MODULAR UNITS, BUILDINGS AND SYSTEMS

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ABSTRACT

Modular and other units of concrete or similar matter, generally precast for various constructions and buildings, and housing. The modular units have portions which are adapted to hold slabs to link two consecutive modules, the modules can be stacked vertically, and the system comprising such modules and slabs can be extended laterally and longitudinally to form a great variety of buildings.

11 Claims, 29 Drawing Figures
MODULAR UNITS, BUILDINGS AND SYSTEMS

The fundamental need for housing presents a continuous challenge to construction and building technology in the United States and abroad. Modular construction involves modules — generally preconstructed or precast — for living spaces which are arranged in accordance with the desired architectural design. To date, various systems involving modular construction have been offered. A particularly attractive material for modular construction is concrete, because of its low cost, fireproof and permanent qualities. The concrete sections can be manufactured by repetitive operations by relatively unskilled labor. Yet, the weight of the concrete, with its attendant transportation problems, and the need for heavy handling equipment are serious drawbacks of the building modular made of concrete.

Habitat in Montreal, Canada illustrates a recent factory-produced dwelling module in a multi-story structure in which the modules are constructed of precast concrete. Yet the economics of the system have been shown to be prohibitive. The recent patent literature discloses various modular building constructions. U.S. Pat. No. 3,388,512 discloses a structure made up of linked tower cores and living units: U.S. Pat. No. 3,395,502 shows central column sections carrying occupiable modular spaces; U.S. Pat. No. 3,430,398 discloses modular, box-shaped units vertically stacked in checkerboard overlapping, off-set relationship to form a building; U.S. Pat. No. 3,455,075 proposes modular building unit having the shape of a right parallelepiped which is mounted on vertical columns; U.S. Pat. No. 3,462,908 discloses a method for erecting precast multi-story building sections; and Saarinen in U.S. Pat. No. 3,468,081 discloses precast elements provided with pitched tooting outside for joining room units into a strong construction. Further illustrative patents include U.S. Pat. Nos. 3,299,588; 3,226,889; 3,331,170; 3,377,755; 3,416,273; 3,442,056; and 3,474,582, which relate to prefabricated building structures including of the modular type. A selective review of the state of the art is also available as Research Report No. 5, Center for Housing and Environmental Studies, Cornell University, Ithaca, N.Y., A REPORT ON THE FACTORY PRODUCED DWELLING MODULE, THE NEW BUILDING BLOCK, 1968. Also see the special report on SYSTEMS BUILDING in Engineering News Record, October, 1969.

Yet, these conventional systems present serious shortcomings and difficulties. An urgent, as yet unfilled, need exists for a modular building system of precast concrete or like material which is adaptable, economical, and which lends itself to efficient, low-cost construction on varied topography, and yet satisfies and conforms to engineering and modern building codes and regulations. The components and system of this invention provide a significant advance in this field towards ideal modern building requirements.

An object of this invention is to provide a new, highly versatile building block element which is easily manufactured, transported, and erected in place in a building.

Another object is to provide a building modular unit which is self-sustaining when erected on location without use of additional temporary structures.

Another object is to provide a building system wherein the building module is adapted to be combined with other units, especially modules for expansion laterally and vertically, and along the longitudinal axis of the module in conjunction with other units, especially with slabs to form a great variety of building configurations.

Another object is to provide modules which, when coupled with other modules vertically or linked for longitudinal extension of the building, form a stable, self-sustaining structure.

Another important object is to provide a new module which, when laterally extended, forms a one or multi-story building in which the floor or ceiling areas exceed the floor or ceiling areas provided by the modules.

Another object is to provide a building wherein the lateral extensions are provided by a bifunctional system of multiplicity of modules linked by multiplicity of slabs.

Another object is to provide a system of building elements, principally modules and slabs which can be suitably assembled at considerable savings of costs.

A further object of the invention is to provide a new module and connecting slabs which can be combined with more traditional building elements into a great variety of building patterns.

A further object of the invention is to provide a building which can be constructed on grounds of varying elevation, thereby making best use of land.

