

Northern Periphery Project Roundpole Construction Sub-Project

INFRA - Industrial Frame Structures

Lead Partner

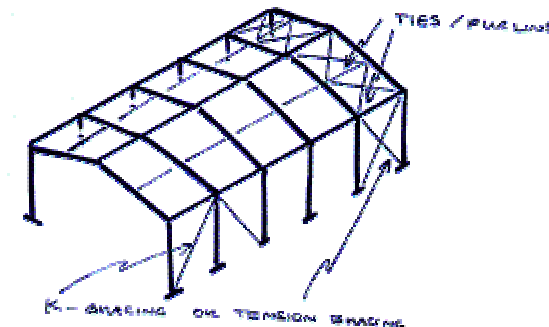
Gaia Architects

With

Buro Happold, Northwoods Construction

Aim

To develop a design for a roundpole structural system to compare with a standard steel portal frame in a typical industrial building.



Summary

The design of an industrial frame for a client in Scotland moved forward the discussion on the efficiency and cost of the proposal.

The application of the principals were then developed on a further building in Scotland to both a modelled and a calculated stage and the results are recorded. The project proved to have too many unique constraints to be readily replicable.

Optimum sizes and spans were investigated and discussed and further projects were sought for a possible prototype. Those identified - including a boat building shed in Ullapool - proved again to have too many unique factors.

It was decided that the best way to develop the project was to design a hypothetical - but relatively standard industrial shed, in order to be able to cost out the likely production implications.

It should be noted that this work represents only an outline design for a building and not full construction information. However, it seeks to provide some engineering to the proposed building, to demonstrate that a roundpole building is indeed viable.

Contents

1. Introduction
2. Mark 1 Design at CSCT, Scotland
3. Mark 2 Design at Glencoe, Scotland
4. Mark 3 Design - Standard Hypothetical Design
5. Conclusions

1. Introduction

The purpose of this sub-project is to test the potential for roundpole construction as a substitute for steel portal frame and truss structures in the provision of typical industrial or large span buildings (i.e. non-domestic scale) in terms of the context of the Northern Periphery area of Europe. The initial design aspects focussed on Scotland. This would take into account the effect of transport costs of a system from a centralised fabrication point to peripheral areas as against locally produced structures. Within this the specific aim is:

To develop a design for a roundpole structural system to compare with a standard steel portal frame in a typical industrial building.

The original objectives were:

- to define a standard timber solution for an industrial building.
- to review existing designs in roundpole for this type of building.
- to look at innovative ways of achieving a structural system.
- to select and develop a preferred option (or options - as appropriate).
- to test the selected design by calculation and model.
- to construct a prototype and test if appropriate.
- to investigate potential methods of mass production of the system.
- to assess the cost and replicability of the system.
- to assess the potential market for the system.

Of these all except the actual building of a prototype have been taken forward. This was due to an inability to identify the combination of a robust project and appropriate client. It is hoped that a potential live project may be identified in the near future.

2. Mark 1 Design at CSCT, Scotland

Terms of Reference

It was determined that the project would compare three types of industrial frame system, cost them out and define the benefits - or otherwise - of each system.

The following presumptions were made:-

- that a steel frame system would be transported to a notional location in Northern Scotland from the most appropriate fabricator based in the UK.
- that an existing commercially available roundpole system, based on a patented system design, would be fabricated within a 5 mile radius of the selected site.
- that a design - or designs - developed by the project design team would also be fabricated within a 5 mile radius of the selected site.

Client

The Central Scotland Countryside Trust required an uninsulated industrial frame building, and were prepared to act as a client, with respect to this project.

Northwoods Construction were interested to act as a potential client for the testing of an innovative roundpole frame system, should such a prototype be necessary within the terms of reference of the developed design.

The benchmark steel portal frame system was taken as a typical off-the-shelf industrial shed structure of 10m x 20m in plan and 4.5m to the eaves, with a 25° pitch and clad in single skin corrugated sheet metal on galvanised Z purlins/rails.

