A NEW CONCEPT OF SPATIAL TRUSSES

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ABSTRACT

The new concept of constructing spatial trusses efficiently utilizes the superior structural characteristics of honeycomb sandwiched panels. The first application of this concept was to the canopy of an aerospace museum. Three principal procedures of structural analysis are briefly explained, the manufacturing and fabricating methods are reviewed. The further application to single layer trusses is described, referring to the existing truss structures

INTRODUCTION

Aluminum brazed honeycomb panels were introduced to the market, as a result of R&D works carried out in the early 1990's. A successful application was their use for the 160 coach shells of Japanese Shinkansen bullet trains built towards the summer

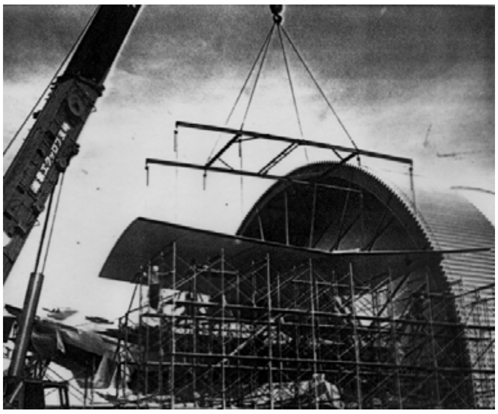


Figure 1 A canopy to an aerospace museum, May 1998 Figure 2 The canopy lifted, Feb. 1992

1998, efficiently utilizing the specific-strength and -rigidity of such panels. In the field of architectural buildings, the first attempt was to form a canopy at the entrance to an aerospace museum which was completed in early 1992. The structural concept there was to utilize panels in place of top chords of double layer trusses. Ever since, several studies have been carried out with the purpose of replacing truss structural shapes by honeycomb and sandwiched panels. Some results of such studies are presented below.

THE CANOPY OF AN AEROSPACE MUSEUM

The first application of this new concept was worked out during the construction of an aerospace museum in the suburb of Tokyo, which was opened to public in 1992. In the middle of the construction period, the architect came up with an idea to cover the entrance to this museum with an aesthetic light roof, imitating the wings of hang-gliders. The canopy originally of a traditional roofing structure was redesigned, then fabricated and erected in time to the opening of the museum. Figure 1 presents the appearance, seen in May this year, six years after the completion of construction. The canopy here is a tiny roof, 16 meter wide, 9 meter deep and placed at the elevation of a little less than ten meter high. Figure 2 is to visually explain the final stage of lifting of the panel, during the erection work of this canopy roof.

To evaluate the new concept, the observer of this structure is requested to realize that a double layer truss is established by using several different structural members analogous to top and bottom chords as well as necessary diagonals. Top chords in conventional double layer trusses are replaced here by a sole but wide aluminum honeycomb sandwiched panel, whose thickness or the total height is a hundred milli-meters. The diagonals are not new, but simply of a fabricated steel tube, pin-joined to top and bottom chords. Bottom chords are conceptual too, and considered to be infinitely rigid. A robust reinforced concrete frame, being a ceiling to inside of entrance doors as well, is considered to be the whole bottom chord, thus forming a double layer truss.

The structural analysis of this tiny double layer truss is not special, but rather straight forward. Since the bottom chord was recognized to be infinitely rigid, two bottom nodes, bundled lower ends of four diagonals each, were treated as the pinned base. Several tie bars in addition were employed to make the truss stable against tilting over the, only two, pinned bases. Generally available computer program for plate and shell analysis was utilized to check the strength and rigidity of the panel roof (a top chord element). One of the results of analysis is presented in Fig. 3.