This recitation of the objects of the invention does not purport to be all inclusive, and other objects will become evident from the description of the invention.

The various objects, features, and numerous embodiments with their attendant advantages of the present invention will become more apparent from the following description of various embodiments, some preferred, of the invention when considered in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view showing a modular unit of the invention;

FIG. 2 is a perspective view of two modular units linked by a concrete slab, thereby forming a basic building unit of the invention;

FIG. 3 is a further perspective view of two laterally adjoining basic building units;

FIG. 4 is a perspective view of the modular unit provided with coupling members for vertical stacking of the modular units in accordance with the invention;

FIG. 5A is a vertical longitudinal section view through a leg member of the modular unit showing a recess and openings therefor in the leg;

FIG. 5B is a vertical transverse section view through the leg member showing the recess and openings therefor at the side of the leg;

FIG. 6A is a view of the leg member similar to that of FIG. 5A, also illustrating a connecting member above the leg on the top member of the modular unit;

FIG. 6B is a similar view to FIG. 5B, also showing a connecting member;

FIGS. 7A and 7B are perspective views of a building constructed of two laterally adjoining modular units of the invention; one in which the modules are offset relative to each other and is anchored on a platform.

FIG. 8 is a perspective view of a two-story building of two pairs of laterally adjoining modular units of the invention stacked onto each other;
FIGS. 9A and 9B are perspective views of a floor of modular units of the invention; FIG. 10 is a perspective view of a multi-story building of the invention composed of laterally adjoining and linked modular units; FIG. 11 is a schematic front view of a building of the invention built on terrain of varying elevation; FIG. 12 is two views (one in perspective and the other a top view) of another embodiment of the modular unit of the invention in which the legs of the unit are not parallel to the transverse axial plane of the module; FIG. 13 is a perspective view of another modification of the modular unit wherein the ledges on the legs extend beyond the wall members to provide a cantilever effect; FIG. 14 is a perspective view of a one-story building of a pair of modular units combined with build-sections having only one leg; FIG. 15 is a similar perspective view of a two-story building; FIG. 16 is a perspective view of a building comprising modular units stacked in combination with other building sections providing multi-story and varying floor and ceiling levels; FIGS. 17, 18 and 19 illustrate further embodiments of the modular unit of the invention, especially different aspects of ledges and legs; FIGS. 20 and 21 are vertical longitudinal section views illustrating means for connecting adjoining modules with their leg members aligned; FIGS. 22A and 22B illustrate in perspective another embodiment of the modules of the invention wherein at least one of the legs is not in a plane substantially parallel to the plane of the top of the module but at an angle thereto; FIGS. 23 and 24 illustrate in perspective further embodiments of the modules wherein the top of the module has curved sides and, in another embodiment, the legs thereof are curved.

Referring first to FIG. 1, there is illustrated a modular unit 1 of the invention having a top member 2; leg members 3 and 4, respectively, are provided with ledges 5 and 6 integral therewith, having surfaces 7 and 8 adapted for bearing or supporting a slab. The slab is positioned, as shown in FIG. 2, on ledges 5 and 6 which support it in cooperation with sides 10 and 11 of the members 3 and 4.

As is illustrated in FIG. 2, the module system of the invention is suitable for longitudinal expansion along the closed ends of the module by repeating modular units and linking two of such consecutive units with a slab in unlimited variations.

FIG. 3 illustrates a one floor building formed with the two pairs of modular units 12 and 13, and 14 and 15 linked by slabs 16 and 17, the modules abutting at their open ends, the respective longitudinal axes being parallel.

It is a significant aspect of the invention that the modular unit, from the time of casting, is a structurally rigid, self-sustaining unit which is easily transported and assembled, and which is readily expanded laterally and along its longitudinal axis in any pattern or configuration by means of one or more linking slabs, and which may recur only a frictional connection of the slab on the ledges in cooperation with the sides of the legs. A precast slab is conveniently inserted or deposited onto the ledges into the space between two modular units.

