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"ARACHNE" (a construction method for industrialized housing)

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By

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The described method deals with "plug-in" modules stacked in a structural frame. The author is aware of the fact that neither modules nor their stacked relationship would in themselves raise more than a limited interest as these concepts have already been widely used. There is however little doubt that among the few hundred thousands housing units that are going to be factory built in the years to come, an increased number will have to be specifically adapted to the "plug-in" concept. It is not the purpose of the present paper to blindly defend this concept versus other ones but to consider the tendency as a fact that has to be coped with by the structural engineer.

A brief survey of the state of the art in the relevant field might prove useful to situate the present method : different types of modules, mainly plastic shells, have been designed for housing purposes for exampleby, to quote only some of them:

- CHANEAC (France)
- HAUSERMANN - CAMOLETTI - HOECHEL (Switséland)
- MANEVAL (France).

All these modules have in common:

- a shell shaped appearance
- suitable characteristics for easy transportation
- the possibility of connecting and/or stacking the housing units at will.

Maneval's module is the only one to the author's knowing to have been factory built on a relatively large scale, and the prospects appear to be impressive (one module a day five years after the first draft).

The general tendency is to provide adequate means to allow for a stacking of these modules; however in the three references quoted, the structural problems of the frame appears to be elusively considered: the vision is correct but incomplete.

It is the purpose and essential object of the present paper to propose such a structural frame that should correspond to the following criteria:

- the frame must be considered as an entity adapted to divide a given space, designed to support variable load conditions and provided with all the necessary "inputs" and "outputs" for the to-be-nested modules.
- the frame must keep its structural strengh independantly from the fact that modules are/or are not nested within it.
- the frame must be simple, cheap and durable.
- the frame must provide a high rate of occupation of the building ground and preserve it at the same time.

The reasons of quoting these criteria have enough evidency not to be emphasized.

If one considers the existing frames, it appears that they might not prove entirely satisfactory for the purposes.

A structural frame, for example in a high-rise building, is not really an entity for the reason that it stays in such a close relationship with floors and walls that it is generally completely hidden when the building reaches completion. On the other hand the rate of occupation of the building ground is so high that it does rarely respect this ground. Generally stated, most of the conventional frames are designed according to cartesian coordinates and would prove therefore inadequate for nesting anything else than cartesian coordinated modules.

One can consider that this is due to the fact that the existing solutions are closely associated with the concept of confined volumes and areas, which concept is essentially related with stone or stone-like building methods. The proposed system tries to get rid of this inheritance and to outline a new approach that might prove to be adapted to the purposes set-forth.

The first point will tend to outline the general aspect of the proposed structure as regards its environmental context. It is indeed considered that the problem of low-cost housing cannot be tackled if it is approached independently from this context. This resolves to consider the question of low-cost housing as essentially related to the previously quoted rate of occupation of the building ground, this being believed to be the main parameter of the problem. This rate has to be high for economical reasons, and must for psychologically evident but too often ignored reasons be such that it does not set an intolerable strain on people. Moreover it would be a good point if the same building system would allow for unlimited control of this parameter, from the private house to a reasonably high housing density.

The proposed structural supporting frame consists of vertical column members placed exclusively at the angles of a net of equilateral triangles and hexagons and connected by horizontal members. The triangular areas are designed for nesting modules or housing units of the previously quoted type. The hexagonal areas provide for a "foamed"appearance of the overall relationship of said modules and will be generally devoted to common facilities.

This net permits a relatively high rate of occupation of the ground. The frame has an immaterial thickness and the sight from modules is diversified and never limited by any sort of wall. There is a great versatility of the general urban planning as this one can be selected from any pattern of the net, according to the ground conditions, circulation included. It allows especially for a transition from high density to low density housing without any discontinuity. The few examples pictured will speak for themselves as regards this feature. The horizontal members provide for the geometrical assembling of the columns and their bracing as regards lateral forces. Their design could be considered as an essential feature of the structural supporting frame.

Vertical utility members which may be staircases, lifts or technichal cores are disposed at suitable places, these being considered as the "inputs" and "outputs" of the modules; they are provided with

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standardized devices for rapid and easy connection to the modules. The net of triangles and hexagons has been chosen for its somewhat attractive versatility. But conventional means of horizontally connecting the columns together would prove inadequate either for the expenses involved (trussed girders or the like), or because the positioning of the modules inside the frame between columns might be impeded (diagonal braces).

Considering that the modules can be readily designed as self-supporting as regards their dead and live loads and may therefore bear directily on the columns, the horizontal members could be eventually designed as non load bearing as regards vertical efforts.

