United States Patent [19]

Fencl

[11] **3,890,748**

[45] **June 24, 1975**

[54] **STRUCTURE OF COORDINATED MODULAR BUILDING CONSTRUCTION**

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[22] Filed: **July 15, 1974**

[21] Appl. No.: **485,461**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 369,562, June 13, 1973, abandoned, which is a continuation-in-part of Ser. No. 294,391, Oct. 12, 1972, abandoned, which is a continuation-in-part of Ser. No. 289,935, Sept. 19, 1972, abandoned, which is a continuation-in-part of Ser. No. 143,547, May 14, 1971, abandoned.

[52] **U.S. Cl.** **52/79;** 52/125; 52/220

[51] **Int. Cl.**[2] **E04H 1/04**

[58] **Field of Search** 52/79, 220, 221, 261, 262, 52/227, 236, 122, 125

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Primary Examiner—John E. Murtagh

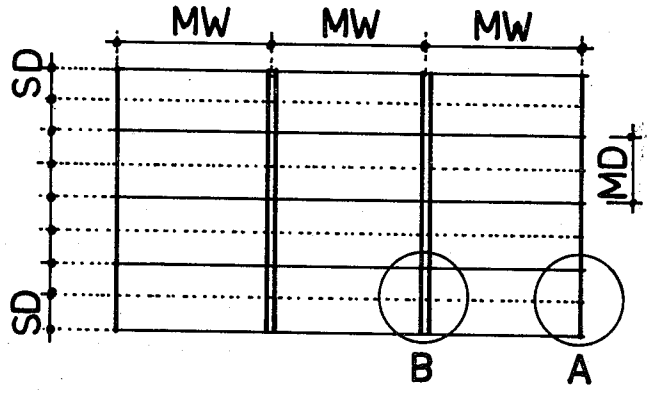
[57] **ABSTRACT**

A structure made of reinforced concrete, related to volumetric modular construction of buildings where building modules of which the structure has the form of a rectangular tubular section are assembled into a modular cluster by "wall to wall" and, or "floor panel to ceiling panel" fashion.

The doubled structure of bearing walls and, or structure of doubled floors are assuming substantially the shape of a ribbed slab so that when combined, they create a cellular structure, thus reducing the weight and, moreover, space thus obtained is advantageously utilized for the distribution of the mechanical equipment such as electrical-signal raceways etc.

In order to secure the efficient use of the doubled floor structure, floor and ceiling panels are combined by means of an epoxy grout during the process of the assembly of the modular cluster into the form of a laminated slab functioning as an integrated horizontal structural element.

