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SPACE PARTITION BY 2-MANIFOLD SURFACES AND THEIR ARCHITECTURAL APPLICATIONS

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M.Burt & A.Korren (1996) *Periodic Hyperbolic Surfaces and Subdivision of 3-Space*, Katachi U Symmetry, Springer-Verlag, Tokyo.
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Abstract:*The morphological research of the space subdivision by continuous 2-manifold hyperbolic surfaces promotes the understanding of organized space and its phenomology. The phenomenon of periodic hyperbolic surfaces that divide the space into two complementary subspaces was dealt with over the years, by many researchers from different scientific disciplines.*

Of special interest are the periodic 2-manifolds which are continuous, hyperbolic (sponge like) and divide the space into two identical subspaces, topologically characterized by two identical (self-dual) tunnel space networks.
Up until 1993 seven such topologically different surfaces were discovered empirically by various researchers.
The discovery of these surfaces was tantamount to the discovery of seven self-dual space network pairs, representing the tunnel spatial arrangement.
A research was contemplated with the goal of proving either the finality of this series of surfaces and their corresponding self-dual networks or discovering additional (new) surfaces and space networks and doing so by employing a rigorous systematic method and an undisputable exhaustive search process.
The selected method was deeply rooted in the theory of crystallographic symmetry groups, the number of which is known and proven to be finite. As it turned out, the employed method reaffirmed the familiar seven topologically different surfaces and the associated pairs of self-dual space networks. But the ultimate result was to remove the method obstacle, which acted to obscure the possibility to conceive a much wider family

of 2-manifolds, capable of subdividing space into two identical subspaces, and facilitate a new start to this, seemingly exhausted subject.
Relating to the results of the present research effort it should be noted that:

1.It is assumed that the emerging number of periodic hyperbolic 2-manifolds, subdividing space into two identical subspaces is amounting to infinity. (Figure 1)

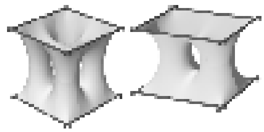

Figure 1 - Periodic cells of the infinite family called the "the multiple-sleeved class"

2.The previously discovered seven surfaces, represented a unique family group, (Figure 2) due to their shared unique property, related to the possibility to generate their elementary surface units (enclosed within their E.P.R's) as minimal soap solution films, stretched on a physical wire perimeter (through a typical dipping process).
The paper describes the utilized method for the exhaustive search and generation of self-dual pairs of space networks, their corresponding periodic-hyperbolic 2-manifolds and the associated partitioned labyrinthine subspaces. The method for the enumeration and classification of the 2-manifolds consists of several consecutive steps; each step narrows down the scrutinized area and brings us closer to the final goal.

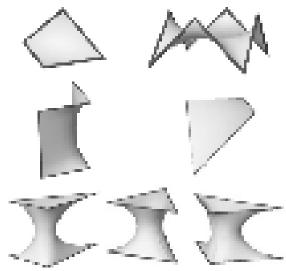

Figure 2 – The seven elementary Periodic units

Two new surfaces were discovered, sharing this same property, thus enlarging the exclusive "club of seven" into of family of nine such surfaces (Figure 3). It is yet undetermined whether this smaller family group is finite, and, if so, what it size may be, although it is likely there are many more surfaces in addition to the nine discovered thus far.

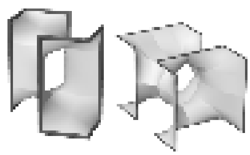

Figure 3 – The two new additions to the "club of seven"

ARCHITECTURAL APPLICATIONS

Space structures are those that owe their structural performance mainly to the way their material is distributed in space. Paradigmatically, their design is dominated by the desire to minimize the amount of invested material and energy in their construction. Therefore, space structures are causal and could be rationalized, analyzed and optimized.
Structural Morphology is mainly concerned with:
1. Investigation of causal structural forms and in particular with the least-effort-stress structures, and the process and dynamics of their form generation.
2. The study of the structure of space, its order, periodicity and organization (and their inhibitive constraints), in relation to the structures which inhabit it, to promote the understanding and manipulative skills required in the process of their design.
The cost-effectiveness of space structures is dependant on their relative adherence to the above mentioned defining characteristics, specifically the mode of their material distribution in space, as well as the level of their periodicity and its manipulation for the attainment of a far-reaching rationalization and industrialization of the process of their