Considering further that the most efficient and unexpensive columns are double flanged steel profiles, and that the best way of locating these profiles on the net is to have these flanges parallel to the height of the triangles, one might be naturally led to draw circles tangent to the flanges of the columns. These circles might be materialized by elastically bowed sheet metal members fastened to the flanges of the columns. A net of curved triangles is thus superimposed to the previous net, tending to create what one could call a spider like pattern ("arachne"). Evidently enough, the system does not work, as there are no forces to compensate the thrust that will be exerted on the columns by the elastically bowed metal sheets. This point will be dealt with later on. Assuming that the structure is in a state of equilibrium, the metal sheets may be made of a sufficient height to provide for a lateral bracing of the columns. It will also be noted that a bowed sheet behaves in a much better fashion as regards plate buckling and moment resisting capacity.

As regards the equilibrium of the structure, it will be sufficient to connect the metal sheets midway their length between columns by some kind of bracing like rings or rods.

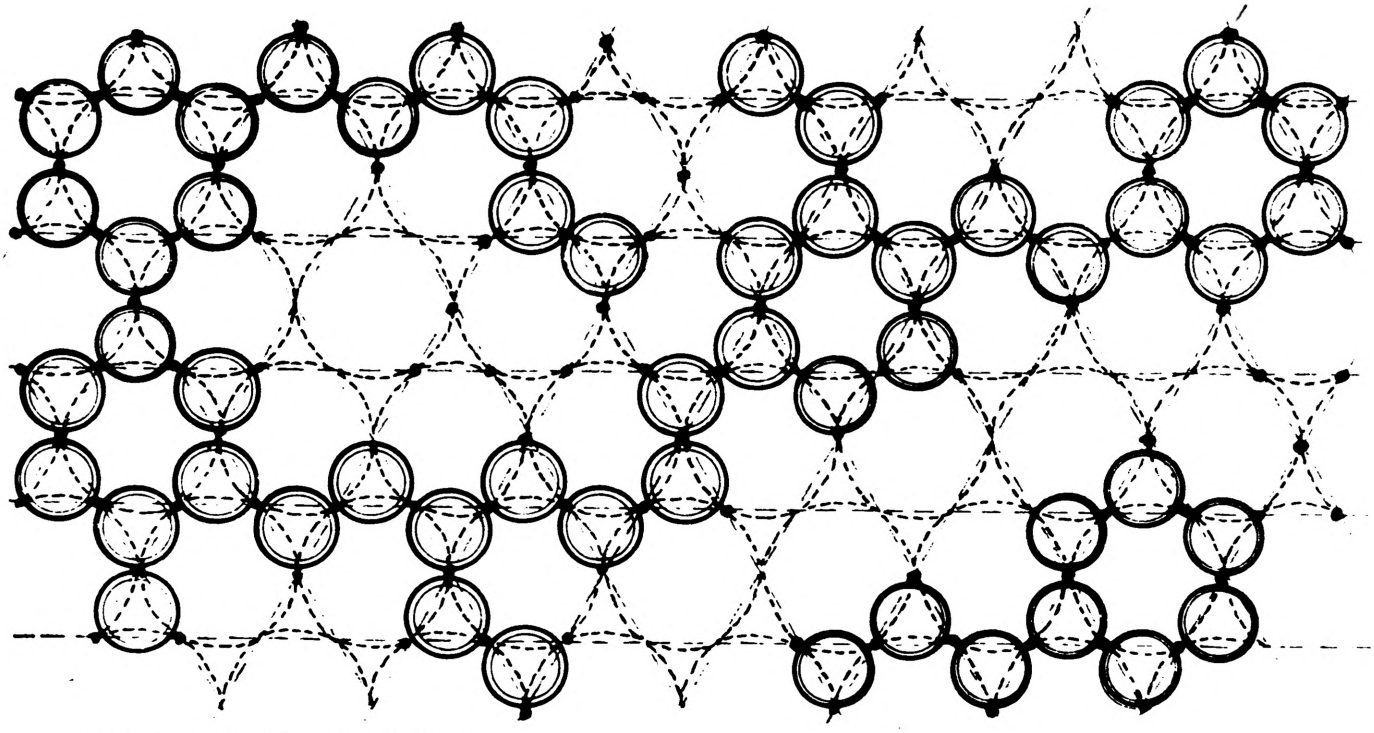
It remains that the whole structure is still subject to consistent deformations since the metal sheet members have no restraint regarding horizontal displacements. It is necessary to prevent these deformations. The proposed means consist of pouring a suitable setting material inside the curved triangles, with the aid of adequate shutterings.