The vertical stacking of the modular units is accomplished, as shown in FIGS. 4, 5A and 5B, 6A and 6B, wherein 18 is coupling male members consisting of a loop or bend material 19 permanently set in a concrete rib 20. The modular unit which is stacked onto the unit positioned below is provided, as shown in FIGS. 5A, 5B, 6A and 6B, with a recess 21 within the lower portion of the leg members of the unit. The configuration and depth of recess 21 is adapted to receive loop element 19 and rib 20 in a snugly fitting relationship. Openings 22 and 23 provide inlet for a hardenable material which is pumped therethrough into recess 21; opening 23 provides a convenient outlet which serves as a measure for determining when recess 21 is substantially full. It is evident that openings 22 and 23 can be on opposite sides of the leg members.

FIG. 7A illustrates a pair of modular units positioned side by side along their open end, the modules being connected on a base platform 24 positioned on the ground with male coupling members 18 set into recesses 21 provided at the base of the leg. FIG. 7B illustrates a pair of modular units positioned side by side but in off-set relationship, with openings 25 (for windows and for stair connections) at desired locations.

FIG. 8 illustrates a two-story building of the invention constructed by permanent vertical stacking of pairs of modular units 26 on a platform by means of the coupling elements (not shown).

FIGS. 9A and 9B illustrate a lower floor of a series of modular units 27-28 extended both laterally and along their longitudinal axes by linking slabs 29 with a series of coupling male members 18 on the floor ready for assembly of another series of modular units to form a second floor of habitable space.

FIG. 10 illustrates a two-story building composed of pairs of modular units of the invention with slabs 29. To be noted is that modular units 27 and 28 can be considered as terminal or end units of a row, and hence generally only require one ledge on the inner-facing side of the building for support of slabs 29. A similar construction is illustrated in FIGS. 2 and 3. Where an additional row of modular units is linked by slabs to the terminal row, said terminal units are of course provided by ledges as both of their legs, as is represented in FIG. 1.

FIG. 11 illustrates the versatility and adaptability of the modular units of the invention on varying grades of topography, this being achieved by the positioning of ledges 30 on the legs of modules 31 at a different height than the ledges 32 on the legs on modules 33.

FIG. 12 illustrates another embodiment of the modular unit of the invention wherein the major plane of the leg members 3' and 4' is at an angle relative to the transverse axial plane of the top member of the module.

With such modules in combination with their linking slabs, buildings of rounded, circular or elliptical shapes can be constructed.

In FIG. 13 a cantilever effect is achieved by extending ledges 5 and 6 to 5a and 5b beyond the width of the legs, thereby facilitating the construction of balconies or similar projecting structures. Noteworthy, too, in this connection is the fact that the slabs to be positioned on 5a and 5b need not be limited to the width of the module but can be as wide as consistent with architectural requirements. In this aspect of the invention.
tion, a module can be in engagement with one or more slabs, which are positioned at 5, 6, 5a and 6a and such flat elements can be of one piece or not.

FIGS. 14 and 15 illustrate modular units as 27 and 34 (L-shaped), each of which has only one leg 35, bearing ledges 38. Such L-shaped sections of modular units in cooperation with modular units 27 provide additional versatility to the systems of the invention.

FIG. 16 illustrates the numerous variations which can be constructed with a modular unit of the invention, 39 and 42, wherein legs 40 and 44 are longer than legs 41 and 43, and wherein ledges 45 on legs 43 and 44, respectively, are positioned at different heights on the legs respective their base. A window 46 is illustrated in leg 40.

FIGS. 17 and 18 illustrate modules wherein legs 47 are of different shapes and widths, thereby showing the variety of practical constructions. In the module of FIG. 18, the ledge-carrying legs do not extend the full side or length of the top element of the module, wherein the module is defined at the back by element 47a which is shown to, but need not, have a ledge 47b. This type of module is attractive where passages in the direction of the slabs are desired, as between 47 and 47a.

FIG. 19 illustrates further embodiments of the module of the invention, with variations of ledges 48 of slabs 49 and positioning of legs 50 of the module.

FIGS. 20 and 21 illustrate means for connecting a face plate 52 to a module or two modules which have their legs aligned, by means of an adjustable anchor 53, 54 representing a sealant covering and 55 a tubing or hollow space provided during casting of the module for a connecting rod 58 between the two legs 57a and 57b. In this manner, permanent and secure alignment side by side of the modules is provided if deemed necessary.