The roundpole systems was to be compared with the benchmark system in terms of cost, performance and environmental and local impact.

Developed Design Ideas at CSCT

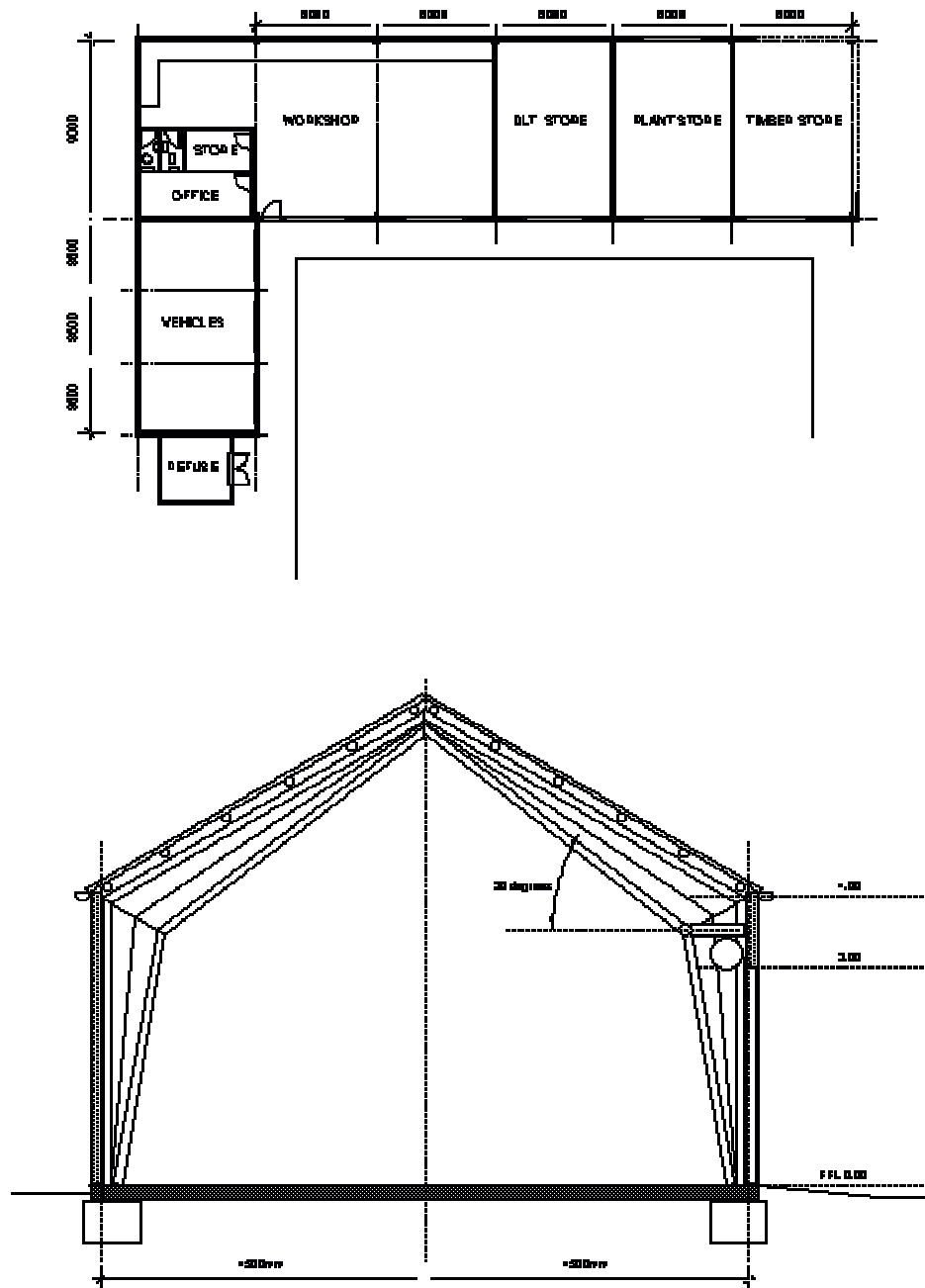


Fig. INFRA 1 Plan and Cross Section of Proposed Framed Structure

3. Mark 2 Design at Glencoe, Scotland

Introduction

A review of the situation to date was made relating to the change in the delivery date of the original prototype for CSCT, and the effect its delay would have on the research support. As a result, it was decided to transfer the output option to the National Trust for Scotland Glencoe project, as this was an identifiable project with a firm commitment from the client. The industrial building within the project was the Woodchip Store, with the benchmark system being the existing structural solution for the building.

Description of building

The Woodchip Store is a simple building; it is a 6m x 6m square in plan with a pyramid roof. The height to the eaves is 2m and the roof pitch is 45°. It has 2.4m wide opening in one side. Drawings of the Building are shown in fig. INFRA 3.

Principles of Design

It was proposed that the structure of the building should be composed of two sway frames at right angles to each other, spanning the diagonal. The frames are connected at the eaves by a beam around the circumference. It was assumed that bracing would not be required because each sway frame resists lateral loading. However, because the centres of each frame are at the same point they cannot provide a resisting couple to eccentric lateral loading although they resist non-eccentric loading.

The inspiration for the design was the Finnish hay barn featured in *Use of Round Wood Structures, Guidelines for Architects and Builders* Griffiths et al, (1999). The barn is constructed from sway frames alternating with posts and trusses. Although, on the outside the barn is straight walled with a pitched roof, the interior of the barn has a curvy, parabolic aesthetic. The barn is shown in fig. INFRA 4. This effect was recreated in the woodchip store frames.

It was assumed that roundpoles with a diameter of 70mm - 150mm would be available for use within the structure.