This material should find some kind of gripping connection with the sides of sheets, and be likely to assume essentially compressive forces. Expandable foam or lightweight concrete are assumed to be adequate for this purposes. The detailed design of the horizontal members, the state of stress in the setting material, and the overall behavior of the structure certainly need both theoretical and experimental investigation in order to propose reliable design criteria.

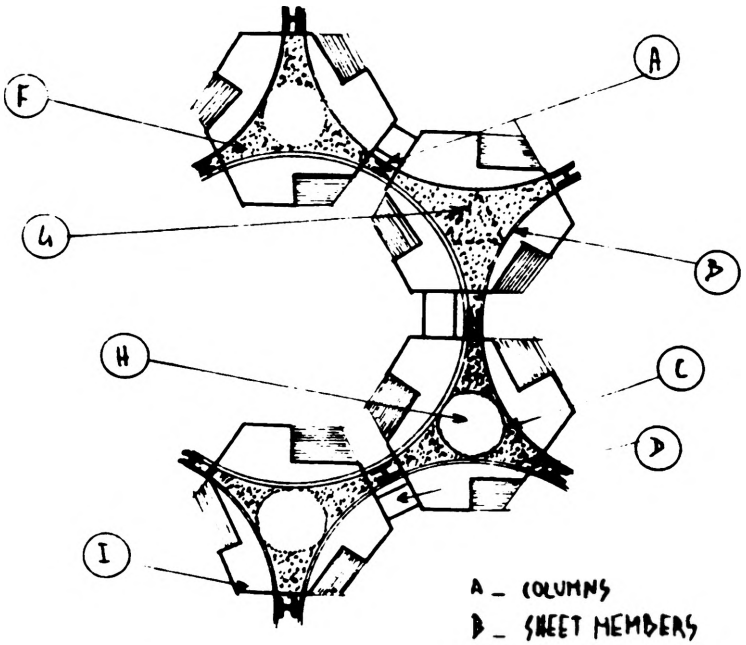
The advantages of the system would be numerous. There is no need of elaborated machining of the steel members, which are conventional mill products. The horizontal members can be disposed liberally along the height of the columns, there being no need of creating horizontal surfaces as it is the case with conventional floorings. The structure can be erected with a temporary filling of the curved triangles with expandable foam which can be sequentially burnt out and replaced by the more reliable lightweight concrete. The modules being completely independant from the frame will only have to fulfil certain conditions regarding dimensioning and bearing devices. The steel frame being entirely exterior to the housing units needs little consideration regarding fire protection. It extends in such a way that its resistance to seismic efforts should be high since all parts of the structure will cooperate to prevent a complete collapse of the more severely concerned members. The liberal relationship between modules is a most favorable feature regarding wind effects; the enormous thrust laid upon conventional highrise buildings is consistently reduced; the corresponding increase in height is considered to be relatively inexpensive.

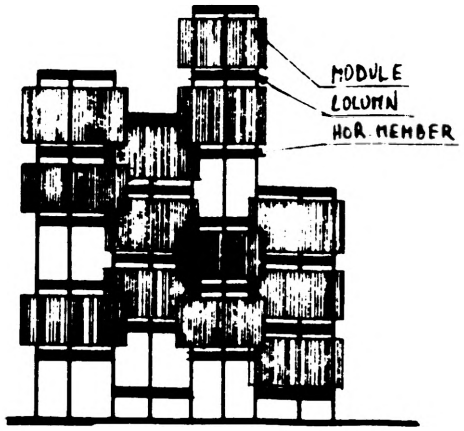
One should however consider that although these features are of importance, they would not in themselves bring a satisfactory answer to any housing program, since every day's life gives little concern to fire, earthquake, wind bracing or other engineering hobbies. Of immediate importance must be the visual appeal of one's home, its personality, its accordance with the environmental context, the subtle sequence of restrained and unrestrained vistas. These should be essentially aimed at, there where borders on the engineer's contribution.

Villedieu, Sept. 9, 1970



THE NET OF TRIANGLES AND HEXAGONS, THE SUPERIMPOSED SPIDER-LIKE FRAME AND RELATIONSHIP OF MODULES.





SIDE VIEW

A _ COLUMNS
B _ SHEET MEMBERS
C _ BRACING RING
D _ HORIZONTAL MODULE CONNECTION
F _ SETTING MATERIAL
4 _ BRACING RODS
H _ VERTICAL MODULE CONNECTION
I _ MODULE OUTLINE

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