

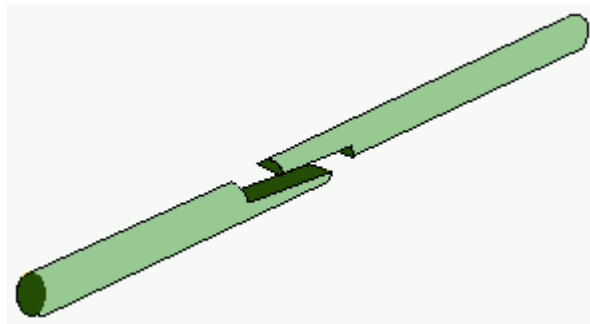
Northern Periphery Project Roundpole Construction Sub-Project

EGLU - Environmentally Sound Glues

Lead Partner
Gaia Architects
With
Buro Happold

Aim

To investigate the use of environmentally sound glues for project elements in support of other projects.

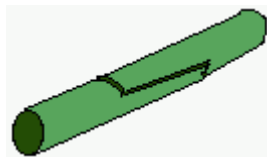


Summary

An environmentally sound approach was an integral part of the project objectives.

It was therefore decided to investigate environmentally sound glues for use in any project which would need glue as part of its design.

It became clear, at the mid-point of the research, that most projects could design out the need for glues. It was therefore decided to contribute a think piece on environmental glues only. This is based mainly on work done by Bjørn Berge of Gaia Norway.



Contents

1. Introduction
2. Design Team Discussion
3. Adhesives and Fillers

1. Introduction

This project has looked not just at the potential of roundpole in the northern periphery, but has also sought to establish such use within the terms of reference of good environmental practice.

Roundpole construction has often depended on high performance glues. The original aim of this sub-project was therefore:

To identify environmentally sound glues for use, where necessary, in roundpole construction.

The objectives were:

- to create a definition for environmental soundness in glues.
- to draw on existing expertise in glues to itemise the more environmentally sound products.
- to choose a long list of potential glues for various purposes.
- to check the extent to which glues are being required for projects within the overall research project.
- to establish a short list of glues and assess them against a range of appropriate performance criteria.
- to calculate the costs of the various glues.
- to investigate the market for the selected products.

In the event it was felt sufficient to contribute a thinkpiece on glues. This is largely based on work by Bjørn Berge, who has published an extensive work on ecological materials - *The Ecology of Building Materials*, Architectural Press, 2000.

2. Design Team Discussion

Background

One of the principal reference projects visited by the study team, the Hooke Park Production building¹, made extensive use of epoxy resin. This was regarded as a positive and creative focal point of the design. However the environmental credentials of epoxy are not good and therefore it has been criticised in this respect. It was considered important to look for alternative glues or alternative detailing solutions to those used at Hooke Park.

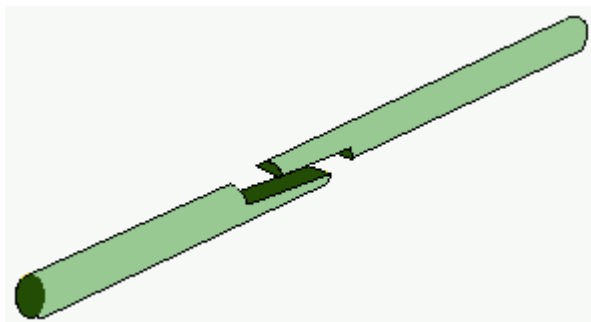


Fig. EGLU 1

Scarf joint used at Hooke Park

This project, therefore, aimed to provide underpinning support for all the other projects under the Northern Periphery Roundpole research programme.

The possibility of testing certain glues was held as an option, although resources were limited and extra funding would need to be identified.

A preliminary paper on environmental glues was prepared by Bjørn Berge and was circulated around the members of the team. The bulk of this contribution was an extract from his recent publication on ecological building materials².

Reactions to this were to be considered in association with roundpole construction. It was then intended to use the advice of an expert panel, however, in the event no further guidance was required as all of the projects avoided the use of glues. The piece has been used as the basis of the following discussion piece. We recommend the publication for information on a wide range of construction materials.

