which are usually of reinforced concrete construction.

It would appear that the drivers for preferred construction materials are social. There is certainly a drive for durability of materials but the preference for a masonry style of house appears to be the perception that this is a quality construction. It is also possible that there is a general shortage of timber for construction and this has made masonry construction a necessity as well as being cheaper.

North America

Prior to the arrival of Europeans in North America the native peoples constructed their houses according to their particular lifestyles. In the colder but temperate north where people followed a settled existence they constructed substantial wooden houses. In the central plains the nomads who followed the buffalo constructed equally mobile housing that was capable of being readily transported to new locations. In the deserts of the south west they constructed permanent mud brick structures capable of lasting for many generations.

With the arrival of the European settlements in the 16th and 17th centuries new traditions of architecture arrived. These however were influenced by local conditions and in particular the abundance of huge amounts of timber which has resulted in the development of the wooden framed house. Nevertheless the European masonry architecture traditions were rapidly introduced into North America and the New England states contain many examples of European brick and stone construction typical of the time in which they were constructed.

The abundance of wood has influenced the development of domestic architecture in North America. The invention of the balloon frame, a system of wood-frame construction, in the 19th century, in which the studs are continuous from the foundation sill to the top wall plate was a most significant event. It was made possible by the availability of structural lumber sawn to uniform sizes. A balloon frame is held together entirely by nails and can be erected faster than a post-and-beam frame, with the use of less-skilled labor; and the end result is stronger and more likely to be square and plumb. Balloon frames exemplify industrialization of housing construction with the introduction of standard sized components and the reduction in the skill levels required for building tradespersons.

The development of North American building practices has mirrored the development of building practices in other countries and seems to have been driven by much the same forces. Thus the traditional masonry architecture of Europe is the preferred option and where other methods such as timber framed construction have been used, they are often combined with masonry to imitate masonry in outward appearance if not in internal structure. Thus it is common to find wooden cladding boards cut to imitate ashlar masonry or similar. It is also common to find brick cladding over a wooden frame where the brick does not form load bearing part of the structure as is the case in traditional brick masonry construction. Another very common building cladding is an imitation of plastered masonry incorporating water proof membrane, foamed plastic insulation and a polymer based coating that often includes cement and sand.

Having said that, it has been realized that wood and other materials can be durable in construction and the acceptance of these materials as primary building materials has grown over the years. Thus many examples of long lasting wooden houses can be found in most parts of the United States and in more recent times imitation wood paneling or planking made from vinyl siding or fibre cement has become very common. Indeed in recent times the vinyl siding has become the dominant material for the domestic cladding market over wood taking around 55% of the total new cladding market in the USA. [James Hardie Market Projections from Annual Report].


OLDER STYLE WOODEN NORTH AMERICAN HOUSE


MODERN SINGLE STOREY NORTH AMERICAN HOUSE

Summary

It has been the author's observation that a similar hierarchy in housing preference exists in America as in Australia and Malaysia. Where it is affordable, Americans Malaysians and Australians prefer masonry houses over wooden or imitation materials such as vinyl and where masonry is not affordable and there is an economical option will substitute an imitation of masonry for the real thing.

Implications for the Introduction of New Materials of Construction

It is clear that industrialized methods of construction predominate in the developed world and there is a trend towards increasing industrialization in the less developed world because there are clear benefits from the standardization of components in sizes and uniformity of properties. Trends in construction costs have been downwards over a long period of time and while in Australia the hours of work required to purchase a average house may have remained relatively static over that period, the size of an average house has increased significantly over the same period and its standard of fit out has greatly improved as well. This has been due to

- steady reductions in the cost of manufacture of building components,
- changes in the types of construction materials including the development of new materials and new methods of construction and
- changes in the way in which housing is constructed, particularly those that substitute factory for onsite labour.

The reduction in the cost of building component manufacture has been due in many cases to incremental changes in the manufacturing process and in other cases in the substitution of cheaper materials.

For example, asbestos fibre cement flat sheet used to be manufactured in 10 individual factories around Australia in the early 1980's but a larger quantity of its substitute (cellulose fibre cement) is now manufactured in only 4. This has been achieved with a reduction in the number of Hatschek machines that produce the material because there have been significant improvements in the reliability and productivity of the newer machines.

The substitution in North America of wood, hardboard and other claddings with vinyl cladding is an example of the introduction of a cheaper material that mimics the more expensive wood.
It is apparent that any new material will have to compete with the existing materials in several ways.

It must be

- as durable as the existing materials
- as cheap or cheaper than existing materials when installed in the house and preferably cheaper before installation than the material for which it substitutes.
- able to be used as a direct substitute for existing materials with little difference in installation methods thus requiring little or no retraining for the skilled tradespersons using it.
- capable of large scale manufacture and production of standardized components[1].
- capable of emulating the appearance if not the substance of materials that are generally considered to be acceptable materials of construction e.g. masonry or wooden cladding.
- have equivalent performance in service as the existing materials.