6 Claims, 19 Drawing Figures



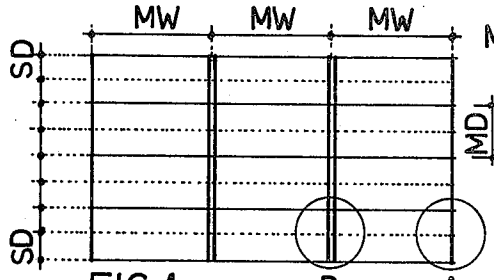


FIG.1

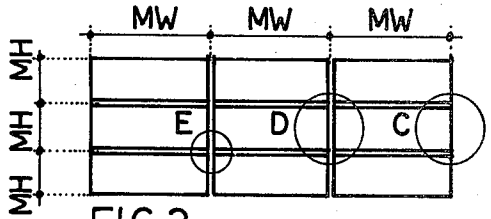


FIG.2

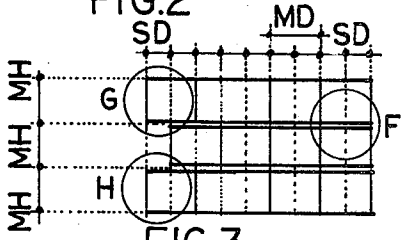


FIG.3

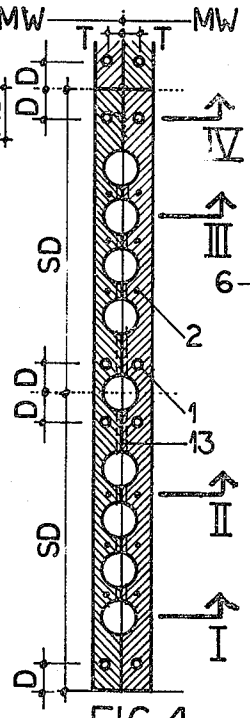


FIG.4

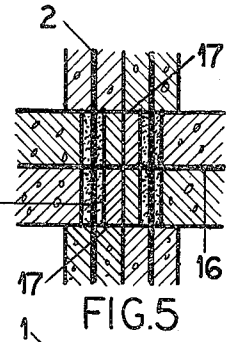


FIG.5

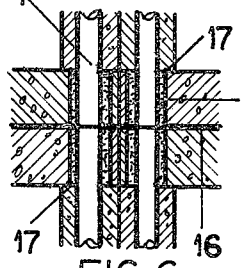


FIG.6

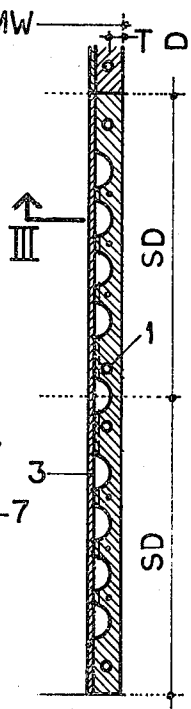


FIG.7