References

- 1 Refer e.g. Case Study: Woodland Shell, AJ Focus, May 1989, pp 25 - 27
- 2 The Ecology of Building Materials, Bjorn Berge, Architectural Press, May 2000

3. Adhesives and Fillers (based on work by Bjørn Berge)

Archaeological exploration indicates that animal glue adhesives were in use as far back as 3000-4000 BC. In China and Egypt casein glue was used in fine joinery. Somehow this knowledge may have disappeared, but had been rediscovered in Europe by the sixteenth century. The first glue factory was built in the Netherlands in 1690. Around 1875 the manufacture of plywood started, and at the turn of the century laminated timber construction began. Synthetic resins came into production around 1930 and today are used across the whole industry. There are between 100 and 300 building adhesives available on the market. It is claimed that a normal Swedish home contains about 700 litres of adhesive, either as pure adhesive or as part of other products, such as furniture, fixtures and fittings.

Fillers, which came into use well into the twentieth century when smooth, even surfaces were required, differ from putty in that they harden and do not retain any elasticity.

Adhesives and fillers used inside buildings, in their soft state, can cause considerable problems in the indoor climate during their hardening period, and sometimes even afterwards.

Adhesives are usually divided into mineral adhesives, synthetic resins, animal adhesives and plant adhesives. Fillers are produced on the same basis as ordinary glues, with powdered stone, fossil meal, wood dust, chalk, perlite and similar substances.

Glued components have very little relation to re-use strategy, as the possibilities of dismantling are few. Both adhesives and fillers pollute their products in such a way that possibilities for recycling and energy recycling are also greatly reduced.

Mineral Adhesives

Mineral adhesives are used mainly for ceramic tiles, but also for masonry, where they are used for precision components with accurate dimensions, such as lightweight concrete blocks. The adhesive used is usually a cement glue with a large proportion of added acrylate. The joint is so strong that dismantling becomes difficult without destroying the blocks. Waterglass glue can also provide the base for a filler by mixing it with clay powder.

Mineral adhesives are based on resources with rich reserves. Both the consumption of primary energy and the pollution caused during production are relatively low. Inside a building, products containing acrylate can cause problems for the indoor climate during their curing process. Pure waterglass products create no such indoor air quality problems. As waste, waterglass glue is considered to be inert, while cement-based glue containing acryl has been identified as special waste.

Synthetic Resins

Synthetic resins are usually divided into thermosetting and thermoplastic adhesives. The former must have a hardener added in order to complete the gluing process, and include urea, phenol, resorcinol, epoxide, polyurethane and acrylate adhesives. Thermoplastic adhesives are usually delivered emulsified in a solvent. Important adhesives of this type are PVAC adhesive, EVA adhesive, chloroprene and SBR adhesive. The latter group represent a sub-group of contact adhesives and require large amounts of organic solvents which can include aromatics and esters. EVA and PVAC adhesives are partly soluble in organic solvents.

Thermosetting adhesives are very widespread in the building industry, but they are less popular as building adhesives on site, except where gluing external components, or if high strength is needed. Thermoplastic glues are the most common glues used on site. Fillers for indoor use are based on PVAC adhesive or acrylate adhesive.

The synthetic resins are based on fossil resources. Their production consumes a great deal of energy and creates pollution.

Within buildings, these products can create problems for the indoor climate through the emission of solvents and other volatile compounds during the curing phase, and sometimes for a longer period, which may be as a result of ageing. Waste from hardened and non-hardened adhesives usually requires disposal as special waste, as do glued products, depending upon which adhesive is used and in what quantity. As a whole, PVAC glue and EVA glue are the least problematic.

Synthetic Resins and Non-Solvent Based Pollution

Formaldehyde Adhesives

Urea, melamine, phenol, resorcinol and phenol-resorcinol formaldehyde adhesives all represent a risk in the working environment. Formaldehyde can be emitted, for example, from a plywood press. Pure phenol is poisonous and can seriously damage health after long periods of exposure. Phenol and formaldehyde are also poisonous if they come into contact with water. Formaldehyde is not as problematic as phenol, as it quickly oxidises to formic acid and then carbonic acid.

In buildings with products glued with formaldehyde adhesives, there will be emissions of formaldehyde. The adhesive with the weakest binder is urea formaldehyde, which therefore has the highest emissions. Relatively small doses of formaldehyde can give acute symptoms of irritation in the eyes, itching in the nose, a dry throat and sleep problems. This can, in the long run, develop into serious problems in the inhalation routes. The substance is also registered as carcinogenic and a cause of allergies.

Epoxide Adhesive

Fresh epoxide, which is the main constituent of epoxide adhesive, is one of the most effective allergens that exists. At places of work exposed to it, up to 80 per cent of the work force have developed epoxy eczema. Epichlorhydrin, which is part of the adhesive, is registered as carcinogenic and allergenic. Epoxide adhesive also contains alkylphenols and bisphenol A compounds, which are suspected environmental oestrogens. The material is also soluble in water and is poisonous and corrosive to organisms in water in low concentrations. Hardened epoxide adhesive is chemically stable.

