Design and construction of timber roof in Dubai

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II

Design and Construction of Timber Roof in Dubai

Projet et exécution d'une toiture en bois à Dubai

Entwurf und Konstruktion eines Holzdaches in Dubai

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SUMMARY
Described is a simple roof system developed to take account of local conditions in the Arabian Gulf. Structural timber elements were based upon the use of local semi-skilled labour, with simple forming and nailing techniques for connections, using timber readily available locally. The net result, as well as being an efficient engineering solution, is an architecturally pleasing roof system, well suited to local conditions.

RESUME
On décrit un système simple de toiture, développé en tenant compte des conditions locales propres au Golfe Persique. On a conçu les éléments porteurs en tenant compte du degré de qualification de la main d'oeuvre locale: découpes simples, assemblages cloués, utilisation du bois disponible sur place. Le résultat obtenu ne se limite pas à une solution techniquement efficace: il constitue aussi une réussite architecturale bien adaptée aux conditions locales.

ZUSAMMENFASSUNG
Beschrieben wird ein einfaches Dachsystem das unter Berücksichtigung der lokalen Bedingungen im Arabischen Golf entwickelt wurde. Die Tragelemente wurden für die Herstellung durch angelernte Arbeitskräfte ausgelegt, wobei einfache Formen und Nageltechniken, sowie lokal erhältliches Holz verwendet wurden. Das Ergebnis ist — neben einer wirkungsvollen Ingenieurlösung — eine ansprechende, den lokalen Bedingungen angepasste, architektonische Lösung.

1. INTRODUCTION

The initial development was for an infants school to become a comprehensive complex comprising Infant, Junior, Middle, Senior and Administration Blocks when complete.

Consideration was given to all types of materials, but the Architect favoured a roof shape reminiscent of local traditional tented forms and timber became the original and final choice meeting the internal aesthetic requirements.

Because of the visual scale, the architectural discipline dictated a relatively deep section for the timber roof members and therefore solid timber sections became uneconomic and unweildly. It was therefore decided to design hollow timber box beams. With the extensive use of plywood, highly dimensionally stable buildings could be constructed to serve satisfactorily in the locally severe weather conditions with the high level of internal air conditioning necessary. A decade of previous experience of building "domestic" type design for bungalow and villa residencies in the Gulf area with nailed plywwod box beams (used for relatively small spans) confirmed the viability of this approach. Taking into account the local relative labour and material costs the choice was also found to be economically suitable.

2. SITE CONDITIONS

The site is located between Dubai and Sharjah in a typical costal desert situation. The site was originally virtually at sea level and much of the surrounding area is still under water. Ground water is always a problem and is rarely greater than a metre below the surface. The site subsoil comprises dune sand, marine sand with silt and coastal subkhas which overlie alternating layers of sandstone and limestone. There is generally a layer of medium sandstone with bands of weakly cemented sand at a minimum depth of about 3 metres below the surface which gives way to weak sands and silts until sandstone is again picked up at about 10 to 14 metres.

The upper levels consists of silty sand, brown sands with organic material and medium dense sands with layers of weak and highly permeable shells which make the construction of foundations difficult. The use of a relatively light timber construction served to reduce materially foundation problems.

3. STRUCTURAL DESIGN CONCEPT

The development of a lightweight timber roof allowed the vertical support system to be loadbearing blockwork which is a 'traditional' material in the Middle East. Reliance on the strength of blockwork however requires strict control. The foundations developed to become a semi-raft/ground bearing slab on the top of the fill material. This obviated costly excavation through the fill into the water laden upper layers of the site.

Figure 1* shows a general elevation and key plan with the roofs of three teaching units and a similar staff area arranged around a larger hall with a 15m span roof. The hall is higher than its surrounding areas and has a flat roof, whilst the other four units are located around the perimeter with a central flat area. These are all stepped levels but with similar geometric properties.

* See Page 237 for illustrations.

Figure 2 shows a typical external appearance. The general architectural requirement was for the internal appearance of a two way grid system. The roof covering had to be light and simple and it was elected to use double sided insulated ply panels with 'Hypalon' patent roof covering.

In the teaching and staff units the main architectural grid is 1.5 m and it can be seen that there are two types of spanning roof member. One is a full frame double bent beam 7.5 m long, the other a half frame single bent beam 4.5 m long. There are of course various detail variations on these two basic elements, but a single design was possible to control the whole structural concept.

Figure 3 shows details of a typical 7.5 m span bent and Figure 4 the 15 m main hall beams.

It was decided very early on in the conception that a timber structure of this type had to be largely insitu in its execution. It was also apparent early in negotiations that local contractors would be involved in tendering. Therefore any regid design requirements or premanufactured units would make local participation untennable.

Two basic decisions were therefore made:

A. The roofs would not be designed as two way spanning grids due to the difficulties in construction the members to satisfy complex design requirements.