Case Studies of Introduction of New Building Materials

Let us consider some examples of attempts to introduce new building materials or components for domestic construction with which the author has personal experience.

Cellulose Fibre Cement replacing Asbestos Cement

The use of cellulose to replace asbestos in fibre cement is not new and the first instances of this substitution were during World War I in Norway when asbestos could not be obtained due to the disruption of shipping. However it was not until the early 1980’s that large scale substitution occurred in Australia and Europe. This development was driven by health and safety concerns for asbestos workers and of the possible effects on users of the product.

The use of cellulose in fibre cement in conjunction with asbestos had been widespread since the mid 1960’s. Incorporation of cellulose into asbestos cement produces a ductile more flexible and nailable board that is easier to use. The general practice however was to keep the asbestos content at about the same level as in pure asbestos cement and use cellulose to replace cement and other minerals that may have been present. Conceptually the cellulose was not seen as a potential reinforcing but rather as a means of making the board ductile and nailable.

With public pressure manufacturers of asbestos cement sought substitutes and essentially removed the asbestos from their products. Two particular types of cellulose cement have evolved, air cured and autoclaved cured. These arose from corresponding asbestos cement technologies and the air cured products are mainly confined to Europe while the autoclave

[1] There is a tendency in the industrialized countries to assume that less industrialized countries which also may have large labour forces will be receptive to labour intensive technologies; this is a mistake. The less developed countries realize that they have an opportunity to bypass the early stages of technology development and move immediately to productive low cost materials. Thus they will usually prefer the latest developments in new fully automated production equipment wherever this can be afforded and if they do not select the fully automated equipment they will tend to select the most automated equipment that they can afford.

cured technologies are found in Australia and elsewhere in the world. The removal of the asbestos from the autoclaved formulations resulted in a more economical product because the expensive asbestos was substituted with cheaper cement and silica.

The development of these technologies was not without initial difficulty because the properties of cellulose cements are different from those of the asbestos cements from which they developed. It is also found that the air cured cellulose cement does not perform well in climates such as Australia where rapid large temperature and humidity changes are commonplace. Both technologies however have been very successful in the appropriate environments and it is instructive to ask why.

It seems that substitution of asbestos by cellulose has been successful for the following reasons.

- Cellulose cement and asbestos cement are functionally identical for the user and there was a minimal need for retraining of installers.
- Cellulose cement and asbestos cement are industrial products manufactured in high volume on exactly the same equipment. There was however a need to add cellulose refining equipment to treat the cellulose so as to develop its ability to reinforce the cement matrix but this had minimum effect on the manufacturing process.
- After the initial problems were addressed, cellulose cement has proved to be as durable as the asbestos cement that it replaces.
- The ultimate users of the product do not see any aesthetic differences in the product
- The product is seen to be safer and more environmentally friendly than asbestos because the cellulose is mostly made from plantation timber compared to asbestos which requires large mining operations generating potentially dangerous mining waste.

Cement Bonded Wood Products

Cement bonded wood products have been in use for many years in many forms but with limited success. A review of the patent literature will show that there have been many attempts to produce cement bonded wood materials and that they take the form of boards, insulating panels (excelsior board), blocks etc. The wood that is used in these products has often been waste wood or sawdust but has often been specially prepared for the purpose. For example in excelsior board, long strips of wood are pealed from the wood stock and in the manufacture of cement bonded wood particle board wood is ground to a particular particle size distribution. It is fair to say that most of the attempts to make cement bonded materials have been motivated to make use of some cheap resource such as wood waste or otherwise unusable timber or to use cheap inorganic binders in place of urea or phenol formaldehyde resins.

It has been the author's experience that such products have limited appeal and that they have limited market lifetimes at least in Australia. Excelsior boards were made for a number of years from the 1950's to the early 1970's and then disappeared. There were also attempts in the late 1960's through to the early 1970's to manufacture a masonry block which utilized sawdust and prepared ground pine chips. Again this has disappeared from the market. The reasons for the disappearance of these materials are many and here the author speculates.

Excelsior boards; these were used as ceiling panels in large buildings such as offices and auditoriums. They appear to have lost out to changing fashions and to the advent of other insulating materials that were more effective and probably cheaper. The author has some experience in trying to compete with gypsum plaster ceiling panels and it is difficult to compete with these for the reasons of their cost and their dimensional stability.