The angle at which ledges 51 meet the face of legs 50 can be varied as shown in FIGS. 22A and 22B. Where the angle is acute, a slab 49a can be positioned which is inclined upwardly, and where the angle is obtuse, a slab 49b can be positioned to slant downwardly. Where the slabs 49a and 49b are positioned in a plane different from a horizontal plane, they can be made to connect with another module, thereby providing inclined connecting slabs, upwardly or downwardly, between pairs of modules.

FIG. 23 represents another embodiment of modules 61 and 63 of the invention wherein legs 60, 64, and 65 and top element 62 which is positioned on ledges 66 are curved. The convex and concave sides 60 and 64 respecting modules 61 and 63, respectively, carry conforming ledges 66 and 67. Such modules are especially favored for curved buildings or portions thereof.

In FIG. 24 there is illustrated yet another embodiment of module 65 of the invention wherein the ledge-carrying legs are in converging planes and where top element 67 of the module has a concave and convex front and back, 66 and 67, respectively. The concave and convex sides 66 and 67 carry conforming slabs 68 and 69.

It is apparent from the above description that the legs of the module can be curved inwardly or outwardly with respect to the inside of the module; the slabs can have one or more sides which are curved in a convex or concave configuration respective the center of the slab. A slab can therefore be oblong, round, square or rectangular or have any other desired shape combining straight and curved sides. It is apparent from the above that the invention provides a system of modules and slabs which are admirably suited for architecturally and esthetically attractive constructions.

According to a major feature of the invention, the modular unit is provided with a protrusion, haunch, or ledge which is integral with and extends along the width of the exterior face of the leg member. The ledge cooperates with a similarly positioned ledge on the exterior face of the opposite leg member of another modular unit which is in spaced relationship relative to the first mentioned modular unit along their longitudinal axes. Both ledges coat to provide load-bearing surfaces for a slab or flat element. The slab is positioned on the upper or load-bearing surfaces of the ledges in a tight-fitting relationship with the opposite end portions of the face of the leg members which extend from the load-bearing surface of the ledge to the top of the top member. The slab is thus held in substantially gapless engagement between two consecutive modular units.

It is a most noteworthy aspect of the invention that the ledges of a pair of modular units together with the linking slab provide the system of the invention with the flexibility for extension along the longitudinal axes of the modules or along their closed ends, as far as is desired without duplication of floors and walls in adjacent units, as is common in conventional precast concrete systems. This feature provides considerable savings in materials and labor, coupled with a high versatility and adaptability to the needs sought to be fulfilled.

The flat or linking slab between a pair of modules can be at varying elevation relative to the base or height of the leg members. The thickness of the slab can correspond to the distance between the load-bearing or upper surface of the ledge and the top surface of the top element of the module (or that portion of the side of the leg extending upwardly above the ledge to the surface of the top member), thereby providing a continuous coplanar surface between the surface of the top element and that of the slab. If it is desired to construct floors or ceilings which are not in the same horizontal plane but to have a step upward from the top member to the slab, the thickness of the latter exceeds the distance discussed above, whereas if it is desired to have a step downward from the top member to the slab, its thickness will be less than said distance.

In accordance with the invention, the modular unit is provided with a single or a multiplicity of ledges on any one leg member. The ledges can be coextensive with the width of the leg member, or shorter or longer, thereby protruding on both or either side of the leg to provide a cantilever effect thereto. The ledge can be a single continuous ledge or it may be segmented, thereby providing communicative conduits between two floors below and above the slab. These conduits may provide practical access for heating or cooling ducts and electrical connections.

It is noteworthy too that the modular unit of the invention can be of different heights, width, length or span and, moreover, that the linking slabs can be of various sizes too. Thus, even with modules of the same span, a remarkable versatility of building structure is
obtained where slabs of different lengths are used to link the various modules. For further horizontal extension to larger building structures, the modular units of the invention can be assembled with their top member in abutting relationship, so that the longitudinal planar axis of the modules are parallel. The transverse planar axis of two consecutive modules can be coextensive or not, the leg members of the two consecutive modules being aligned, or these legs may be in an off-set relationship relative to each other when this axis of two consecutive modules is not coextensive.

