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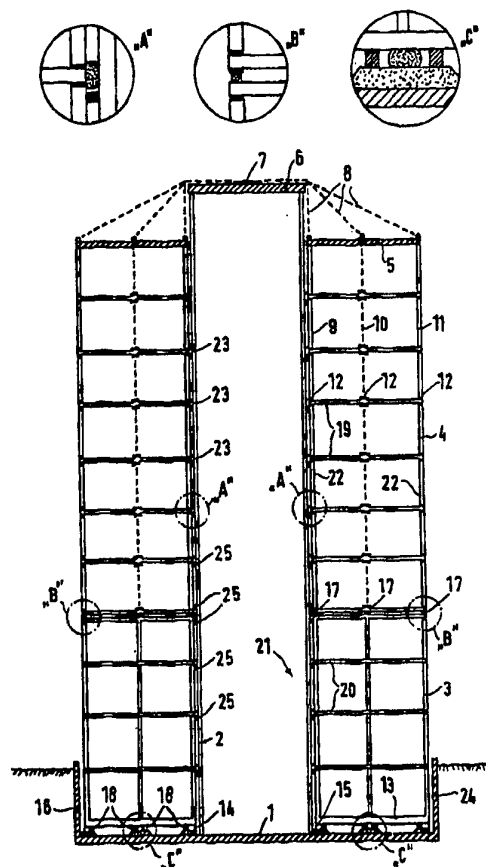
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(54) Title: GLOBAL VIBRO-COMPENSATING STRUCTURAL SYSTEM (GVCS) FOR INDUSTRIALIZED CONSTRUCTION OF
VIBRO-ISOLATED AND SEISMO-RESISTANT BUILDINGS

(57) Abstract

Advanced civil engineering is recently remarkably focused to the application of various isolation devices, located generally at the building base, for solution of problems related to vibro-isolation and construction of earthquake-resistant buildings. However, during the recent development years, the system design in practice is primarily focused on single building cases. The present invention represents a specific global vibro-compensating structural system, application of which provides industrialized construction of effective vibro-isolated and improved seismo-resistant buildings. The invention introduces a new building system created of a single building module, composed of three global structural segments, the first segment (2) representing a vertical ductile building core structure, the second segment (3) representing a lower base-isolated peripheral structure, and the third segment (4) representing a suspended (on the building core structure (2)) upper peripheral structure, and by equipping them with properly incorporated isolation and energy absorption devices (15, 17, 18, 25) at various locations, an improved and optimized building system for construction of vibro-isolated and seismo-resistant buildings is created. The aim of the invention is firstly to introduce a more effective and more safe building system for dynamic loads, secondly to enable industrialized faster and more economical building construction with application of the modular concept of a single unit, and thirdly to achieve flexible in-plane geometry arrangement of the integral building structures, satisfying specific architectural requirements.



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Description

GLOBAL VIBRO-COMPENSATING STRUCTURAL SYSTEM (GVCS)
FOR INDUSTRIALIZED CONSTRUCTION OF VIBRO-ISOLATED AND
5 SEISMO-RESISTANT BUILDINGS

Technical field to which the invention relates

The invention represents adoption of new industrialized building technology
10 for construction of vibro-isolated and seismo-resistant buildings through
implementation of the invented global vibro-compensating structural system
of adaptive building module, favorable for satisfying optimal multi-
objective construction requirements, including improvement of building
seismic safety, achievement of high construction quality by dominant
15 industrialization of the erection process, reduction of construction time,
application of advanced new construction materials by changed loading
actions, elimination of critical and costly construction phases, shortening of
building finalization phases, and effective reduction of total building
construction cost in the earthquake prone areas, areas exposed to artificial
20 vibrations, and in the sites with common ground and environment
conditions.