Cement bonded wood particle board (CBWPB); CBPWB has never been made in Australia but has occasionally been imported. The author was involved with an evaluation of this material and purchased several large pallets of the material which were stored in a warehouse. The material was seen to spontaneously develop shrinkage cracks in protected storage during a hot summer. It has been the author's experience that moisture movement is a problem with this material and that it is not suitable for an arid climate such as Australia where it may be dried out excessively and crack. It is also extremely heavy and is disliked by the installers for this reason. It is also considerably weaker than conventional particle board and thus requires more supporting beams when used as a structural member. It is not perhaps surprising considering this evidence that CBPWB has not gained acceptance in Australia where its disadvantages are particularly apparent.
However Cement bonded wood particle board does have some very good properties. Its density gives it good acoustic properties and its composition makes it very fire resistant. Thus for applications where these properties are required it is very suitable and may be better than other materials. Thus it has applications for fire and sound resistant partitions between individual occupancies in apartment blocks or for fire and sound resistant roofing systems. It is not in the author's opinion a good general purpose building board although it may complement the manufacture and sale of other building boards. Thus it is difficult to make a profitable business of it by itself and this was certainly the author's experience in Malaysia where he worked with a manufacturer of building boards that included the sale of CBWPB. These were most successfully sold where their unique properties were used to advantage and attempts to sell them as a general purpose board were the cause of many customer complaints and problems for the company. Indeed the manufacturer of these boards had been an independent company and market acceptance problems resulted in it becoming available for acquisition from the previous owners.
However it is not always the case that CBWPB is not generally used and CBWPB is extensively used in Japan for domestic cladding. However, it should be noted that the Japanese climate is very different from Australia and the humidity seldom drops to the levels in Australia. Thus the moisture movement of CBWPB is not an issue. The market for these boards is very sophisticated and has been in existence for many years developing many technical advances. There are other factors that are unique to Japan that have contributed to its success and one is that housing construction costs relative to land costs are low. Thus it is possible to sell building materials in Japan that would be uneconomical in other countries because they have relatively less effect on the cost of the housing package.

Sawdust Cement Masonry Blocks; these have occasionally been made in Australia but are not made currently. There are as usual a number of reasons for this and the author speculates as follows

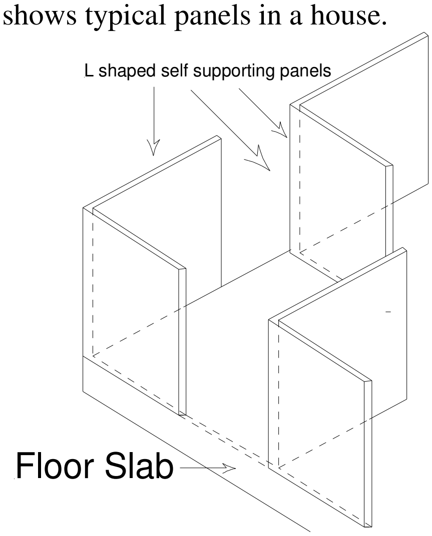
- Manufacture of any wood cement based product requires the removal of cement inhibitors from the wood and until recently it has not been realized that this is often achieved by action of moulds and bacteria. Thus the inventor who had fortuitously used aged sawdust in his formulation and then changed to new sawdust suddenly encounters unanticipated problems. The variability of woods from different sources or even different ages from the same source brings the same problems and it may be difficult to undertake continuous industrial scale manufacturing as a result.

- Wood cement products have inherently high moisture movement and if this is not allowed for in the construction practices early failure of the product may result. Given the legal liability imposed on builders in most industrialized countries such failures are a serious deterrent to continued use of the product and the product disappears from the market.

Panelised Building Systems

The author has been directly involved in two attempts to introduce panelized systems into domestic and commercial construction.

Free Standing L-Shaped Light Weight Concrete Wall Panels; no specifically environmentally friendly materials were involved in the fabrication of these panels but there were some interesting lessons to be learned from them. The motivation for designing and using the panels was to reduce the dependence on bricklayers and to increase the speed of erection of houses. Each panel was L-shaped in plan and so could stand without propping. Each panel would form the corner and 2 sides of a wall and was designed to sit on a concrete floor slab. Panels were composed of foamed concrete with a density of around 1500 kg/m^3 and so were relatively light. Panels were 125 mm thick and 2400 mm tall with wall lengths from 600mm to 1500mm. The illustration shows typical panels in a house.



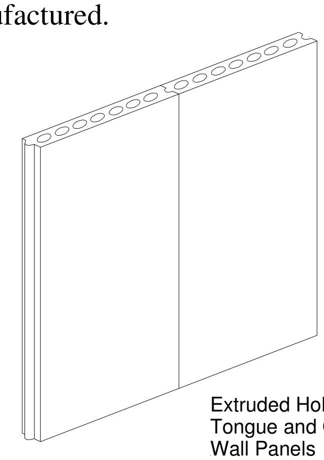
Several houses were constructed using this panel system as well as a small school block but the acceptance of the panels was low for a number of reasons.