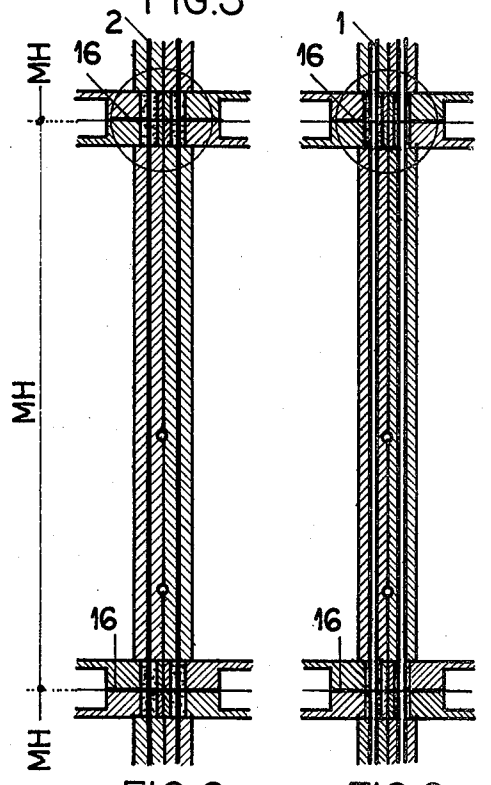


FIG.8

FIG.9

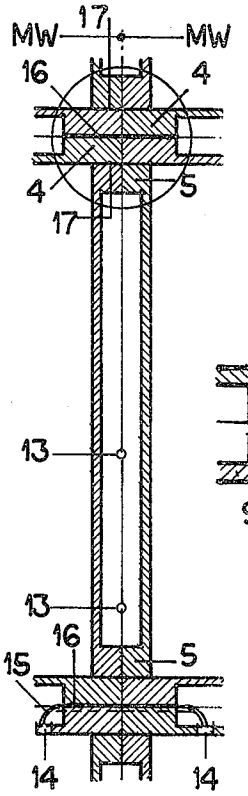


FIG.10

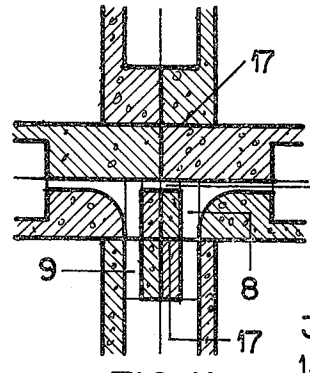


FIG.11

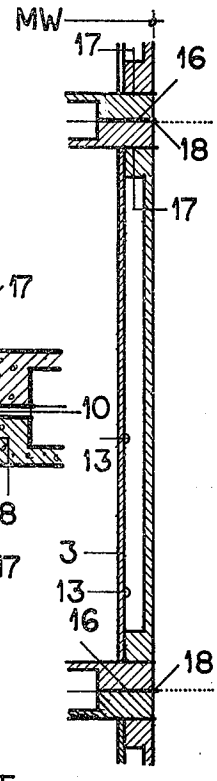


FIG.12

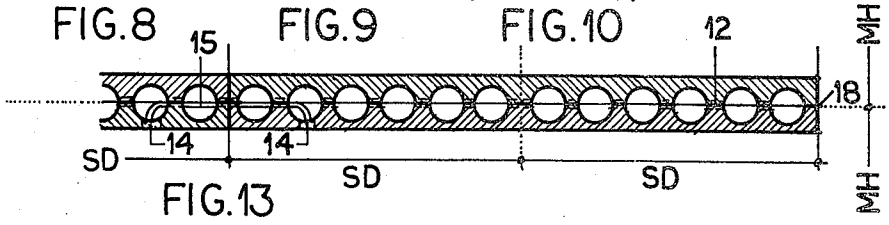


FIG.13

FIG. 14

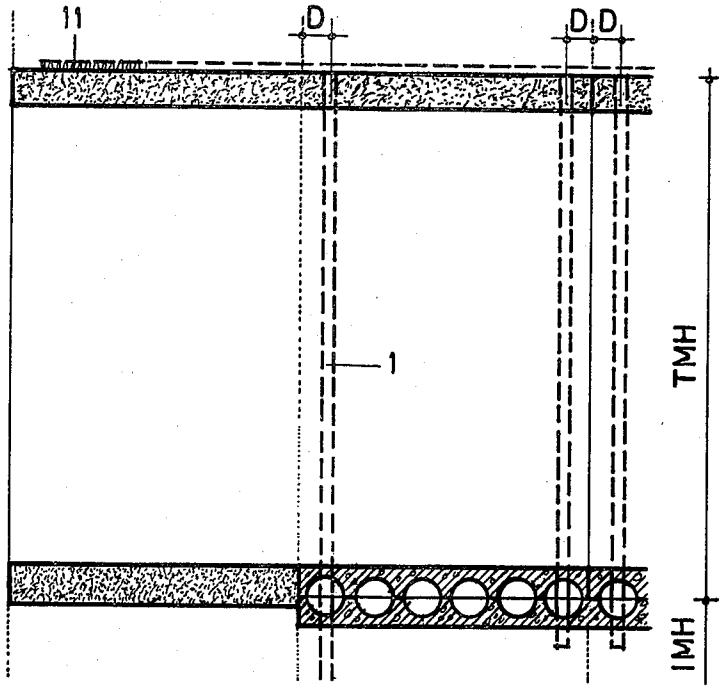


FIG. 15

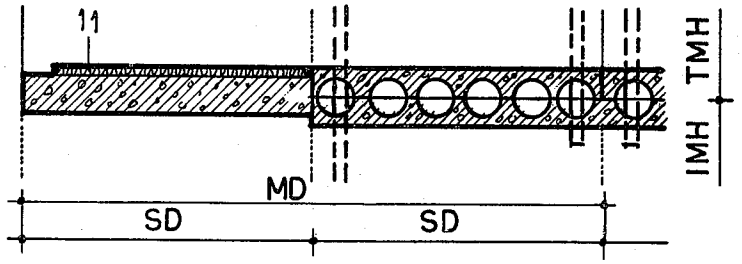
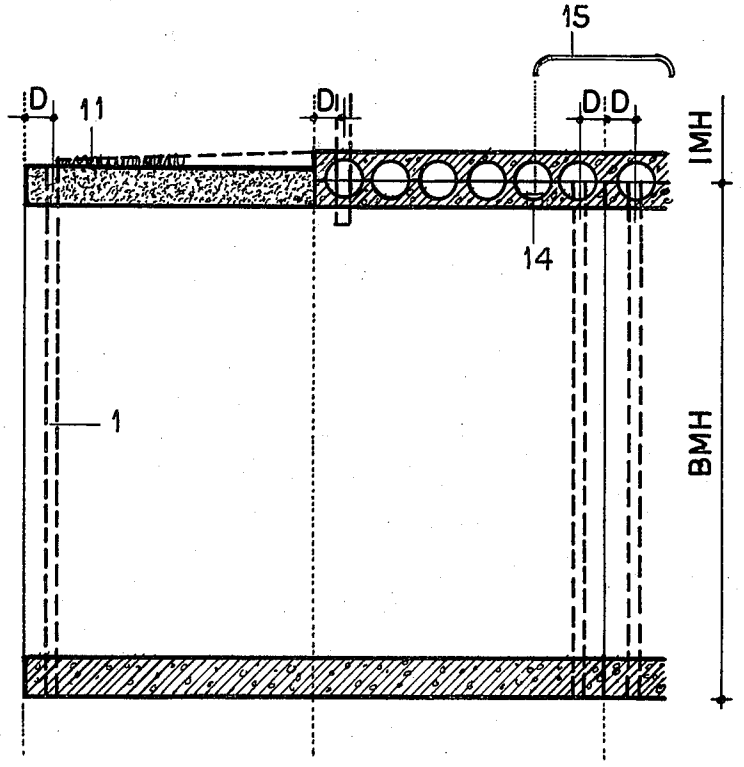