Polyurethane and Isocyanate Adhesive

Isocyanates can cause skin allergies and asthma. They can also cause a degree of sensitivity and mucous membrane damage such that later exposure can induce asthmatic attacks, almost totally independent of the degree of exposure. The problems are greatest in industry and on building sites, but there can also be emissions from inside a building where the adhesive has not completed its reaction.

Synthetic Contact Adhesives

Chloroprene and styrene butadiene adhesive are the main synthetic contact adhesives in common use. Butadiene is registered as carcinogenic. Styrene is mainly a nerve poison, but is suspected of being carcinogenic and mutagenic. Chloroprene adhesive is considered responsible for reducing fertility and causing deformities and sperm cell damage. These effects are most likely to occur in the working environment. In a completed building there can, however, be emissions from adhesives that have not completed their reactions.

Acrylate Adhesive

Acrylate adhesives can emit excess monomers in a completed building, which can increase the frequency of over-sensitivity and allergies.

EVA and PVAC Adhesives

These have softeners added, most often dibutyl phthalate (DBP). Together with the excess monomers of vinyl acetate, these can be released from ready glued surfaces and result in irritation in the inhalation routes. Softeners, particularly DBP, are also suspected of causing more serious damage, such as nerve damage, hormonal disturbances and reproductive problems. PVAC adhesive can also contain sulphonamides which can damage the immune system.

Animal Glues

Animal glues are based on substances rich in protein such as milk, blood and tissues, and are divided into three main types: protein glue, blood albumin glue and casein glue. These are soluble in water. They are all good glues for timber and can be used for everything from veneers and furniture to large laminated structures.

Animal glues are mostly based on waste from slaughterhouses and fisheries. Casein glue comes from milk. In buildings, under dry conditions the products cause no problem. In combination with damp cement they can emit ammonia which irritates respiratory passages. In continuously damp conditions there is a good chance of mould or other bacteria developing and the rotting products can cause bad odours, irritation and allergies. This can also lead to the deterioration of the building structure. Waste from the glues can lead to the growth of algae in water but this and the amounts are usually small. Glues that have strong fungicide additives must be deposited as special waste in some countries.

Materials glued with animal glue can normally be disposed of in ordinary incinerators, or can be dumped without any particular restrictions.

Protein Glue

These glues are made from the tissues of animals containing collagen, a protein. Collagen is not soluble in water, but boiling it at a low temperature in an evacuated vessel turns it into glue. This is then dried into a granulated powder or into small bars. Gelatine is animal glue which has been cleaned of colour, smell and taste. There are three different types of animal glue: bone glue, hide glue and fish glue. The first two are often called gluten glue. Bone glue is made of bones and knuckles, hide glue is made from waste hides from places such as tanneries. Fish glue is made of fish bones and other fish waste and has a characteristic smell. All of these glues are strong, but hide glue is considered the strongest.

Animal glue bars or powder can be placed in cold water to soften up and then dissolved in water at 50-60 °C using about two to three times as much water as the weight of softened glue. The powder can also be released directly into warm water. Temperatures above 60°C decrease the quality of the glue. Bone glue and hide glue have to be used warm and the pieces to be glued must be put under pressure before it stiffens. The glue cures quickly when cooling. Fish glue can be used cold, as can the other animal glues when calcium chloride is added.

To make a good animal glue filler, sawdust or wood flour can be mixed in. Colour pigments can also be added. The filler works well on timber surfaces and is not as visible on untreated surfaces as on treated ones. Adding gypsum makes the filler white.

Bone glue and hide glue have been used a great deal for gluing veneer.

Animal glue was dominant in furniture making up to the Second World War and there are still craftsmen who say that the quality then was much higher than that achieved today with adhesives such as urea formaldehyde (Brenna, 1989).

Animal glue can be used on all woods. The disadvantage with the animal glues is their lack of resistance to damp, which restricts their use to dry interiors.

Blood Albumin Glue

Blood Albumin is soluble in water. It is prepared from fresh blood or from blood serum which is allowed to swell in water. The glue is made by adding ammonia and calcium hydrate solution. Ammonia is corrosive and can cause eczema. The objects must be warmed up during the actual gluing until the protein coagulates, then the glue joint becomes totally watertight. The joint should be kept dry. Adding fungicides provides some limited resistance to damp conditions.