- Because of the height of the panels and because of the need to transport them vertically, specialized trucks with a low deck were required. Such trucks are in short supply and it was often difficult to obtain them at short notice.
- The panels were fitted with metal cleats that were welded to corresponding cleats cast into the floor slab of the house. Thus the floor slab had to be specially prepared and welding equipment had to be available to fasten the slabs in place. In areas where there was no electrical power this sometimes posed a problem and since in general builders were not trained as welders this posed another problem.
- It was necessary to have a crane available when the panels were delivered to site so coordination of the delivery the crane and the tradespeople to unload, place and fix the

panels was also often a problem. It was also necessary for the crane to have special lifting hooks to pick up the panels and this had to be supplied by the factory.

- Use of the panels was relatively easy on flat sites where the crane could get close to the position where the panel was to be placed. However it was almost impossible to place panels on hilly sites because most mobile cranes could not get to the spot where they could hoist and place the panels.
- L-shaped panels impose some constraints on design flexibility that did not fit well with local building concepts and they did not look like conventional brick construction.

The panels did offer considerable cost savings because it was possible to complete the structure of a house in one day. However because they disrupted conventional small scale building practices and had other disadvantages, they did not gain acceptance in the market place and are no longer manufactured.



Extruded Hollow Core Tongue and Groove Wall Panels

Extruded Wood Cement Panels; these panels were developed by one developer of wood cement concrete blocks and offered the advantage of light weight with the benefit of being able to be cut and fixed as if they were made from wood. Thus once in place they could be cut and finished by traditional building tradespeople such as carpenters, plasterers painters etc.

The panels are fire resistant and have excellent acoustical properties but they are suitable only for wall panels because their flexural strength is not high enough for them to be used as structural flooring. However, their compressive strength is reasonably high and they can be used as structural walls in 2 or 3 storey construction where the loads are relatively low. Because of their fire resistance and acoustic properties they are very suitable for dividing walls in apartments and other multi-tenancies.

It is possible to install panels manually because of their light weight and two people working together could lift and put them into place. However panels are not free standing and need to be supported until sufficient structure is in place to hold them. In that sense they are no different from framed systems but since they form only part of a wall they require individual temporary support until they are bound together as a unit. In reality they are better suited to commercial and industrial construction where heavy equipment is available to handle larger building components. They are also only suited to slab on ground construction and this limits their utility in hilly terrain.

The first attempt to manufacture and supply these panels failed for several reasons. There were subtle technical problems with their manufacture arising from the fact that the extruder that had been purchased could not handle the mix required. The extruder had been shown to be suitable for extrusion of conventional concrete to which had been added small amounts of hammer milled wood for tensile reinforcement, but it would not extrude mixes that were approximately 35% by weight wood. It was found that the extruder would not extrude smoothly and continuously and extruded in a series of jumps. It appears that wood in the mix compressed under pressure and locked the extruder until sufficient pressure was applied that the mix started to move relative to the outside of the extruder mould. Once moving the friction between the mix and the extruder reduced and the mix then expanded. This reduced the pressure on the incoming mix which then was recompacted under the action of the extruder and the mix compacted again. The result was irregular changes in the density of the panel which induced changes in the mechanical and other properties of the panel making them susceptible to develop cracks from one side to the other. There inservice performance was compromised and of course this was not apparent at the time of manufacture of apparently good panels. There were many panels that did not leave the factory because they cracked before they could be sent out but nevertheless significant numbers of faulty panels were put into service.

The developer of the panels has now redesigned the extruders and the manufacturing equipment and is currently attempting to set up a new factory for their manufacture. Despite the problems he has sufficient evidence of satisfactory performance of properly made panels and of interest from possible customers to start again. It will in the author’s opinion be a long and difficult path to get to a profitable operation with these materials and to gain acceptance for them in the market. It also appears that they will have a limited market niche comprising mainly commercial and industrial construction with a small amount of domestic use because the panels require special equipment to handle them. In addition they do not imitate other acceptable methods of construction such as masonry when used as external walls.

Summary and Conclusions

The above discussion leads the author to the following conclusions.

Industrialisation of the manufacture of building components has meant that it is almost certain that any novel material will have to fit in with the existing manufacturing system.

It is important that any new material be able to be produced at the same or preferably less cost than the material for which it substitutes.

It is preferable that the final building component utilising the new material will either have to require little or no change in existing building practices and thus require little special training for the installers or it must offer substantial cost and performance benefits that offset the initial training and changes to building practice.

The novel material must perform as well in service as the material that it replaces.

Customer preferences for building materials and styles will influence the success of a new material. If the new material is able to imitate the appearance and performance of a preferred building style while fitting with conventional manufacturing and installation practices then it stands a good chance of gaining market acceptance and success.