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THE WALES INSTITUTE FOR SUSTAINABLE EDUCATION (WISE): NON-CONVENTIONIAL MATERIALS IN MAINSTREAM CONSTRUCTION

Richard Harris[1], Jon Shanks[2], Tobias Hodsdon[3], Pat Borer[4]

[1]BRE Centre for Innovative Construction Materials, University of Bath
[2,3]Buro Happold
[4]Pat Borer, Architect

Abstract: The paper discusses the materials and construction methods adopted for the Wales Institute of Sustainable Education. The paper describes the construction methods and addresses how to achieve success with the various materials used. The building is an important development towards the use of non-conventional materials in mainstream construction.

Keywords. *Lime; Limecrete; Rammed Earth; Hemp; Timber*

1. Introduction.

The Centre for Alternative Technology (CAT) was founded in the early 1970's as a place to develop technologies to solve the planet's problems. It has been largely constructed on using self-build methods. The WISE building is on a larger scale and has meant a departure from the Centre's usual approach; it moves the craft building to a modern affordable form of construction. The design was adapted to make it more amenable to mainstream construction. This paper describes the methods used and reports on levels of success achieved.

The architectural concept of WISE is an evolution of all the buildings at the Centre of Alternative Technology (CAT). It takes the best of what has been done before in environmental building, but on a much bigger scale (Figure 1). When students come to WISE to learn about green building techniques the building will be used will as an example of the best possible practice.

[1]Professor of Timber Engineering. R.Harris@Bath.ac.uk
[2]Senior Engineer. Jon.Shanks@burohappold.com
[3]Senior Engineer. Tobias.hodsdon@burohappold.com
[4]Architect. Psborer@aol.com

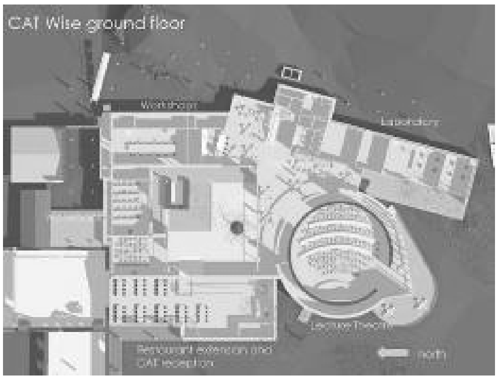

Figure 1. Architect’s plan and section of the building

The building uses materials with as low an embodied energy as possible. The Client brief was to get as close to zero carbon as possible with good insulation and renewable energy. The features of the design that can be considered ‘sustainable’ include:

Energy

- · Use of passive solar, natural ventilation and day lighting in the environmental design
- High levels of insulation and care over cold-bridges
- Good air tightness
- Photovoltaic panels on the roof
- Wood-chip CHP to heat the building, with gas back-up
- Rammed earth walls to the theatre to lend thermal mass
- Highly efficient low-e triple glazed windows

Water

- Low-flush toilets and use of soakaways for surface water
- Reed beds for toilets (as for the whole site)

Materials

- Extensive use of FSC certified timber
- Glue laminated timber frame with solid 150mm thick timber floors for long spans
- Rammed earth walls (with no cementitious binder)
- Minimise use of cement by replacing with hydraulic lime or ground granulated blast furnace slag (ggbs)
- Locally sourced materials, labour and professional services
- Use of secondary aggregates in the concrete and lime-concrete
- Use of a lime-hemp composite to construct walls
- Autoclaved calcium silicate bricks
- Unfired earth blocks (Sumatec unfired clay block from Lime Technology) as non-loadbearing partitions

Construction commenced on the 5th of June 2006. It is not yet complete and is currently scheduled to be finished in Winter 2009/10.

2. Foundations

The site lies in a redundant slate quarry. Trial pitting showed the foundation stratum to be slate bedrock, overlain by weathered rock and sandy silty clay. In many locations this was covered by slate waste. The conditions varied across the site. The steep hillside onto which one of the three-storey wings to the building was to be built (Figure 2), is covered with tipped slate quarry waste, Concerns here included risk of rock fall, slope stability, stability of excavations, provision of drainage.