FIG. 16



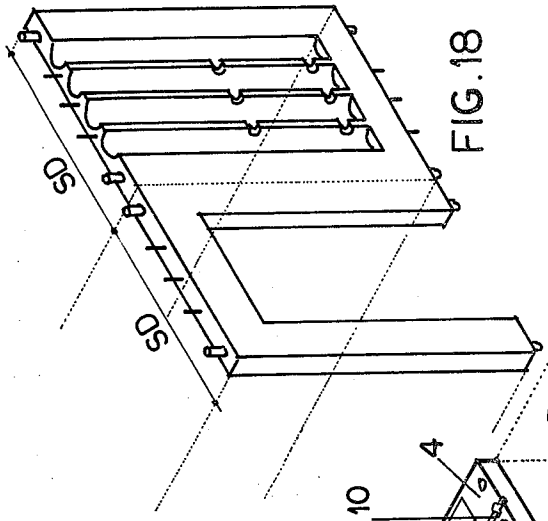


FIG. 18

FIG. 17

FIG. 19

STRUCTURE OF COORDINATED MODULAR BUILDING CONSTRUCTION

CROSS REFERENCE TO RELATED APPLICATIONS (Amended)

This application is a continuation-in-part of a now abandoned application Ser. No. 369,562 filed on June 13, 1973, which was a continuation-in-part of an application Ser. No. 294,391 filed on Oct. 12, 1972, now abandoned, and which was a continuation-in-part of an application Ser. No. 289,935 filed on Sept. 19, 1972, now abandoned, and which was a continuation-in-part of an application Ser. No. 143,547 filed on May 14, 1971, now abandoned.

From the technical point of view, this application is closely related to an application Ser. No. 472,925 filed on June 5, 1974 by this applicant through his Patent Attorney as a continuation-in-part of the now abandoned application Ser. No. 369,562 mentioned above.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of modular building construction in which building modules are manufactured in an assembly-line process in the field or in the factory, and thus fully precompleted with all trades integrated to the largest possible extent, building modules are assembled into the form of the building i.e. into a modular cluster.

Particularly, this invention relates to construction techniques employing structurally self-supporting modules of which the structural enclosure is made of flat reinforced concrete panels. More particularly, this invention belongs to the class of construction techniques employing the "stack-bond" fashion of modular assembly, i.e. modules related horizontally wall to wall and front end to back end, and vertically floor panel to ceiling panel.

2. Description of the Prior Art

This invention has found its antecedence in the related invention of this applicant filed under the title "Coordinated Modular Building Construction" as mentioned in the preceding chapter. It represents its preferred embodiment with respect to the problem of the construction of doubled walls and doubled floor structures.

The problem of the duplicity of the structure, which is inherent to any modular technique using fully, or partly the assembly mode described before, is well known in the technical society in the world today and it is described in the literature under an inaccurate term "The Problem of the Structural Redundancy." It is generally believed, that the mentioned problem is detrimental to any modular construction employing such "redundant" structural concept.

This applicant submits, that such standpoint is narrow and superficial and contends, that successful solution can be found by a thorough scientific exploration of the problem in it, complexity. The economical analysis indicates, that the costs of the structure performed in accordance with this invention do not exceede the cost of the conventional construction technique, thus offering substantial savings achieved through the advantage of modular construction with all trades integrated before installation to place.

OBJECT OF THE INVENTION

The primary object of this invention is to confirm the economical feasibility of the concept described in the preceding invention submitted under the title Coordinated Modular Building Construction, thus achieving all objects described there.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan of the building structure consisting of **3** bays, illustrating its division into structural modules and modular segments as described in the antecedent invention submitted under the title: "Coordinated Modular Building Construction."

FIG. **2** is a schematic longitudinal sectional view of the plan shown in FIG. **1.**

FIG. **3** is a schematic transversal sectional view of the plan shown in FIG. **1.**

FIG. **4** is an enlarged plan section of the encircled portion "B" of the FIG. **1,** illustrating the "doubled-wall" structure.