Four sway frame options were designed and these were modelled at a scale of 1:50. These models enabled the buildability of the structure to be assessed (e.g. how each frame would be put together, how connections would be formed, and how the two frames in each building fit together.). Each frame option was analysed, and the capacity of each frame to resist the applied loading was checked. The analysis confirmed that the roundpole members have sufficient capacity and that deflections of the frames are within suitable limits.

Some simple connections were designed for the frames, and these are shown in fig. INFRA 5. Fig. INFRA 6 shows a roundpole connection designed by Buro Happold and Gaia Architects for 'Raymond's Smoke Shed' a straw bale and roundpole structure in Dunning, Perthshire.

Discussion

The physical models showed that frames with fewer members would be easier to construct and connect together. The analysis confirmed that the simple frames would be able to resist the applied loading and deflections would be within appropriate limits. An example of the analysis output is shown on page 10.

The woodchip store does not need to be constructed of sway frames with bracing; it could consist of simple posts and trusses with a bracing system.

Alternatively, the pyramid roof could be replaced with a duopitch roof. In this situation, the structure could consist of two parallel sway frames. Bracing would be required to resist lateral loading perpendicular to the frames but not in the plane of the frames.

The frames designed could be adapted for a portal framed industrial shed.

Conclusions

The main conclusion from this work is that the Glencoe woodchip store is too specific a project to focus the INFRA design on. It would also be more appropriately designed as a post and truss structure with bracing.

It was decided that future work should concentrate on designs for a typical shed; the kind of shed that is used for small business workshops or for storage of agricultural equipment, preferably composed of sway frames and benchmarked against a steel framed building.