Casein Glue

Casein glue was used by craftsmen in ancient China. It is made from skimmed milk. The milk is warmed up and rennet is added to separate out the casein. The casein is then dried and mixed with 2.5g of lime per 100g casein. The powder is mixed with three times as much water so that the lime is slaked. A glue is then produced which, after setting, tolerates damp better than other animal glues. Casein glue is often classified as poisonous, due to the addition of lime which can burn bare skin. However, with careful handling it is very benign. In permanently damp surroundings and with timber at 18 per cent moisture content, the glue can be attacked by micro-organisms. This raises the question of the addition of fungicides such as sodium fluoride to provide resistance. By adding fungicide the glue loses many of its environmental advantages.

Casein glue can be used for internal load-bearing structures, stairs, plywood, laminated timber, etc., without fungicide. During the Second World War, casein glue was used in the manufacture of fighter planes. However, it is seldom used nowadays. Producers of laminated timber prefer adhesives that can be used in all situations, and therefore choose resorcinol formaldehyde, which has a high resistance to moisture. Strengthwise, casein glue is as good, and there is proof of its long lasting qualities in structures that are 50 to 60 years old which have kept their strength (Raknes, 1987). A very impressive example of its use can be seen in Stockholm Central Station, where enormous laminated timber arches have been put together with casein glue.

There is a need for a renaissance for environmentally-friendly casein glue. This does not necessarily conflict with economic considerations: it has been shown that casein glue can be produced for less than 25 per cent of the cost of resorcinol formaldehyde.

Plant Glues

Glues from plants include soya glue, natural resin glue and cellulose glues as well as glues based on rye flour and potato flour. These glues originate from renewable plant sources. Products usually cause little pollution in their manufacture, the exception being cellulose glue, the main one of which is methyl cellulose. The production of methyl cellulose involves chlorinated hydrocarbons such as methyl chloride, methyl iodide and dimethyl sulphate. Possible alcohol solvents can be produced from the plants themselves.

Soya glue is a water-based protein glue taken from the waste products of cooking oil production. Natural resin glues are based on the sticking properties of resinous substances, such as lignin from coniferous trees, and have to be dissolved in organic solvents. Cellulose glue is available in both water and solvent based variations. The water-based cellulose glue is usually called paste, and is mainly used for putting up wallpaper. The paste can also be made of potato starch or rye flour.

Cellulose glue is not attacked by micro-organisms, even in damp conditions. Soya glue and flour paste should be restricted in their use to dry areas. The solvent used for natural resin products and cellulose glue is turpentine or pure alcohol, the latter up to as much as 70 per cent.

During building use, these products do not cause problems. Waste from glue can cause the growth of algae in water systems, but this risk and the amount of glue is usually small. Glues with strong fungicides added are an exception to this. Materials glued together with plant glue can usually be disposed of in normal incinerators or deposited without special restrictions.

Starch Glue

Starch glue or carbohydrate glue is based on vegetable starch. The paste is relatively weak and is used primarily for pasting paper and wallpaper, but it can also be used for lighter woodwork and is used in the USA for gluing plywood. Potato flour paste and flour paste are starch glues.

Potato starch is dissolved in warm water and mixed to a porridge. The porridge is allowed to stand for 10 minutes so that the water is absorbed by the grains of starch and thickens. Afterwards cold water is added to make it easy to stir. The mixture is then boiled and thickens more; water is added until a workable consistency is obtained. The glue must not be used until it is cold.

If the paste has to stand for a time a little alum is added to prevent it turning sour. If hydrochloric acid is added to the potato starch, dextrine is formed, which gives a glue of a far higher durability. Dextrine is also used in fillers containing gypsum.

Flour from wheat, maize or rye is used to make flour paste, which is stirred in warm water to a white sauce, adding water carefully so that the paste does not become lumpy. The mixture can also be sieved. This glue must also be used cold, and it is a definite advantage to add alum. Paste from wheat flour is mostly used to stick paper and wallpaper. In commercial products, fungicides are often added. Rye flour paste is a little stronger and is used for sticking paper on hessian, linoleum and wallpapers, and as a filler. Sago flour is used for the gluing of wood.

Rye Flour Filler

Emulsion filler based on rye flour is based on 9 dl boiled linseed oil, 9 dl water and about 0.5 kg chalk. This is gently mixed and allowed to stand for half an hour without being stirred. A pinch of rye flour is sprinkled on the mixture and thoroughly stirred in. More chalk, which acts as the filler, is added, until the mixture has the consistency of porridge. Pigments such as umbra and ochre can be used to colour it.