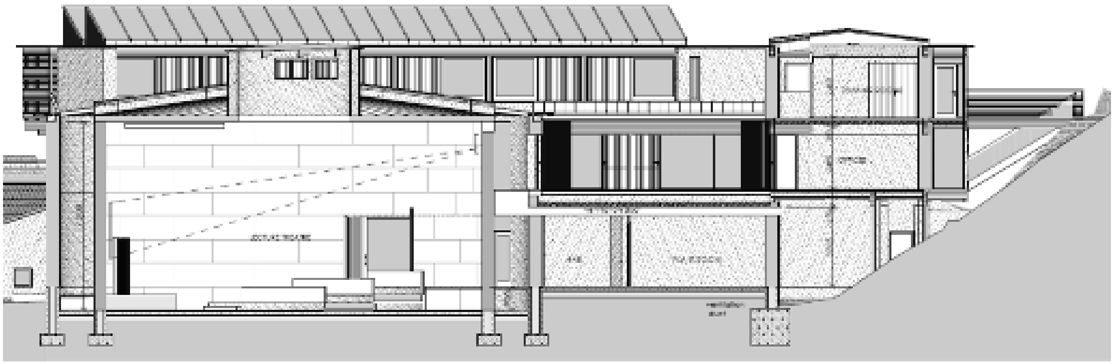

Figure 2. Architect's section, showing - theatre (left); study bedrooms (right)

Where possible, foundations are simple strips of Limecrete (Figure 3), which is concrete made using hydraulic lime - NHL5 to BS EN 459−1: 2001) as the binder. Limecrete was delivered from Shropshire, local to the supplier's works at Much Wenlock and mixed on site using truck mounted pan mixers with weight and water control

Figure 3. Limecrete footing

Figure 4. Calcium silicate bricks with cork insulation to separate inside wall from outside

Calcium silicate bricks are used to bring the foundation out of the ground (Figure 4). These are manufactured in an autoclave and so have lower embodied energy than fired bricks. It is assumed that water can lie at ground level and the wall cavities are filled with perlite below ground level, which insulates the inner leaf of the wall from the outer (Figure 5).

The hillside, adjacent to the building was formed, when the quarry was active, from loose tipped quarry waste. Foundations on this slope presented a structural challenge. The solution is to use conventional reinforced concrete, made with a ground granulated blast-furnace slag (ggbs) cement replacement. The building load is carried through the concrete, which can distribute it over a large area, resisting the forces from the building trough a combination of resistance normal to the slope surface and a strut load through the concrete to the solid rock at the toe (Figure 6).

Figure 5. Cavities filled with perlite

Figure 6. Conventional reinforced concrete on slopes

3. Ground-bearing Floors

The ground bearing slabs are constructed of Hempcrete, a material that uses a lime-based binder with hemp shiv (Figure 7). The Hempcrete is laid on 200mm of perlite insulation, used in bags (Figure 8).

Figure 7. Store of hemp shiv

Figure 8. Laying Hemcrete floor on bags of perlite

A vapour control/radon barrier is needed and this is supplied by a recycled polythene membrane (Zedcore). Floating floors are laid onto all floors (including suspended floors – se Section 4). All have a layer of Silencio Thermo grooved softboard and under floor heating pipes. The floor is finished with a proprietary floating floor with plywood and loose-laid, secretly nailed ash floorboard,

4. Superstructure

The primary structure is a braced glued laminated (Glulam) timber frame (Figure 9), with galvanized steel flitch plate connections. The first floor and roof structure are of solid timber construction, made by placing joists next to one another and then sheathing with plywood on the top surface. The floor was fabricated in panels and laid into notches in the upper surface of the Glulam beams.

This method achieves large spans, maximising future flexibility, creating an architectural soffit, and sequestering a large amount of CO_2 into the frame. Through pre-fabricating the solid timber floor into 1.2 metre wide cassettes, with movement gaps between each panel (Figure 10), the system tolerates movement due to moisture content changes during construction.

Figure 9. Glulam frame

Figure 10. Solid floor panels

The geometry of the building is complex. The time between erection of the timber frame and waterproofing of the building lead to considerable ingress of water. Whilst the movement joints have worked well, there has been considerable damage to the finish. To some extent this can be removed, through light abrasion when dry, but in more sensitive areas the timber cannot be left with its natural finish in the manner originally intended.

