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REPORT ON THE STRUCTURAL DETAILS
OF
THE PROPOSED SCHEME FOR THE MINOR HALL AUDITORIUM CEILING

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OVE ARUP & PARTNERS
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SYNOPSIS

This report is an examination of the proposed scheme for the Minor Hall Auditorium Ceiling prepared by the Architect. It demonstrates that the scheme requires substantial modification in structural concept to make it practical. It recommends for consideration a scheme based on a structural steelwork frame supporting plywood cladding.

1. TERMS OF REFERENCE

Following upon meetings with the Architect and the Director of Public Works on 2nd December and 13th December, 1965, this investigation and report have been prepared to include the following:-

- 1.1 An examination of the structural engineering aspects of the plywood scheme for supporting the auditorium ceiling, as proposed by the Architect in drawings nos. SOH 1093, 1380, 1381, 1382.
- 1.2 Comments on the desirability of utilising large (50' x 9') sheets of plywood.

2. DESIGN REQUIREMENTS OF CEILING SCHEME

- 2.1 The ceiling must be capable of being carried by the surrounding concrete structure designed to support it. Provision for support of the auditorium ceiling has been made as follows:-

- i) At front of auditorium -
 - a) from side shell arches, within a 20° vertical cone of attachment points in the diaphragms. Maximum weight of ceiling allowed for in design was 60^{*} lbs/sq. ft. measured on plan area.
 - b) from stage tower steelwork, which has been designed for a vertical load of 35 tons (equivalent to 17 lbs/sq. ft. of ceiling)
- ii) At rear of auditorium - off cantilever balcony.
- iii) At side of auditorium - off 42' level slab.

2.2 Acoustics:

The sound attenuation to be provided from outside to inside is 50 dB in the outer layer. The shape and texture of the inner surface is used to control the auditorium acoustics.

* Because the form and weight of the ceilings had not been established at the time of designing the side shell arches, it was necessary to assume and agree with the Architects certain maximum load conditions.

2.3 Mechanical Services:

Preliminary details of the mechanical services required to be contained within the ceiling, are shown in Steensen & Varming's drawings nos. 5757/C307.

2.4 Light Bridge:

A light bridge is to be accommodated within the depth of the ceiling.

EXAMINATION OF THE PROPOSED SCHEME

- 3.1 The factors that are important in assessing the suitability of a structural solution are weight, support, erection procedure, materials, splices and connections, and cost. The proposed scheme has been examined with these points in mind. A number of problems and difficulties have become apparent and these are discussed below.

As a result, two modified schemes, visually the same as the proposed scheme and embodying the requirements of Section 2, have been put forward. They overcome the difficulties encountered with the proposed scheme. The two modified schemes, A and B, are shown in drawing no. 1112/SK/S246. In scheme A, plywood box beams support plywood cladding. In Scheme B, structural steel framing supports plywood cladding.

3.2 Weight of Construction:

The weight of the proposed ceiling is greater than that which can be supported.

<u>Scheme</u>	<u>Weight at Front</u>	<u>Weight at Rear</u>
Architects' Proposed Scheme	200 lbs/sq.ft.	80 lbs/sq.ft.
Scheme A	95 lbs/sq.ft.	80 lbs/sq.ft.
Scheme B	75 lbs/sq.ft.	70 lbs/sq.ft.

Designed capacity of side shell arches - 60 lbs/sq.ft.

3.3 Method of Support:

The suggested locations of the hanger points for the proposed scheme lie outside the regions of support from the side shell arches and are not feasible. Heavy transverse portals would have to be incorporated to carry the loads to the concrete base level.
A more comprehensive analysis would be required but this would probably involve changes of internal shape and would result in the need to underpin and strengthen the existing concrete substructure.

3.3 (cont'd.)

The location of hanger points for schemes A and B can be made to suit the side shell arches.

3.4 Method of Erection:

The erection of large units, 50 ft. long and 10 tons weight as required by the proposed scheme is considered difficult and expensive because of the size of the units, the weight and the restriction of the shells above. It is not possible without a detailed investigation to determine the actual procedure that would be adopted. The cost of erection, however, would be considerably above that for the two modified schemes.

3.5 Splices:

Positions of splices shown in the proposed scheme are structurally unacceptable because of changes of the support locations. Splices must be positioned to minimise unit weights and lengths and to reduce stress build up. Schemes A and B can readily fulfil these conditions.

3.6 Material:

High durability can be expected in all schemes provided there is no exposure to marine atmosphere. The timber proposed, White Seraya, has high strength but is subject to a degree, to 'nail sickness'. Further investigation would be required into the use of a less prone timber for those structural components which are not visible.

3.7 Cost Comparison:

In conjunction with Rider Hunt & Partners, an estimate of the material and fabrication (but not the erection) costs of a typical radial box of the ceiling has been made for the proposed scheme and each of the two modified schemes. Erection costs will be considerably less for the two modified schemes.

	Architects' Proposed Scheme	Scheme A	Scheme B
Amount of Plywood	16,400 sq. ft.	11,400 sq.ft.	7,500 sq.ft.
Amount of Steel	-	-	2½ tons
Cost of Timber	£13,300	£9,300	£6,000
Cost of Steel	-	-	£ 400
Total Cost (including Fixings, insulation etc.)	£15,400	£11,600	£9,000

3.7 (cont'd.)

Whilst these figures on the foregoing page are indicative of the relative costs of each scheme, they cannot be considered as an absolute estimate until working details have been prepared.

CONCLUSIONS AND RECOMMENDATIONS

4.1 We, therefore, strongly recommend Scheme B, the structural steel solution, for the following reasons:-

- i) The weight of the ceiling can be supported by the facilities already provided.
- ii) The erection sequence would cost considerably less than the other schemes.
- iii) Erection could take place before the building was made weatherproof.
- iv) The provision of ducts and openings e.g. the light bridge, is more easily accommodated in a structural steelwork scheme.
- v) Any future modifications to shape or otherwise could be readily incorporated in a steel scheme.
- vi) It utilises a well tried structural medium for which very competitive tenders would be received and tight contract control exercised.
- vii) On the analysis carried out, the indication is that the costs are significantly lower than for the other two schemes examined.

4.2 We do not recommend scheme A, the modified plywood scheme, because of cost, weatherproofing of the building and general constructional difficulties; because it offers no significant advantage over the structural steel solution.

4.3 The use of 50' x 9' plywood sheets in schemes A and B is free from all engineering considerations since it is a form of cladding and is not part of the structure of the ceiling.

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