Fig. INFRA 2 Photographs of four models of the Glencoe Woodchip Store

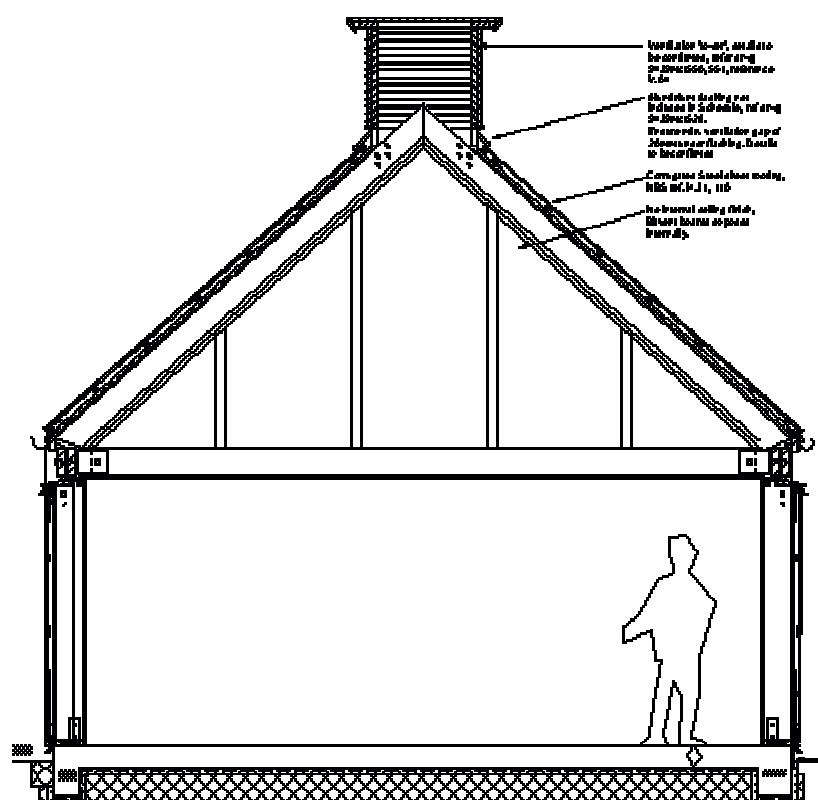
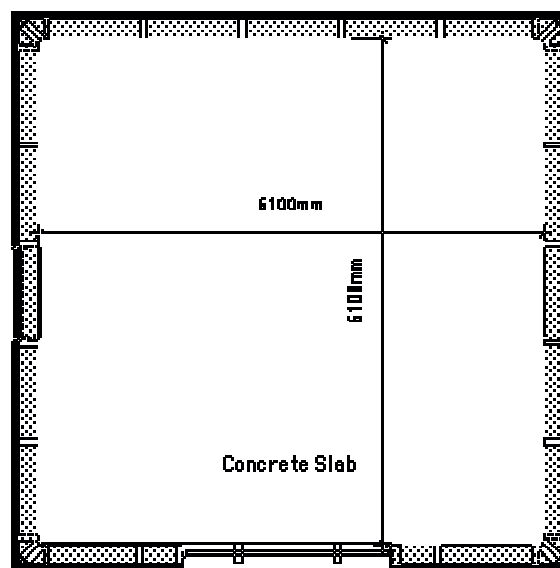


Fig. INFRA 3 Plan/Section Benchmark Flitch plate Structure of Glencoe Woodchip Store