FIG. **5** is an enlarged fragmentary section of the encircled portion of the FIG. **8,** cut at sectional line II of FIG. **4.**

FIG. **6** is an enlarged fragmentary section of the encircled portion of the FIG. **9,** cut at sectional line IV of FIG. **4.**

FIG. **7** is an enlarged plan section of the encircled portion A of the FIG. **1,** illustrating the "simple wall" structure.

FIG. **8** is an enlarged vertical sectional view of the encircled portion D of the FIG. **2,** cut at sectional line II of FIG. **4.**

FIG. **9** is an enlarged vertical sectional view of the encircled portion D of the FIG. **2,** cut at sectional line IV of FIG. **4.**

FIG. **10** is an enlarged vertical sectional view of the encircled portion D of the FIG. **2,** cut at sectional line III of FIG. **4.**

FIG. **11** is an enlarged fragmentary section of the encircled portion of the FIG. **10,** as if cut at sectional line I of FIG. **4.**

FIG. **12** is an enlarged vertical sectional view of the encircled portion C of the FIG. **2,** cut at sectional line III of FIG. **7,** illustrating the "simple-wall" structure.

FIG. **13** is an enlarged vertical sectional view of the encircled portion F of the FIG. **3,** illustrating the "doubled-floor" structure.

FIG. **14** is an enlarged vertical sectional view of the encircled portion G indicated in FIG. **3,** illustrating the simple- and doubled floor structure.

FIG. **15** is an alternate of the lower portion of FIG. **14.**

FIG. **16** is an enlarged vertical sectional view of the encircled portion H indicated in FIG. **3,** illustrating the simple- and doubled floor structure.

FIG. **17** is a schematic isometrical view of the typical structural module, partly exploded, illustrating its disassembly into structural components.

FIG. **18** is a schematic isometrical view of the wall panel in its alternative form with one stiffenning rim at bottom.

FIG. **19** is a fragmentary vertical section through the portion of the wall panel at the top showing the embedded pipe with the lifting nut welded inside.

SUMMARY OF THE INVENTION

As mentioned before, this invention relates to modular construction techniques employing self-supporting modules of which the structure is made of reinforced concrete, and such modules are assembled in what has been denoted as the "stack-bond" fashion. This particular invention deals with the very critical consequence of such a mode of assembly, namely with the problem of the doubled wall structure and the doubled floor structure.

More specifically, this invention deals with particular features of the concept disclosed in the closely related invention cited before.

Modular structure, therefore, recognizes coordinating dimensions denoted as the modular height, modular width, and modular depth expressed in multiples denoted as the segmental depth.

Modular structure is constructed of components - flat panels - assembled in an assembly line process with the assistance of a special mechanical apparatus denoted as the mechanical jig. Advantages of such a method are explained in the above cited invention.

Connecting means needed for the structural interconnection of modules are integrated within modular structure and their position governed by the coordinating system described in the cited related invention.

Congruent horizontal structural components, i.e. floor- and ceiling panels of adjacent modules, are combined by a laminating process during the modular assembly on site into one structural unit denoted as the doubled floor structure.

Structural components are designed substantially in a ribbed slab shape which offers following advantages:

1. The shape reduces the weight of the structure and the quantity of concrete mixture.

2. The shape lends itself to the most advanced method of manufacture of flat panels known today, i.e. to the method of hydraulic pressing.

3. Structural components, when combined into a doubled structure, create a cellular sectional profile which offers very conveniently a space for the distribution of mechanical equipment within the modular structure, such as specifically the electrical-signal conduits, thus eliminating the inconveniency of the embedment of such an equipment during a process of the manufacture of panels.

In order to facilitate the distribution of conduits between horizontal and vertical components, flutes of the ribbed-slab structure are generally aligned.

Vertical pipes embedded in wall panels and vertical reinforcement bars are both used advantageously for vertical reinforcement of the structure and as well as dowels needed for the interconnection of components during the process of manufacture of modules. Moreover, lifting nuts welded inside pipes at the top, are used for the purpose of the attachment of the lifting frame.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In order to simplify the matter, the invention deals only with the structural aspects of the construction of the building. It is to be understood, that the structural enclosure of the building module, denoted as the modular structure, has to be complemented with all other parts of the building to become the building module, which then constitutes the particular portion of the modular cluster, which is the substantial portion of the total building.