realization. Structural design may aspire to reach an art form level. When it comes to pre-stressed fabric membrane structures, two main alternative design strategies are considered:
1 .The "free form" (cable perimeter) membrane structures, best epitomized by the German Pavilion in Montréal Expo (Frei Otto 1976).
2. The "rigid edge", modular membrane structures. And, of course, some hybrid, cross-gene mutations.
The "free form" design strategy, morphologically characterized by a two layer distribution of point wise supports (upper points supported by mast poles and sometimes by arched rigid elements or otherwise) which determine the spatiality of the structure, and a peripheral cable edge system, responding to membrane tension forces, imposed by the stability-rigidity requirements of the overall structure. It is at its best when in open (natural) environment, as a free floating unenclosed pavilion space. When, because of programmatic constraints, the interior must be column-free, it must revert to edge supported solutions. In order to preserve required membrane curvature levels, the masts become considerably higher, or alternately, to compensate for the reduced curvature, much higher stresses and pre-tensioned fabrics must be used, in the wake of which the whole design and construction process must undergo a significant shift in the direction of rising complexity and costs. The above affects structural analysis, cutting patterns, detailing, materials, masts and anchorage solutions and erection techniques. Especially, this approach reaches a higher level of conflict in a closely knit urban environment, where free forms could not harmonize with the crystalline like morphological space regime.

THE AMADO ROOF STRUCTURE CASE STUDY

The membrane structure which was defined from the outset as a 'low-cost enterprise', had to conform to a rigidly imposed programmatic and site conditions within a grip of an orthogonal building geometry, which dictates a column-free interior prearranged space, constraints on structural height and imposed orthogonal morphology on the steel support structure and the fabric membrane modules. The realized membrane roof structure is very characteristic of the rigid-edge design approach and clearly demonstrates the inherent technological and structural advantages of its morphology.

Fig. 4 – Amado roof membrane structure

DETAILED DESCRIPTION

•The membranes, due to the relatively low inner stresses (because of the higher curvature levels), may adhere to wide range of reinforced P.V.C. fabrics, generally supplied by the current industry, namely – P.V.C. sheets with polyester or nylon fibers, with the appropriate thickness (weight) to meet the prescribed requirements.

•The skeletal lattice structure is solved to conform to the overall space given constraints, inclined mostly to “orthogonality”, and to generate the straight (aligned) perimeters of the modular membrane units and fenestration facades. Standard industrial metal profiles are employed, complemented with specially designed and produced metal sheet components, as required.

The skeletal structure is globally stabilized through the employment of tension cables and relatively simple tensioning accessories. In a final performance mode, the membrane medium may be perceived as a substantial or even critical contribution to the overall stability and stiffness of the structure, although, according to the author’s professional experience, it is wise to stabilize the space lattice structure so it could perform independently of the membrane medium, for breaking down the construction process, as well as for maintenance reasons, as necessitated by local membrane failures and the like.

•Rigidity and stiffness of the skeletal structure generates the right conditions for incorporated fenestration facade solutions, to provide for hermetic closure and the sought climatic control of its interior. Accordingly the peripheral elements are solved so as to conform to the structural and functional requirements, imposed by the facade design considerations and the attached membranes.

•Edge solutions of the membrane modules, simplified as they are by the lowered tension forces, must give an answer to the tensioning and sealing-waterproofing problems. A system of edge-wise screws is employed for pretension and controlling the distance between the membrane’s edge perimeter and the structural steel beams, and when combined with suitable steel sheet gutters, provide for the drainage system, which carry the accumulating rain water through the structural components all the way and beyond the structure’s bounds.

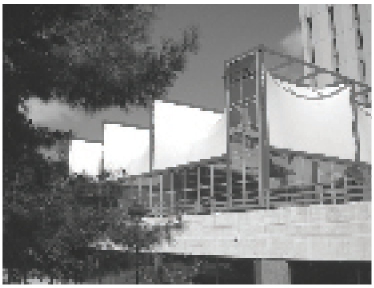

Figure 5: The Amado membrane roof structure – the overall orthogonal assembly composition of rigid-edge membrane units.

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