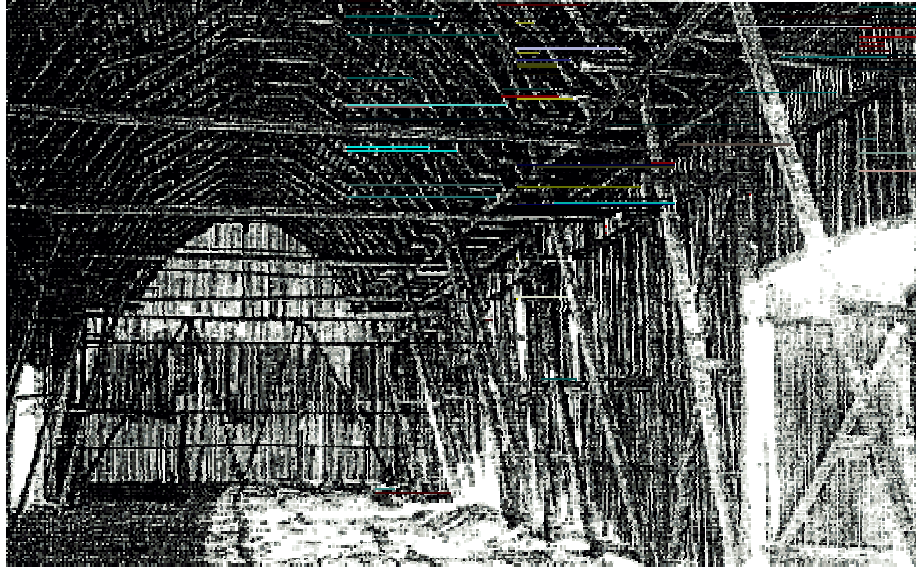


Fig. INFRA 4

Finnish Hay Barn

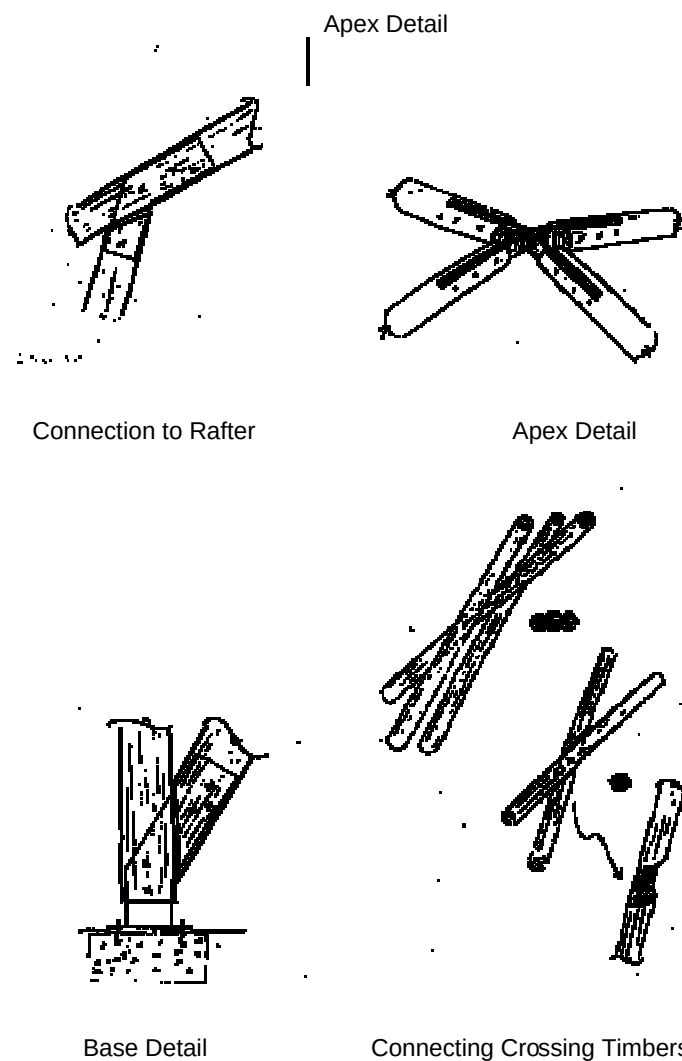


Fig. INFRA 5

Sketch details of Proposed Roundpole Alternative Frame to Woodchip Store at Glencoe



Fig. INFRA 6 Roundpole Connection using Galvanised steel pieces at Raymond's Smoke Shed in Dunning, Perthshire