B. All details had to be such that site manufacture would be possible therefore all units would be designed as nailed elements. Glue would not be used because control is difficult and pressure glueing is not viable due to lack of suitable equipment also the shelf life of glues in such climates is very limited.

These two decisions required the beams to be designed as self supporting single units with infill secondary units at right angles, once the infill units and roof panels were in place the whole structure would then become a complete stiff diaphragm to transmit wind loads to foundations. Figure 5 shows local workmen engaged on site manufacturing.

4. DETAIL DESIGN CONSIDERATIONS

All design was carried out in accordance with the British Code CP112 Part 2 albeit the code is very limiting in its coverage of members of the type we wished to design.

The type of timber used had to be carefully controlled. Again only visual grade selection could be carried out locally so a grade 65 with basic $9N/mm^2$ of category J2 hardwood, with softwood alternatives, was selected for the design. In the event, hardwood was eventually selected for the tension members and softwood for all other parts. Ply webs were hardwood faced.

Apart from some few experimental papers there are very little published data on nailed beams. A lot of reference literature was available from the Plywood Manufacturers Association, British Columbia. With the available information the design was developed from basic first principles and nail stresses calculated from the rolling shear relationship in the plywood webs. This appears to give sensible results and with the use of improved annular ringed nails and predrilled holes the design and detailing of the units was built up.

The main beams, being double bents were designed for moment development about the knees and in these instances double sided shear connectors were used to transfer the related shear forces between separate sections of timber.

Allowance was made in the detailing for a notional amount of relaxation due to long term relief from shrinkage and deflection and therefore horizontal forces were considered at the bearing locations of all main beams. Stiffening effect of the transfer members was accounted for and these infill members were designed with continuous splices at main beam connection points with a notional 25% of the main moment values allowed. No direct account was taken of the stressed diaphragm effect of the roof panel especially as these were separate panels, except that the panels were laid with discontinuous joints and horizontal thrusts were considered as suitably dissipated into bearing points.

At the bearings, the main double bent beams were connected into the top of an insitu concrete column reinforced to accept the lateral thrusts from the beams. Where nominal units occurred at hipped ends, at right angles to the main beams, the thrusts were allowed to be spread through the whole diaphragm and accepted on the blockwork.

All beams were fixed onto timber wall plates using metal angles which were rag bolted into the blockwork or columns to allow for thrusts and wind uplift forces.

The hall beams were straightforward large span beams at 1.5 m centres and spanning across 15 metres. The bearings were haunched and had cantilever spurs flying out beyond the external wall face to afford sun shading effects to the high level clerestory windows. Movement was allowed at one end of the bearing.

Loadbearing blockwork generally was solid but where connections were required, hollow blocks were used with the bolts bedded into concrete in the block cavities. All beams were constructed with cambers to allow construction deflection and also to give drainage falls on the areas of flat roofs bounded by the pitch sides. Expansion joints were provided between the various units and these joints were reflected in blockwork and in the semi raft foundation.

The walls consisted of 200 mm internal loadbearing leaf with 50 mm cavity and 100 mm non-loadbearing outer skins. The outer skin was split every three metres to allow thermal movement independent of the remaining structure.

The last illustration Figure 6 shows the completed school in occupation.

5. CONCLUSIONS

With the difficulties encountered in the Gulf States, with aggregate control workmanship and chloride contents in concrete, it is felt that the solution to the problems on this particular structure indicate that it is possible to construct economic and aesthetically appealing structures using natural timbers. We have, therefore, demonstrated that the economic structural use of engineered timber is structurally satisfying and the end product architecturally pleasing.

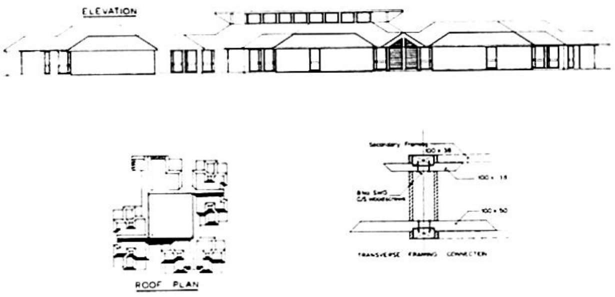

Fig.1: Key plan and elevation.