STRUCTURAL ANALYSIS FOR DESIGN

The development of honeycomb welded structures, which are structures built by combining honeycomb and sandwiched panels by mostly welding, necessitates the development of structural analysis methods for design. Several methods were reviewed , and three essential processes were established [1]. The most common of the

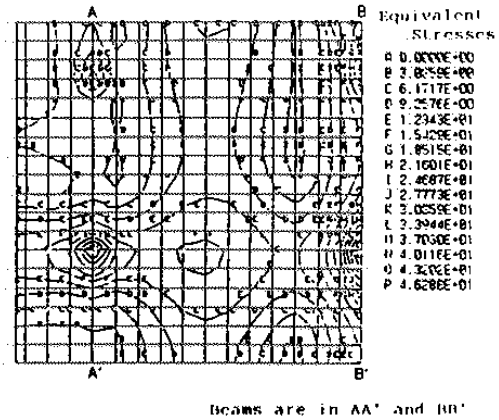


Figure 3 Principal stress contour of the roof

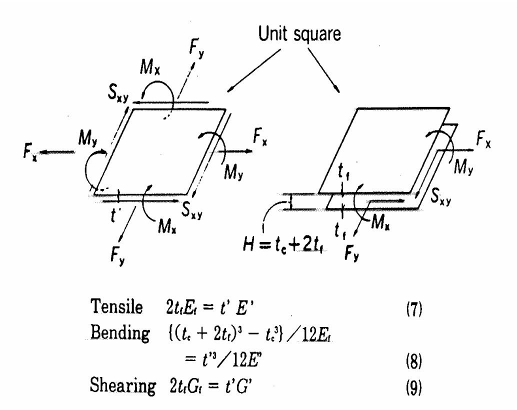


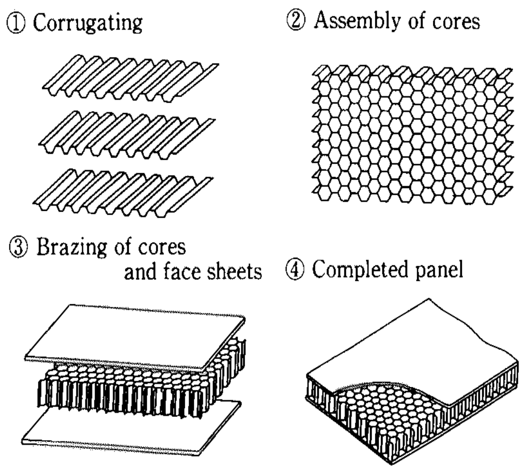
Figure 4 The equivalent thickness method

three should be the so called "Equivalent Thickness Method". Figure 4 illustrates the principle of this method. There, the rigidity of the panel, in which any contribution of honeycomb or sandwiched core is neglected for the purpose of simplicity, is equated to that of a single plate of the equivalent thickness. Such a single plate, sometimes combined with the existence of bar elements like the case shown in Fig. 3, can be analyzed with the aid of usual computer programs for plate-and-shells.

HONEYCOMB AND SANDWICH PANELS

Honeycomb panels in the past were manufactured by gluing honeycombs to the face plates using organic substance as adhesives. Since the organic material burns out at the relatively low temperature, these panels were unable to be joined to the other structural members by any process of fusion welding. Aluminum brazed honeycomb panels, on the other hand, consist of no organic materials and are manufactured by the process which is graphically explained in Fig. 5, [1]. The term "brazing" used here refers to the one particular method of fusion welding, because the filler metal which is an aluminum alloy is heated very close to the melting point of the parent metal which also is another aluminum alloy, thus making welded connections possible to be fabricated.

Another different method of manufacturing similar-to-honeycomb panels is illustrated in Fig. 6. This could be deemed as an alternative to the aluminum panel introduced in an international conference, INALCO '88 [2]. A press formed, resulting to have several cup shapes, thin core sheet {B} and its turned over counterpart {C} are joined each other, at the bases of the cup shapes, first and then two face plates, {A} and {D}, are welded to form a welded and sandwiched panel, two meter long and one meter wide in this figure. This alternative could be applied to manufacture steel panels by applying any fusion or even non-fusion welding processes, like spot, laser, plasma or diffusion welding techniques.