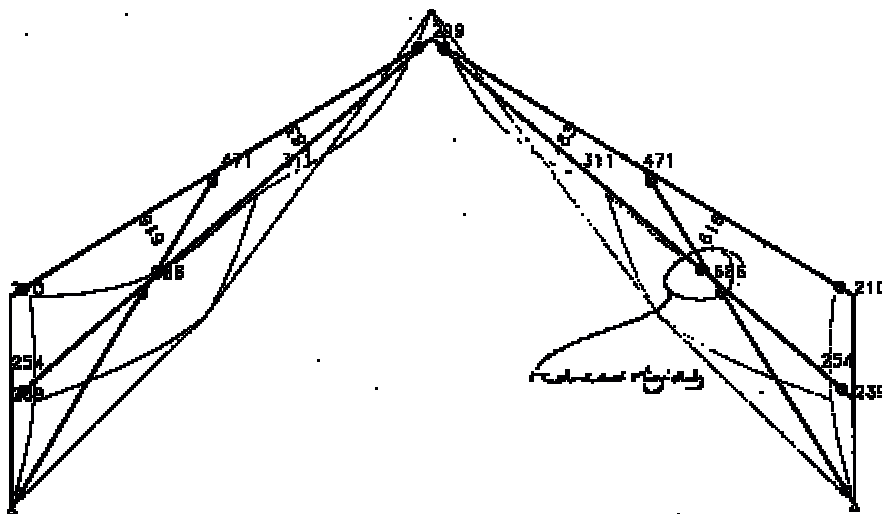


Fig. INFRA 7 Example of Analysis Output of Structural Forces acting on Sway Frame

4. Mark 3 Design - Standard Hypothetical Design

Previous work on industrial framed buildings involving designing a roundpole solution for the woodchip store in Glencoe concluded that because the store did not represent a typical industrial building, future design work should look at the design of a building more applicable to a wide range of uses. The frames should be simple with a limited number of connections. If the frames are too complicated, they will be too costly and difficult to build, and therefore are not a viable option.

It was decided that a typical building would be 20m long and have an 8m span and a height to eaves of 3.5m. A building of this size is suitable for use as a small business workshop or to store agricultural equipment and vehicles. It was determined that the solution to this building should be a portal frame. Roundpoles make good compression and tension members, but are not suitable in bending because they have insufficient depth. A tie and a haunch were put into the portal to reduce the bending moments in the poles.

Frame Variations

Three variables for the frame were identified; the span of the building, the roof angle, and whether the building is fully or partial clad. The output variable would be the spacing of the frames. There is a conflict between number of frames and simplicity of each frame. For example, frames with few members may need to be spaced at 1.5m intervals, but frames with twice as many members could be spaced at 2.5m intervals. However, there is an advantage to the frames being spaced at not more than 1.5m: the purlins can also be made of roundpoles.

An industrial building must be thought of as a complete structure. The structural framework should not be looked at independently of the cladding, the internal use of the building, or the access to the building.

Choice of Cladding

The choice of cladding has an influence on both the external and internal environment. If the building is to be an unheated storage building, the cladding can simply be a rainscreen. If the building is to be naturally lit, then some of the cladding in the roof may be replaced by glazing or translucent sheets. However, if the building is to be occupied, and therefore heated, the building will need to be insulated.

The forces on a building due to wind are dependent on whether a building is clad or unclad, and the type of access to the building also has an effect on the wind loading and therefore the structure. A large access opening in the front or side of a building needs its own structure both to trim the opening and to support the door. The large opening may also interfere with the bracing scheme for the structure.

In a typical steel framed industrial building, the walls would either be clad with sheeting, brickwork, blockwork or concrete. However, within the context of the roundpole project, it would seem appropriate to use timber to clad the building. In a very simple shed, planks of roughly sawn timber could be nailed directly to the frame. In a larger building, a system of purlins and timber cladding could be used. For the generic design, a system of split roundpole purlins with a roughly sawn timber cladding was considered.

Design Development

The work on the INFRA building took the design of the building up to the outline design stage, backed up by calculation using the appropriate codes.

There were several outputs for this work:

- Sketches of a range of portal frame options.

- Drawings of the chosen portal frame type - elevation, plan, section showing bracing scheme and openings.

- Drawings showing connection details.

- Drawings showing foundations and connections to these foundations.

- Cladding suggestions.