Background art and assessment thereof

25 To achieve an optimal level of building seismic safety in earthquake
regions and vibro-isolation in areas under permanent vibrations, in recent
years civil engineers are focusing specific research toward establishing
appropriate building design and construction criteria. By introducing in
engineering practice the official seismic design regulations in many
30 countries of the world located in seismic zones, great qualitative
contribution for seismic risk reduction has been made. However,
demonstrated past destructive earthquake effects to modern code-designed

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buildings, expressed in accumulated heavy damages, including partial or total collapse, clearly showed the evident need for development of improved or "intelligent" building structural systems. Besides problems with destructive strong earthquake vibrations, in many cases it is necessary
5 to isolate and control permanent vibrations originated by various artificial sources, such as heavy machines, railways, city sub-ways, etc. in order to satisfy prescribed vibration tolerance criteria and provide optimal serviceability conditions.

10 To solve the specific technical problems mentioned above in the field of civil and earthquake engineering, recently significant research has been devoted to development of various vibration control devices and systems applicable for different civil engineering structures. The existing systems for seismic or vibration control are generally classified in three basic
15 groups: (1) Passive seismic (vibration) control systems based on application of base isolation, energy absorption and other specific devices not requiring external energy supply for their operation, (2) active seismic (vibration) control systems of different types which need external energy to achieve on-line control, and (3) seismic vibration control systems of mixed type.

20 Up to date, application of passive vibration control is mostly achieved on the "single-structure" basis and only for specific structures with application of very sophisticated design procedures.

25 In the case of stiff structures or low rise buildings, application of base isolation is common for vibration control since it directly contributes to avoid resonant effects in the case of local earthquakes. Otherwise, vibration control of tall or multi-story buildings is usually achieved by appropriately distributed specific devices along total building height. In both cases, for
30 some frequency ranges, significant negative effects may be invoked because frequency content of earthquake ground motion can not be accurately predicted in advance. On the other hand, practical application of vibration

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control is considerably restricted due to the necessity to apply complex dynamic analysis techniques and advanced design procedures which are not appreciated in common design practice.

5 The above facts make clear that effective capability of vibration control systems is not sufficiently explored in civil and earthquake engineering practice for vibration-isolation and improved earthquake-protection of modern building structures. To overcome problems with inadequate isolation against permanent site vibrations and/or heavy damages including
10 total collapse of modern buildings in future strong earthquakes, a development of improved structural system possessing additional structural and construction advances is highly needed including: (a) reduction of building construction time, (b) industrialization of the erection process to achieve high quality standards, (c) implementation of new materials with
15 advanced performances, (d) elimination of critical and costly construction phases, (e) simplification of building finalization phases, and (f) effective reduction of total building construction cost. The integral technical problems listed above are considered to be solved by the teaching contained in the characterizing portion of claim 1.

20

Disclosure and advantageous effects of the invention

By adopting the presently disclosed building construction technology based
25 on incorporated global vibro-compensating system (GVCS), which integrates an optimal combination of: (a) effective base vibration isolation system (BVIS) for the lower building part, (b) specific hanging vibration isolation system (HVIS) for the upper building part and (c) adjusted interactive vibration isolation system (IVIS) between two globally separated
30 building peripheral segments, the energy transmitted to the structure or the building excitation intensity can be rapidly reduced including convenient change of the response frequency for the case of actual ground excitation

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originated by strong earthquakes or any other artificial source. This new and entirely integrated global vibro-compensating system (GVCS), together with promoted industrialized construction technology, provides very significant practical advantages compared to existing concepts for construction of vibro-isolated and seismo-resistant buildings primarily expressed in: (1) improved structural safety, (2) effective vibration control by vibro-compensating system, and (3) more economical building construction. In the adopted globally separated structure, vibration response of the lower building part is basically controlled by the base vibration isolation system (BVIS) possessing advantageous capability for vibration control of stiff low-rise structures.

The vibration response of the upper building part is dominantly controlled by the advantageous hanging (suspended) vibration isolation system (HVIS), while the interactive vibration isolation system (IVIS) serves as compensation device to transmit positive effects between the two out-of-phase activated isolation systems into the remaining building part, achieving in general vibration reduction of the integral building, increased safety level under strong earthquakes or effective elimination of unacceptable building oscillations under differently generated permanent or transient ground vibrations.