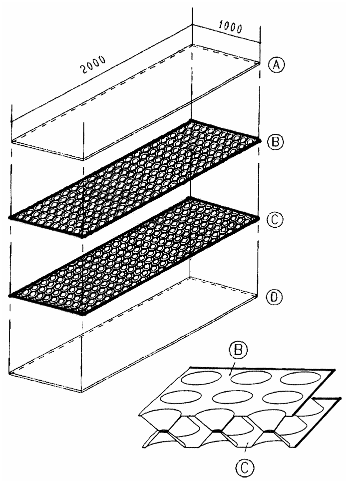


Figure 5 Process of manufacture, honeycomb panels Figure 6 Production of welded panels

SINGLE LAYER TRUSSES

Recent tendency is to form single layer trusses in place of double layers like the ones described on Fig's. 1 and 2, for the same purpose of covering column-free, wide areas. Two examples of such single layer trusses are illustrated in Fig. 7. It is the further development of sandwich panel members to replace structural line elements here by the plane elements. An attempt by one of aluminum panel suppliers is to cover forty meter span area by a barrel roof of ten meter rise.

For the design of conventional dome structures with extruded aluminum members, Kissell introduces the importance of stability checks [3]. He refers to the SSRC guide [4] where the stability problems of shell like structures are extensively treated. Although a preliminary calculation indicates that 100mm high honeycomb panels sustain wind loads on this 40m span barrel, there may be needed to place stiffeners, as a result of the stability check. The stiffeners may be of welded or extruded aluminum shapes, making panel-to-panel joints as shown at the bottom left of Fig. 10 in the next Chapter. When one studies the effect of welding residual stresses on the buckling behavior of I- or H-shapes, it can be recognized that the edge of their flanges preferably have tensile residual stresses as the result of cover plate welding.

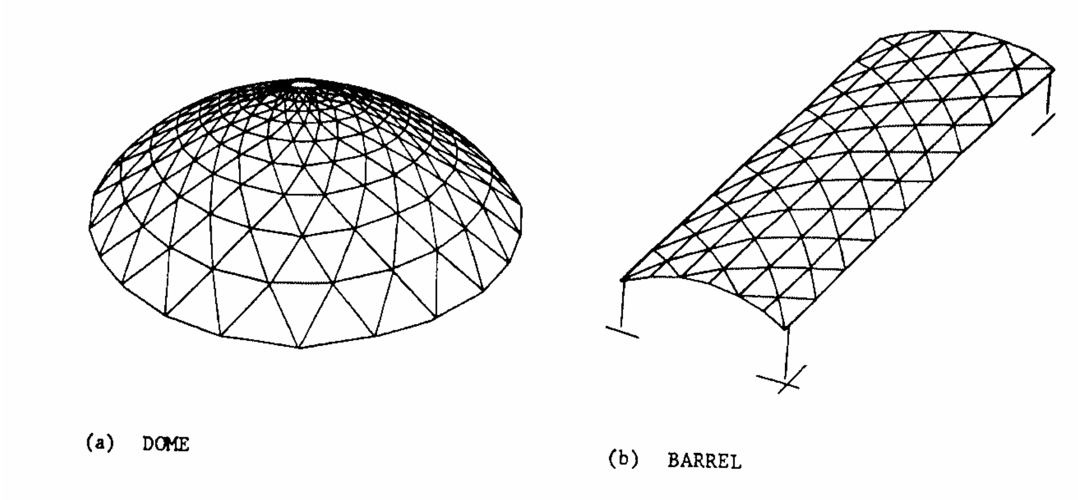


Figure 7 Two examples of grid formed shell-like structures

Another example of single layer trusses is a hyperbolic paraboloidal (HP) shell. The principle of forming such an HP shell by rotating a straight line around another not-parallel line is schematically drawn in Fig. 8. As is seen in the center area of the elevation which is to the right of the plan here, if the square panel element is placed in such an HP shell, it can be very slightly bent or, in some cases, be of not-bent panel.

FABRICATION TOPICS OF HONEYCOMB PANELS

Bending procedures of honeycomb sandwiched panels are not different from traditional plate bending methods. One example to form HP shell elements is by a press bending method, as illustrated in Fig. 9. This study was carried out, incidentally, in the course of developing honeycomb welded ship hulls [5]. One meter square and 30mm high aluminum panels were pressed between top and bottom dies, and any threshold radius of bent HP elements was investigated.