The applicability of the invention is demonstrated here on a simple example of a building section consisting of 3 bays and 3 habitable stories. Openings for stairwells, elevator shafts, plumbing chases, doors, windows, etc., the exterior enclosure of modules, balconies, terraces, roof parapets and similar features are not illustrated.

The coordinating system applied here in accordance with the related invention cited before introduces coordinating dimensions denoted as:

a. the modular height - MH - (FIGS. **2,3,8-10,17**) which is eventually specified as the bottom-, intermediate-, top- modular height - BMH, IMH, TMH;

b. the modular width - MW - (FIGS. **1,2,17**);

c. the segmental depth - SD - of which a certain multiplicity, not less than 2×SD, constitutes the depth of the module (FIGS. **1,3,4,7,13-17**);

d. the modular depth - MD - (FIGS. **3,15,17**).

The coordinating system governs also the disposition of connecting means, in this particular case represented by steel pipes **1** embedded in wall panels at distances D from SD-coordinates and at distances T from MW-coordinates (FIGS. **4,6,7,9,14-17**).

The typical modular structure of an interior-bay - intermediate-story building module is illustrated in FIG. **17.** It consists of two wall panels, a floor slab and a ceiling slab. For structural reasons, as a rule, wall panels are manufactured as a one-piece panel. Horizontal slabs, however, as a rule will be divided in panels of which the width will be determined by the dimensional capacity of the manufacturing method. In most cases, the width of the floor- and ceiling-panel will be equal to SD, some methods will allow for the width equal to 2 × SD, or more.

Wall panels are designed and manufactured substantially in the sectional profile denoted as the ribbed slab. The flat surface is oriented typically toward habitable space, thus a couple of wall panels between adjacent modules creating a doubled wall structure (FIGS. **4,8–10**). In cases of the simple wall structure, typically, flat surface is oriented toward the exterior of the building and the ribbed interior surface is enclosed by panels **3** (FIGS. **7,12**) eventually comprizing a layer of thermal insulation. For structural reasons, any portion of the section may be solid, such as around pipes, door openings, etc. Stiffening rims **5** (FIGS. **10, 12, 17,18**) are provided at both top and bottom (FIG. **17**), or, where manufacturing method does not lend itself readily to creation of both rims, such as the method of pouring in vertical batteries, the stiffening rim is provided only at the bottom of the wall panel (FIG. **18**). Rims provide for larger bearing area and facilitate the application of the grout, so that the process of grouting can eventually be automated. Openings are located typically within SD distance which offers the advantage of uninterrupted vertical interconnection of the modular structure. Reinforcement bars **2** and pipes **1,** both protruding at top and bottom of wall panels, function as vertical reinforcement of the building structure and simultaneously as dowels needed for the interconnection of modular structure. In addition, pipes with lifting nuts **20** (FIG. **19**) welded near the top serve as connecting means for the structural interconnection of

modules and simultaneously for the attachment of the lifting frame.

Floor and ceiling panels are similarly designed and manufactured in the sectional profile of a ribbed slab with flutes generally aligned with flutes of wall panels. Stiffening rims 4 (FIGS. 8,12,17) are provided at both wall ends in order to complete the wall panel for its final function as the vertical structural element. Holes 6, 7 (FIGS. 5,6,17) are provided at both rims, matching the position of pipes 1 and bars 2 of wall panels. In cases, where manufacturing method cannot produce stiffenning rims, such as the method of extrusion, the volume of rims is created by an additional fill 19 (FIG. 17) during the manufacturing process, or during the process of the assembly of the modular structure in the assembly jig.

The structural interconnection of the modular structure performed in the process assisted by the assembly jig, is secured by the adhesion of the epoxy grout 17 (FIGS. 5,6,10,12) applied on contacting surfaces between components, and by the bond between pipes and bars and the grout filling holes 6,7 (FIGS. 5,6).

Electrical-signal raceways are distributed within modular structure in spaces provided by flutes in all panels connected by notches 12 in floor and ceiling panels (FIGS. 13,17) and notches 13 in wall panels (FIGS. 10,12,17); by grooves 10 (FIGS. 11, 17) in ceiling panels; by specially shaped holes 8 (FIGS. 11,17) in ceiling panels; and, where applicable, by vertical holes 9 (FIGS. 11,17) in the top stiffenning rim of wall panels.

The process of the lamination of the combined floor- and ceiling panels into one doubled floor structure is accomplished during the process of the assembly of building modules in the following procedure:

1. Stopping strips 18 (FIGS. 12,13) are applied at the perimeter of the building structure on the top of modules at each story in order to prevent the grout 16 (FIGS. 5,6,8-10,12) from oozing out to the exterior.