For vertical extension to multi-story buildings, the modular units of the invention are adapted to be vertically stacked one on top of another for vertical construction to multi-story buildings and the lowermost modular unit is adapted to be affixed on a platform, base or footing generally on the ground. Two modular units of the invention can be vertically coupled to form a vertical coupled pair of modules which can be extended in height to any elevation of building desired. The vertical coupling of a pair of modular units is performed by means of at least one coupling or connecting member, hereinafter referred to as the male portion, which comprises a loop member generally shaped as an inverted V or U, the open ends of which are permanently set into a concrete rib. The loop member may be rigid, as when a steel rod, or supple and pliable, as when a steel cable, for instance. The rib is an integral part of and protrudes from the top member of the modular unit. For maximum strength, it is preferably positioned on the top member above the leg in the same vertical longitudinal plane as that of the leg member, and the rib is substantially centered relative to the width of the leg. The modular unit of the invention is provided with as many male coupling members as are desired for rigid connection with another modular unit. Four of such members, a pair on each side of the top member above the legs, generally provide adequate rigid connection with the unit which is set thereon. The unit which is positioned on the top of a base modular unit within its leg members with a recess, or female portion, which is open to the bottom or base of the leg, and which is preferably substantially centered with respect to the width of the leg. The recess is adapted to receive the rigid male coupling member in a coupling relationship. The size and configuration of the rib and of the recess substantially conform to each other so that the coupling member fits into the recess when a modular unit is stacked onto a base modular unit. The recess is provided with one or more openings to either or both sides of the leg to provide for a inlet and outlet. When it is desired to permanently couple two modular units which are stacked onto each other, or a base modular unit on the male coupling members affixed to a suitable footing on the ground, the hardenable mass is pumped into one of the openings until the recess is substantially full, as may be evidenced by outflow at the other opening, and allowed to set into a permanent coupling. A suitable hardenable mass may be cement, grout, plastic material like an epoxy resin, and the like. The lowermost modular unit of the building of the invention can be affixed generally on the ground on a footing, a concrete slab, for instance, which is provided with the male coupling mem-

bers as described above. The modular unit is then placed thereon as discussed above.

It is a highly noteworthy aspect of the invention that, by virtue of the male coupling member and the conforming recess, and prior to the use of the hardenable mass, the modular units can be stacked vertically and maintain static stability during the construction operations and resist horizontal stresses due to the rigid bent and external loads like wind. This is important, since this feature obviates additional support or shoring operations and equipment so common with precast traditional buildings and constructions. Yet in this coupling arrangement the units are in a separable relationship which permits relocation and moving of the modules with respect to each other and other units, if this is desired prior to permanently connecting the modules to each other and/or to the footing member and, for instance, the positioning of the slab member between a pair of modules. The modules thus offer structural and static stability combined with amenability for transport and rearrangement for as long as this is desired.

The male coupling members function, prior to engagement with the recess of the module to be connected, as convenient means for transporting, raising or lowering the modules by suitable cranes and other hooking devices. The position of the male coupling member distributes the lifting stress throughout the entire leg members and therefore does not affect the mechanical integrity of the module.

The modular units of the invention and the linking slabs are suitable for manufacture in a great variety of dimensions. Suitable dimensions range, for instance, from 8 by 8 feet or, when it is desirable that the open space or span of the module be longer, dimensions of the module commonly range from 6 by 10 feet a span to 6 or 8 by 24 feet a span, with any intermediate size as desired. The sizes of the module permit their shipment by conventional vehicles. It is noteworthy that, since three habitable spaces of a building can already be constructed with two modules, horizontally linked by one linking slab, considerable savings in cost and space are obtained in shipment when compared to conventional practices which require three modules for a comparable habitable space.