The options are suitable for a frame spacing of between 1.5m and 3.0m depending on the species of timber, the frame spacing, the required clear internal height, the wind loading on the building and the frame cladding. For example, in geographical areas where wind speeds are high, a stiffer frame will be suitable. However, if the frame spacing is reduced, a less stiff frame would be fine.

Four of the options are shown in fig. INFRA 9, with the elevation and cross section of the proposed structure shown figs. INFRA 10 and 11.

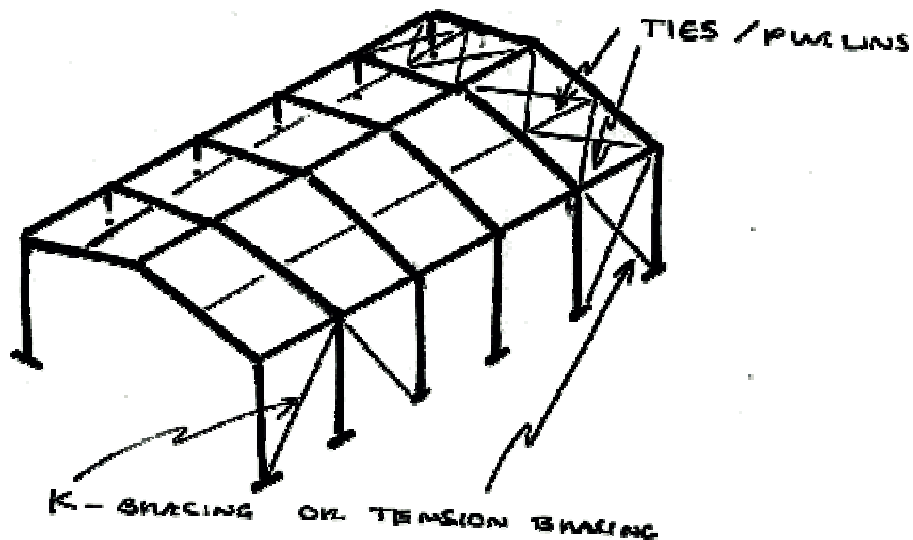


Fig. INFRA 8 Sketch View of Proposed Portal Frame Structure

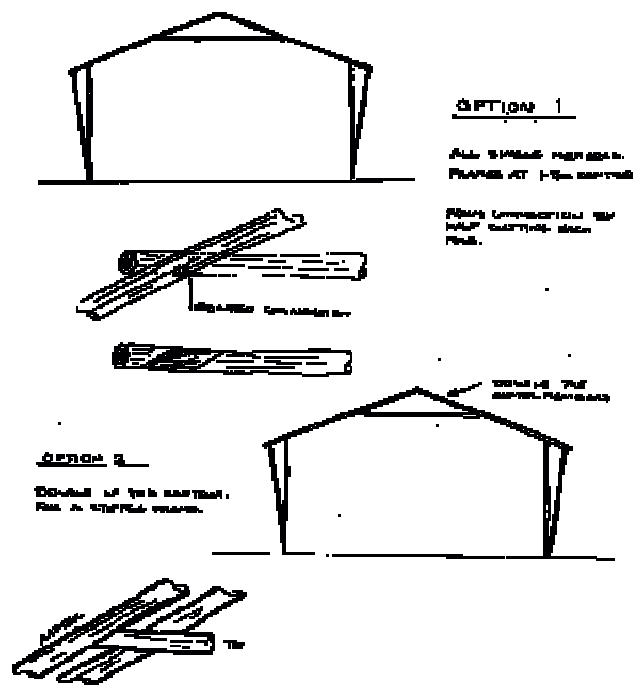


FIGURE MISSING HERE

Fig. INFRA 9 Showing four of the options which could be considered for the INFRA structure.

