LIGHT STRUCTURES FOR LIGHT SHOWS

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1 – Introduction

Born in Southern Italy in the 17th century, festival illuminations were built by major artists on the occasion of important ceremonies; the design of the hanging structures described in the followings has been drawn directly from that old tradition. As these allegoric figures were once made of wood and covered with colourful bulbs fixed with nails, nowadays it would have been impossible to build up such structures satisfying both safety requirements and construction codes.

Figure 1 – The central dome.

In order to renew the ancient illuminations and turn them into a modern lighting project meeting international quality standards, the design work has been mainly focused on safety and project management, where technology and organisation replace precariousness and improvisation without loosing original aesthetical quality.

That’s why those structures needed to be studied from different points of view:

- their great size;
- complexity of shape and geometry;
- total weight and number of bulbs to be carried (about 10000);
- safety of people (visitors)
- behaviour under seismic actions.

Figure 2 – The big sand glass

Time feeling and measurement was the subject of a set of giant figures settled in the International Market Place in Osaka, Japan (see Credits). Among all the light structures built up, the most significant ones are two hanging structures representing a huge sand-glass (7 meters height and 3 meters width) with sand changing colour while falling (Fig. 2) and a dome sited in the main hall of the building. The central dome, 8 meters width and 5 meters height, was divided in 16 slices covered with shining images; a set of historical tower clocks was supported at the bottom (Fig. 1).

2 – The project site and the safety requirements.

IMP building belongs to Matsushita Investment and Development Co., Ltd, and is a new, high technology building sited in Osaka Business Park. It has 26 floors, mainly used as office, and 2 basement floors. First three floors are occupied by International Market Place, housing over 60 shops and restaurants. Light structures had to be settled over market visitors head, so as to involve them in a long-lasting show.
Both Big Sand-Glass and Central Dome had to be hanged on using liftable frames suitable for maintenance.

3 – Materials

The choice of materials to be used was strategical. Structures need to be light, as well as resistant, because seismic load is proportional to total mass. In order to meet these two requirements, two different solutions has been adopted. The big sand-glass required to be made by skilled craftsmen, being composed of curved shapes with welded joints; moreover, it was a light structure for himself (self weight = 7.25 kN), so that normal steel (quality Fe360, according to UNI 7810) was chosen. If the big dome would have been made of steel as well, total weight would have resulted of about 20 kN. It means that, according to Japanese Code, vertical and horizontal seismic load to be considered in the analysis would have been respectively 30 kN and 20 kN. Such a huge load would have cause non-allowable stresses and displacements in both frames and strands, so we decided to look for a new material suitable to our needs of lightness and resistance. Aluminium quality A6063-T6/165 (according to Japanese code), with a 27 kN/m^3 specific weight and a 165 N/mm^2 allowable stress, perfectly met our expectations. Besides, using material directly produced in Japan (Fig.3), reduced the quantity of items to be sent from Italy. Hanging supports and horizontal bracing has been realized with steel strands Ø 6 mm type S1 according to UNI 7294.

Figure 3 -- Central Dome: a skilled worker is grindind aluminium top ring

4 – Loads

Frame outline has been designed according to efficiency of used materials and to both static (long term) and seismic (short term) loads. Long term load considered is vertical self weight (frame plus bulbs and electric wires). Seismic loads have been taken into account in a static equivalent way by increasing vertical load and adding an horizontal load. According to Japanese Code, seismic load is to be taken as dead load ×1.5 in vertical direction and equal to dead load in the horizontal one. Wind load was not considered because structures were to be sited indoors. Maximum service load has been defined both by long and short term analysis.

5 – Finite element analysis

Due to complex geometry of both structures, stress evaluation has been made by a finite element analysis of frame outline, in which bulbs and electrical wires weight are applied to nodes. Self weight of structure is automatically evaluated by the program. Strands are simulated by truss elements whose self weight has been neglected.
In pictures below (Fig. 4-5-6) are shown geometry and frames data as reported on drawings and modeled in f.e.a. meshes.