2. Grout of suitable properties, such as the epoxy grout, is applied on the top surface of rims 4 of the ceiling panel and also within an adequate length on the top surface of ribs of ceiling panels.

3. Spacers of suitable material and the thickness equal to that of the connecting plates (if such hardware is used for the horizontal interconnection of modules) are distributed in the layer of the grout spread at wall ends.

4. The gravity of the upper module installed, distributes the grout uniformly, while spacers secure the necessary presence of the grout at any point of lamination.

Thermal insulation of floor and ceiling panels which are exposed to the exterior climate can be provided by two modes:

a. Exposed portions of horizontal slabs are made of concrete with the proper insulative capacity. If needed, an additional insulation 11 may be provided (FIGS. 14,16).

b. Conventional concrete is used and rigid thermal insulation is provided on top of such slab (FIG. 15). In the case of the projected slab, however, the exposed slab portion must be depressed in order to level the top surfaces of adjacent floor panels. The bottom floor panel (FIG. 16) usually does not require insulation because of the heated space below.

Electrical-signal raceways are installed during the process of the assembly and manufacture of building modules. Each module functions as a separately prewired unit. The electrical-signal interconnection between building modules is provided by special fittings 15 (FIGS. 10,13,16,17) applied during the process of the assembly of the modular cluster on site. Such fittings are placed in accordance with particular conditions between junction boxes 14 (FIGS. 10,13,16,17), in grooves 10 (FIGS. 11,17), and notches 12 (FIGS. 13,17).

Having so described my invention, I claim:

1. A modular structure assembled of a plurality of self-supporting modules made of reinforced concrete, each module having a form of a rectangular tube defined by two walls, a floor slab and a ceiling slab, said structure being composed in a "wall beside wall - front end to back end - floor slab over ceiling slab" fashion so that adjacent walls create a doubled wall structure and adjacent floor-and ceiling slabs create a doubled floor structure;

each said module being imaginarily divided into several equal tubular segments of which the depth is denoted as a segmental depth - SD - ;

said modules being composed of structurally interconnected components - walls manufactured as one-piece panels, floor- and ceiling slabs consisting of one or several panels manufactured in widths which are multiples of SD;

said components being manufactured substantially as a ribbed slab with one surface flat and opposite surface fluted at least one flute of ceiling slab aligned with a corresponding flute of walls;

solid rims being provided at both wall ends in said floor- and ceiling panels;

solid rims being provided at bottom of said wall panels;

at least two vertical pipes - each provided with a lifting nut welded at top - being embedded in each said wall panel and positioned at uniform distance T from outer side of wall panel and at uniform distance D from wall end or SD line, respectively;

vertical reinforcing bars being embedded in each wall panel and positioned generally on rib- and wall thickness centers;

both said pipes and bars protruding at wall top and wall bottom to the extent of the thickness of the corresponding floor panel or ceiling panel, such protrusions serving as dowels grouted in holes provided in floor panels and ceiling panels in corresponding positions.

2. A modular structure as recited in claim 1, including solid rim provided at top of wall panel, said rim being penetrated by at least one vertical aperture positioned on center of wall flute.

3. In a modular structure as recited in claim 1,

adjacent floor panels and ceiling panels being combined during the process of assembly of modular cluster by a grout of suitable properties applied between contacting surfaces of solid rims provided at wall ends;

stops of suitable material being applied at top edge of modules around building perimeter to prevent spreading of grout;

spacers of suitable material being applied within grout layer at adequate distances, to secure the presence of grout at all points of lamination.

4. In a modular structure as recited in claim 1,

the ribbed slab shape of panels being such, that flutes are of a substantially oval sectional profile.

5. In a modular structure as recited in claim **1,** the distribution of electrical-signal raceways being conducted in flutes of wall panels and ceiling panels interconnected by notches provided in ribs of wall panels and ceiling panels;

further being conducted in grooves and apertures provided in solid rims of ceiling panel;

the linkage of electrical-signal raceways between adjacent modules being provided by fittings having the form of a loop and interconnecting corresponding junction boxes of adjacent ceiling panels.

6. In a modular structure as recited in claim **2,** the distribution of electrical-signal conduits being conducted in vertical aperture of the rim at top of wall panel.

* * * * *