The dimensions of the other elements of the modules can also readily be cast to suit the desired needs. A module of convenient size consistent with architectural, construction, and good design requirements can have a leg height of 6 to 10 feet, a leg width of 6 to 8 feet, a thickness of 6 to 8 inches, a ledge of a thickness of 6 to 8 inches, a width of 4 to 8 inches, and the distance of the supporting or load-supporting surface of this ledge to the top of the unit can be 4 to 8 inches, this accordingly being the thickness of the linking slab where it is desired that the surface of the slab is a level extension of the top of the module. A room of a size of 24 by 16 feet is readily constructed by assembling in abutting relationship two modules of 8 by 24 feet next to each other with their legs aligned.

The modular units of this invention and their interconnecting slabs can be constructed in a wide variety of materials, such as concrete, plastics, and the like, and techniques best suited to their manufacture, such as prestressing, postessing, skin stressing, stamping, ex-
3,724,141

It is apparent from the above description of the invention that it involves a new construction concept predicated to a significant measure on the dynamic coaction of a three-dimensional building unit, a new module, having certain defined construction attributes, with a uni-dimensional unit, the slab, to give a technically and architecturally meaningful multidimensional building defining habitable spaces.

The above description also brings out that the invention is socially meaningful and has importance in terms of political economy, in addition to its technical advantages. The invention is adapted to reduce the costs of dwellings and to shorten the realization of private and public building programs. An important contribution, too, is the provision by way of construction in accordance with the invention on grounds heretofore considered sub-marginal or marginal because of topography variations. Further, because the system of the invention is compatible with other more conventional precast concrete shapes, its potential use is further expanded and economies realized. In all of these aspects and others apparent from the above description, the invention contributes to the solution of the housing problem prevalent in the world.

I claim:

1. A pair of modular units coupled in vertical relationship, the bottom modular unit having two spaced leg members integrally connected by a top member, at least one of the leg members having a load-bearing ledge which has a surface in a plane substantially parallel to the plane of the top member and is integral with and extends on the outer face of the leg member and said modular unit having a connecting member comprising a loop member permanently set into a rib which is an integral part and protrudes from the top member of the modular unit, and a modular unit positioned above the bottom unit, said modular unit having two spaced leg members integrally connected by a top member, at least one of the leg members having a ledge which is integral with and extends on the outer face of the leg member, at least one leg member of said modular unit defining at least one recess which is open to the bottom of the base of the leg, the connecting member of the bottom modular unit being engaged in the recess of the top modular unit, the modular units being thus vertically stacked in static relationship by means of a hardened mass filling the recess within the leg of the modular unit.

2. The pair of modular units of claim 1 wherein the hardened mass is grout.

3. The pair of coupled modular units of claim 2 wherein each leg member of the bottom modular unit has a load bearing ledge.

4. The pair of coupled modular units of claim 2 wherein each leg member of the modular unit positioned above the bottom unit has a load bearing ledge.

5. The units of claim 1 which are of concrete.

6. The units of claim 1 which are of precace concrete.

7. A method of construction which comprises coupling a first modular unit having two spaced leg members integrally connected by a top member, at least one of the leg members having a ledge which is integral with and extends on the outer face of the leg member and said modular unit having a connecting member comprising a loop member permanently set
3,724,141

11 into a rib which is an integral part and protrudes from the top member of the modular unit with a second modular unit having two spaced leg members integrally connected by a top member, at least one of the leg members having a ledge which is integral with and extends on the outer face of the leg member, at least one leg member of the modular unit defining at least one recess which is open to the bottom of the base of the leg, by fitting the loop member of the first modular unit into the recess of the base of the leg of the second modular unit, thereby mating said two elements and forming a self-sustaining static building which defines a multiplicity of habitable spaces, inserting a hardenable material into the recess of the leg of the modular unit in which the connecting member is positioned and allowing it to harden to form a hardened mass.

12 8. The method of claim 7 wherein the hardened mass is grout.

5 9. The method of claim 7 wherein each leg member has a ledge and a recess and both loop members are fitted into the recess of the base of the leg.

10 10. The method of claim 9 which comprises inserting a hardenable material into the recesses of the legs in which the connecting member is positioned and allowing it to harden.

11 11. The method of claim 10 wherein the hardened material is grout.

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