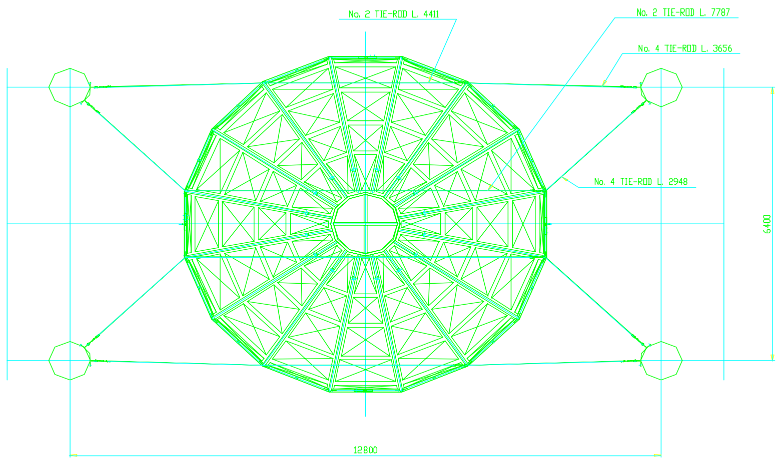

Figure 3 -- Central Dome: plane view from top

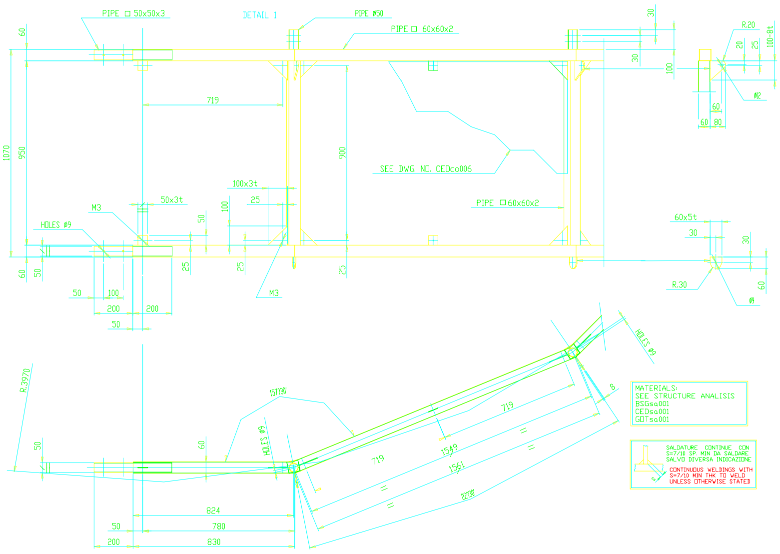

Figure 5 -- Central Dome: detail of bottom crown

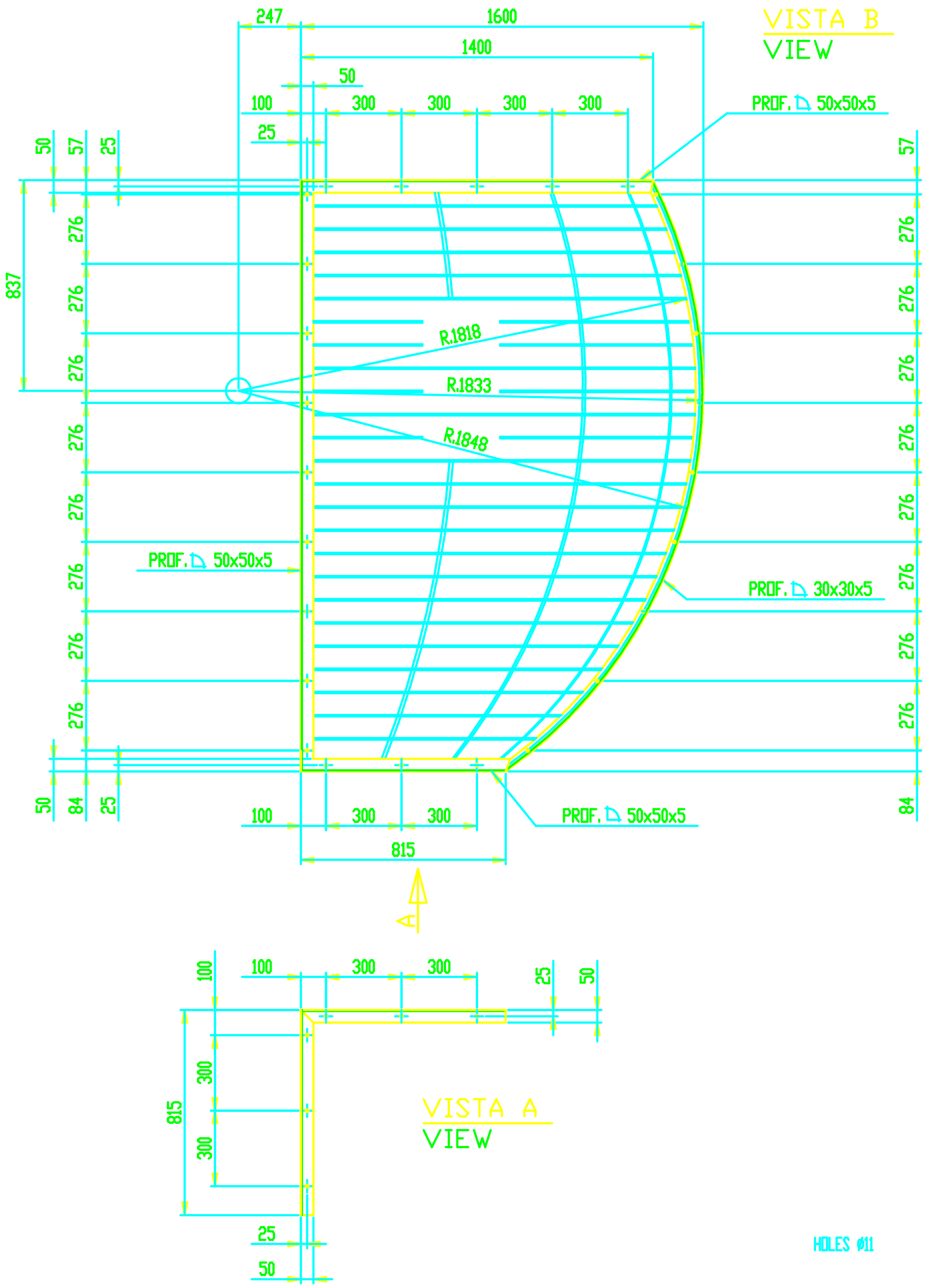

Figure 6 -- Big Sand Glass: detail of a quarter top

Stress evaluation has been carried out for both long and short term load conditions, combining bending moments and axial forces effects on sections. For strands can't stand compression forces, short term analysis has been made by iteration; in the first run all strands were active, allowing to check in output the compressed ones, which were removed in the second run.