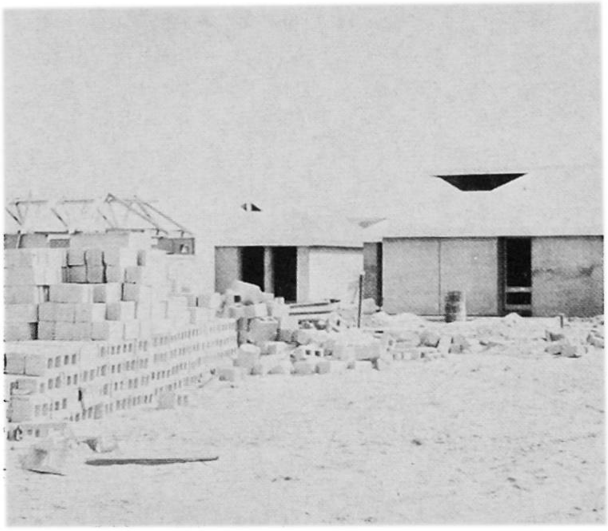

Fig.2: Photograph of typical elevation.

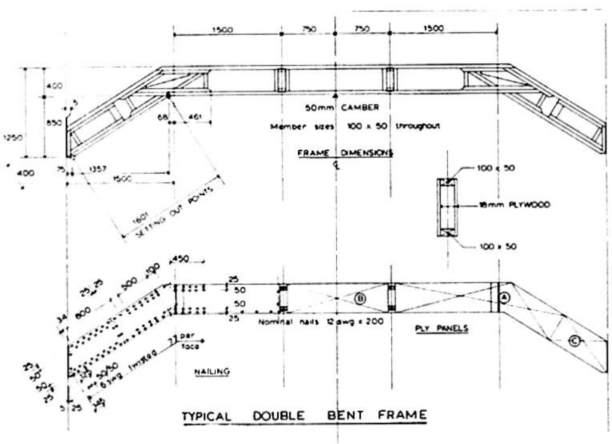

Fig.3: Drawing of 7.5m span bent.

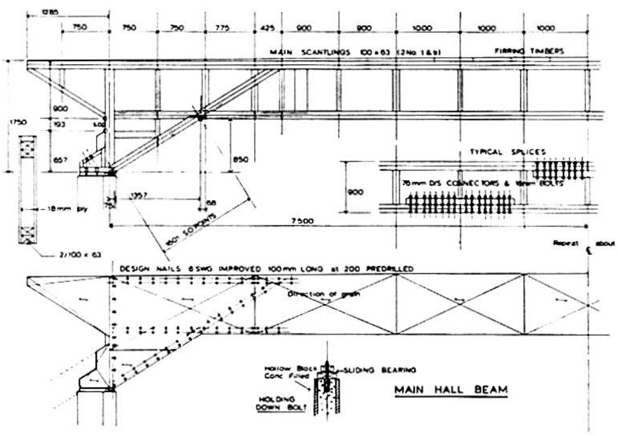

Fig.4: Drawing of 15m span main hall beam.

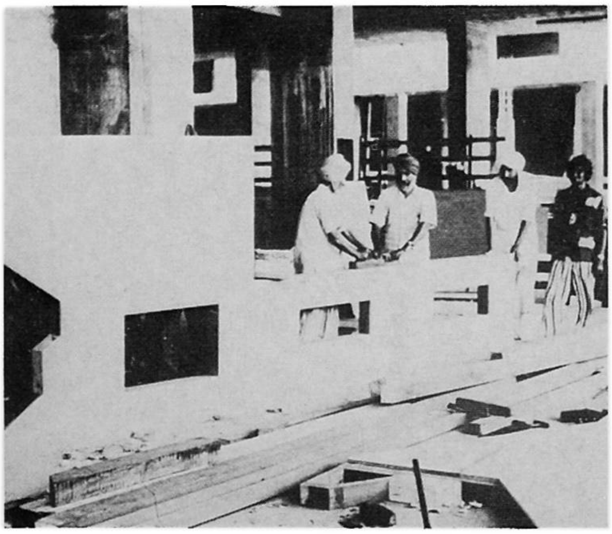

Fig.5: Photograph of fabrication on site.

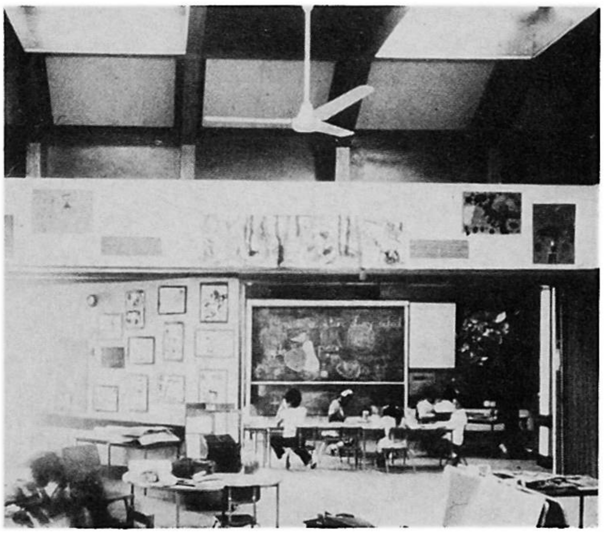

Fig.6: Photograph of interior of completed school.

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