Another importance of fabrication is of forming panel joints. Various examples usually required in the course of panel fabrication are studied extensively and some of them are summarized as shown in Fig. 10. Since panels themselves are manufactured by welding, most of the joining process relies on welding. It is also recognized in Fig. 10 that almost all the joints there (I, T and L or corner joints) are very similar to the shape of connections applied in the welding of thick metal plates. One

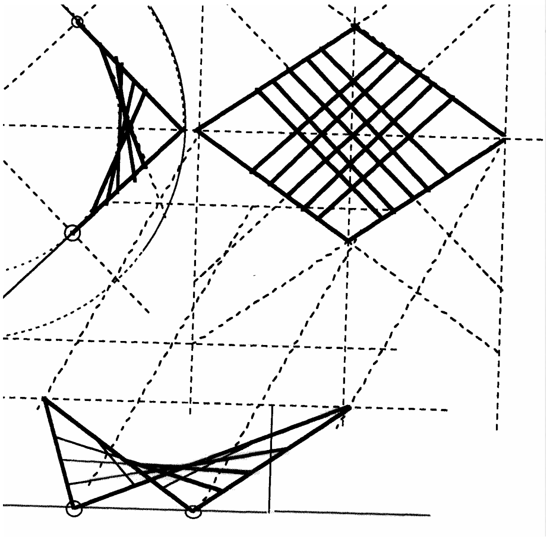


Figure 8 Principle of HP shell forming

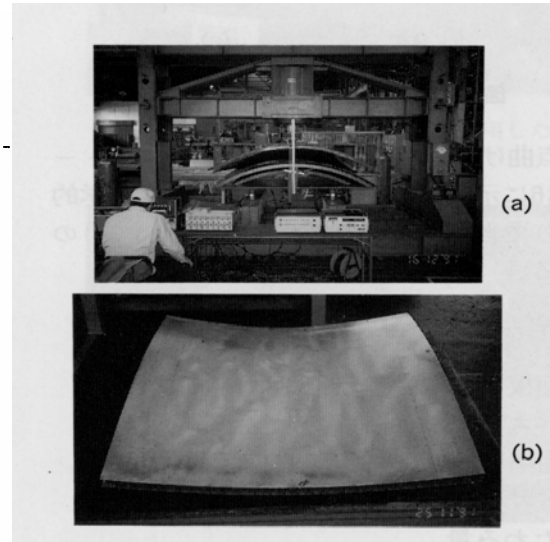


Figure 9 Press bending of HP shell element

particular point should be highlighted onto the way where the welding indicated in this figure needs to be worked out from both sides of panels, unless a specific one-side welding process is invented and applied as was done in case of the canopy construction that is described in the Chapter in the beginning, Fig's. 1 and 2.