5. Walls

Most walls are non-load bearing; they are infill between the Glulam elements of the structural timber frame but there are also load-bearing walls. This section first describes and discusses load-bearing walls and then the non-loadbearing external walls.

5.1 Rammed Earth The walls to the lecture theatre are of rammed earth and are load-bearing. The lecture theatre walls are 500mm thick by 7 metres high and form a circular structure of 15 metres diameter.

In principle, rammed earth should be one of the lowest environmental impact materials available. The material uses locally available material and is rammed without a lime or cement binder. At WISE, the walls are load-bearing; they provide high levels of thermal mass and are visually attractive. But, particularly for such an ambitious wall as that at WISE, the arguments for use of the material cannot be justified on solely on environmental grounds.

Rammed earth wall construction of this type must be a carefully controlled, skilled operation.

Figure 11. Rammed Earth Wall under construction

Rammed earth must be protected from damage by rain. This can be achieved by use of a temporary roof. On WISE, the Contractor chose to use sheeting was needed for protection (Figure 11). There was a carefully controlled specification for the source material, which was sensitive to moisture content at the point of ramming. Earth was imported from a quarry at some distance from the site, which had provided suitable material for previous rammed earth walls at CAT. Once on site it was mixed and at times dried to ensure correct moisture content for placing (Figures 12 and 13).

Figure 12. Mixing earth for even grading and moisture content

Figure 13. Drying earth in winter conditions for reduced moisture content

The material was rammed in 100mm layers (Figures 14 and 15) to a specification based on achieving a density (98% of optimum when tested using the Modified Proctor method (BS 1377-4:1990)) and strength (Characteristic strength of the mix specified as achieving a minimum characteristic unconfined cylinder dry compressive strength of 1.5 N/mm2, and a minimum characteristic unconfined cylinder wet compressive strength of 0.25 N/mm2. Cylinders prepared and tested in accordance with Walker et al 2005).

Figure 14. Earth rammed in layers

Figure 15. Earth rammed between steel shutter panels

Figure 16. Completed rammed earth walls

Figure 17. Load-bearing slate wall with brick skin

5.2 Slate walls. A particularly successful form of construction proved to be a method commonly used locally - slate walls, laid with non-hydraulic lime mortar (Figure 17). Their construction employs local labour and uses abundantly available local materials.

5.3 Hemcrete®. Most walls are non-loadbearing infill within the structural timber frame. Internal are timber stud with Warmcel® as required for insulation. Careful attention was paid to soundproofing, with resilient layers placed under the studs. External walls are 500mm thick and are made with Hemcrete®, a proprietary material mixed with hemp shiv and Tradical® binder. The walls achieve a U-value of 0.14 W/m²K. Hemcrete® absorbs CO_2 in its manufacture and so has a negative embodied CO_2. It is made using renewable UK grown hemp based materials. It is a highly insulating material resulting in walls with a very low U. It is claimed that, unlike other insulators Hemcrete® also has thermal inertia similar to thermal mass and so buildings built of Hemcrete® reduce heating loads significantly below lighter weight buildings with the same U value. It is vapour permeable and, when used with lime based renders and plasters, it creates a breathable walling system.

The building uses two techniques – sprayed and tamped. The sprayed method involves spraying Hemcrete® onto a skeleton of studs. The tamped method uses temporary shutters into which Hemcrete® is pumped. The second method proved more successful than the first, which tended to lead to a large amount of wastage. A research programme is ongoing, using information from sensors built into the walls to monitor moisture content.

Figure 17. Sprayed Hemcrete® wall

Figure 18. Hemcrete® cast between shutters

6. Conclusions. It is in conditions of very high moisture content that unconventional materials do not work well. Conventional construction materials are high energy and often do not work well in accommodating the dynamics of building environmental control but they have gained widespread use because they are quick to gain strength and less sensitive to water. Hence the main challenges for using non-conventional materials in mainstream construction are:

- Keeping materials dry and protected from rain
- Developing methods to suit materials that are slow to lay and gain strength (roof first and build under cover is a good principle)

References

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