As expected, after first analysis with seismic loads Central Dome mainly showed displacement problems (Fig. 7), althought reduced by using light-weight material.

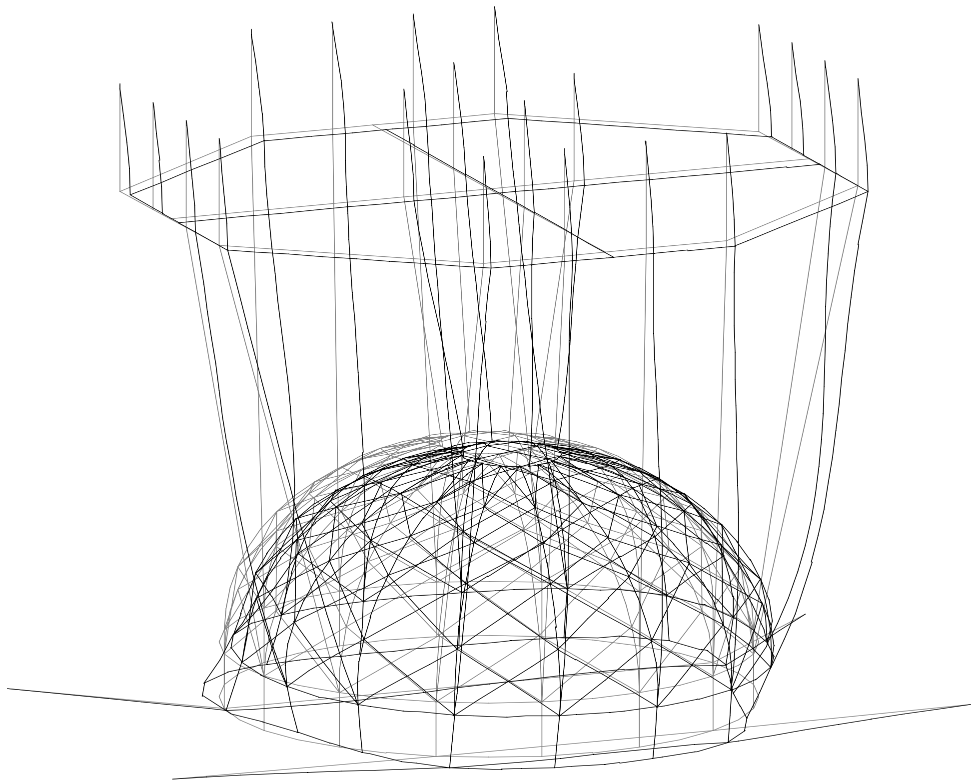

Figure 7 -- Central Dome: deformed shape (seismic load analysis)

Due to its peculiar shape, Big Sand-Glass had a resistance problem when loaded with horizontal seismic load because in its middle height, where section is small, there's maximum bending moment. Further analyses showed that reduction of weight wouldn't be enough to solve the problem, so we reinforced the "backbone" frame of the structures (Fig. 8).