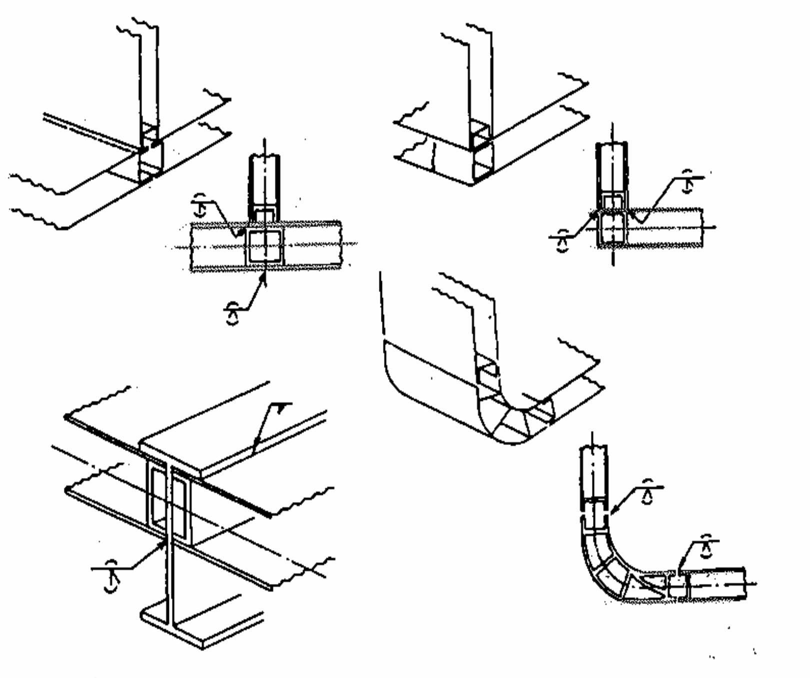


Figure 10 Joint samples

AN EXAMPLE OF SINGLE LAYER HP SHELLS

One example of HP shells, for the similar to which the panel replacement is considered, is shown in Fig's. 11 and 12. This example was recently constructed as a terminal building of KL international airport in Malaysia, and partly introduced at the

Figure 11 HP roof shell, (view to South)

Figure 12 HP roof shell, (view to North)

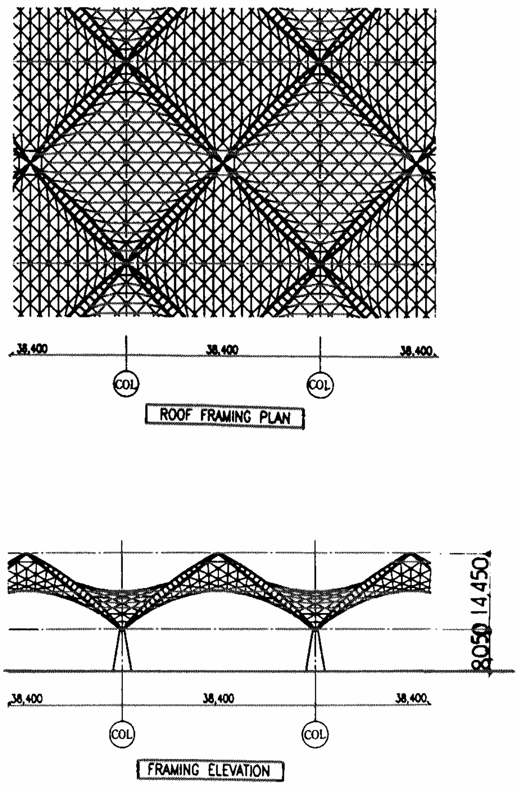


Figure 13 Part drawing for KLIA main terminal building

[6]. A portion of the drawing is reproduced in Fig. 13. It could be easily observed that the elevation shown in Fig. 13 is exactly the same as the oblique side view drawn in Fig. 8. This means that such HP-shell-like trusses presently built by combining structural shapes could be replaced by the combination of honeycomb sandwiched panels.

Another spatial truss which is able to be viewed at the site of Fig's. 11 and 12, although no replacement idea is attempted so far, is a double layer steel truss employed in the construction of Satellite 'A' or the second terminal for building of the same airport. Figure 14 shows a portion of this double layer

last IASS meeting in Singapore, 1997

truss, where the so-called spine truss of forty meter long which connects the center ring truss to one of the four adjacent wing building structural frames is clearly observed.

CONCLUSION

Several aspects needed to apply honeycomb sandwiched panels to spatial trusses are presented, starting from the first example truss for architectural building, followed by brief description of structural analysis for design, manufacture and fabrication of honeycomb sandwiched panels, and the conceptual applications of such panels to single layer trusses. One aspect not fully covered due to limited space and time allocated herewith is the explanations and samples for mathematically treating formula, analysis, and calculations or computations. However, it is strongly anticipated that the concept presented in this paper, utilizing those panel elements in the truss structures, could result in making them ideal structures with higher specific strength and higher specific rigidity.

Figure 14 'Spine Truss'
KLIA Satellite 'A' building

ACKNOWLEDGMENT

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