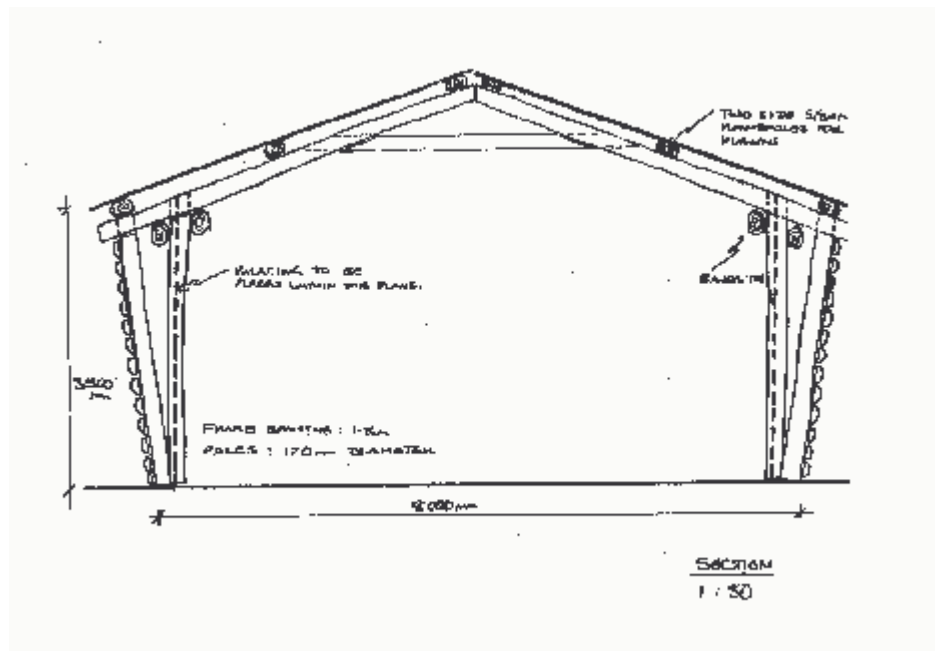


Fig. INFRA 10 Cross Section of Proposed Structure

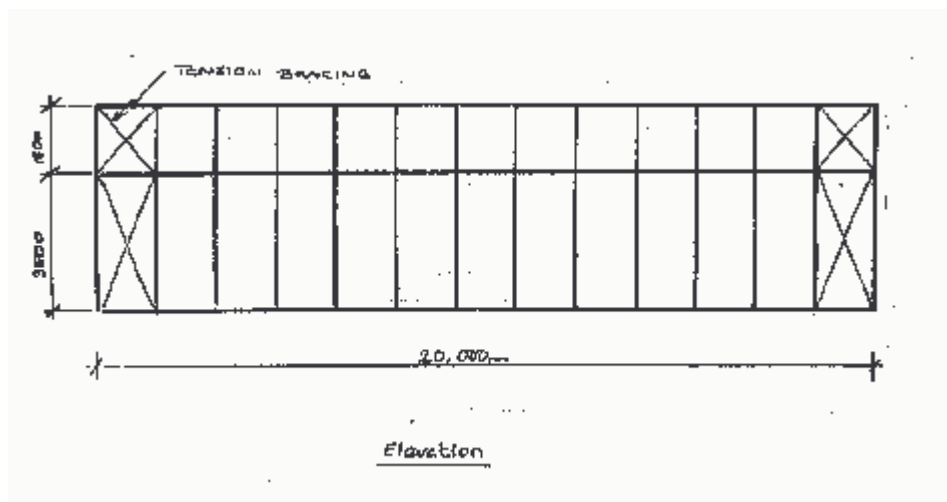


Fig. INFRA 11 Elevation of Proposed Portal Frame Structure

5. Conclusions

The initial design of an industrial frame for the CSCT project moved the discussion on the efficiency and cost of the proposal forward.

The application of the principals were then developed on a square building at Glencoe to both a modelled and a calculated stage and the results are recorded. However, the project proved to have too many unique constraints to be readily replicable.

Optimum sizes and spans were investigated and discussed and further projects were sought for a possible prototype. Those identified - including a boat building shed in Ullapool - proved again to have too many unique factors.

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