In addition to that, for both structures, but in particular for the Central Dome, a set of tie-rod was placed to fix them to the building and to avoid swinging during earthquake.

In the following table we summarize loads and displacements of finite element analisis.

Vertical Loads	CENTRAL DOME	BIG SAND GLASS
Structure weight	3.50 kN	7.30 kN
Luminaries weight	10.00 kN	2.90 kN
TOTAL WEIGHT	**13.50 KN**	**10.20 KN**
MAXIMUM DISPLACEMENTS	**CENTRAL DOME**	**BIG SAND GLASS**
x direction	2.087 cm	1.452 cm
y direction	3.288 cm	1.430 cm
z direction	– 0.373 cm	– 0.565 cm

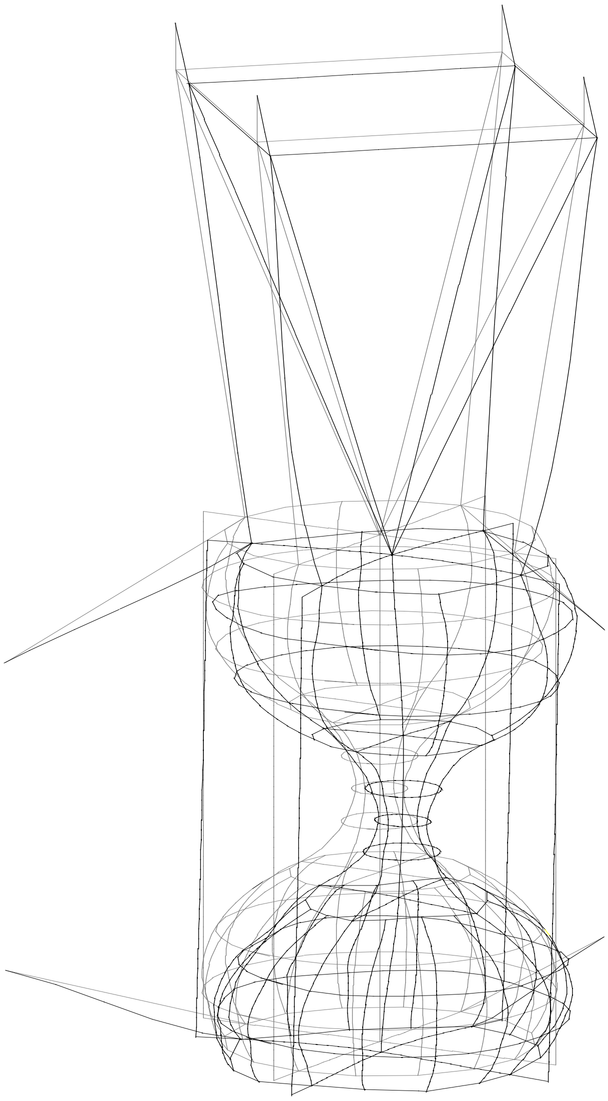

Figure 8 -- Big Sand-Glass: deformed shape (seismic load analysis)

7 – Assembling and maintenance phases

Main and general criteria about maintenance and safety concerning both structures have been focused to prevent damage or accidents by participation and collaboration among all people involved, who so had the common aim of safety. In order to avoid dangerous behaviours maintenance staff had been: (i) trained to requested works; (ii) acknowledged about procedures; (iii) fitted for requested works; (iv) properly equipped.

All assembling and maintenance phases have been previously designed in order to verify feasibility by people and used machines. Meanwhile, IMP have never been closed to visitors.
In particular, for Big Sand-Glass the computation of weights allowed to reduce the number of pieces to be carried from outside to inside and to be assembled by hand or hanging (Fig.9, Fig. 11). Moreover, packaging for overseas fligths have been optimized.
In assembling on site, Heart-S Co. Ltd. Staff have been involved (Fig.10).