The significant advantage of this building system is expressed in the possibility of dominant application of the industrialized building construction technology based on in situ assembling of modular prefabricated elements. The main advantages are disposed in the following: (1) simplification of structural design process, (2) reduction of building construction time, (3) achievement of high construction quality, (4) implementation of new materials with advanced performances, (5) elimination of some specific and costly construction phases, (6) simplification of building finalization phases, and (7) reduction of the total building construction cost.

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Finally, by adopting the developed unified building modules (units) it is made possible to create flexible architectural building compositions in both building plane and building elevation

5 The claims 8 to 12 describe the features of the GVCS-building system in a condensed manner. These claims aim like the previous claims at providing a building system, which is resistant to vibrations induced by earthquakes or by any other source and which can be constructed with the application of modern industrialized building construction technologies. Generally, both
10 peripheral structures contain at least one story of the building. In special cases it may also be possible to leave out the lower peripheral structure. This way the peripheral structure suspended from the core structure takes immediate contact with the foundation structure either by means of energy dissipating devices or by means of bearing systems which take up a part of
15 the weight of the peripheral structure.

**Description of at least one way
of carrying out the invention
by reference to the drawings**

20 One way of carrying out the invention is described in details below with reference to drawings 1, 2 and 3 which illustrate only one example of a design of a typical ten story prototype building unit or module, implementing basic structural system in accordance with the invention,
25 characterized primarily by the incorporated global vibro-compensating system (GVCS) for construction of vibro-isolated and seismo-resistant buildings, where:

Fig. 1 shows the typical cross-section of the considered ten story
30 prototype building module (unit) designed with incorporation of global vibro-compensating system (GVCS).

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- Fig. 2 shows a building plane and the distribution of suspension cables and suspension verticals for the upper part of the building peripheral structure, and
- 5 Fig. 3 demonstrates flexible architectural in-plane combinations achieved by separate structural units as typical variation examples for practical applications.

The basic bearing and global vibro-compensating system (GVCS) of the building unit according to the invention is composed of various components with specific functions starting from firstly constructed at appropriate level, the principal foundation structure [1] which is used for stabilization of the central vertical hollow reinforced concrete (RC) building core structure [2], which is somewhat box-like and acts as the principal vertical building stabilizer. Around the building core structure [2] spaced are two separated building peripheral structures [3] and [4] which have square-shaped, ring-like or other convenient section forms. The first segment represents a foundation-supported lower-part of the building peripheral structure [3] through common fixed-base support or preferably through some standard base-isolation system, and the second segment represents a separated suspended upper-part of the building peripheral structure [4], typically made as light-weight construction system. The suspension of the upper-part of the building peripheral structure [4] is provided by the adopted stiff top-peripheral suspension or hanging structure [5] incorporating appropriate joints of top vertical and inclined suspension (bearing) cables [8]. The central hollow core structure [2] is covered by top-central covering structure [6] used for supporting suitably arranged cables network, for example according to Fig. 2, and also used to accommodate the installed top-central joint of the intersecting cables equipped by compensation system [7]. Separate story weights of the upper part of the building peripheral structure [4] are carried in this example by three systems of vertical cables where the first one consists of 8 or any

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other convenient number of vertical cables of the central suspension system [9], denoted by 9-1 to 9-8 in Fig. 2, the second consists of 16 or any other convenient number of vertical cables of the middle suspension system [10], denoted by 10-1 to 10-16 in Fig. 2, and the third one consists of 24 or any other convenient number of vertical cables of the side suspension system [11], denoted by 11-1 to 11-24 in Fig. 2. Each vertical cable actually consists of a single element or of a set of an appropriate number of cables with a smaller diameter and with equal/or different length which are accordingly used to sustain the weight of each separate story by their anchoring into floor structures by adopted floor joints of vertical cables [12]. The lower part of the building peripheral structure [3] rests on a selected base-isolation system [15] spaced between its base support [14] and conveniently designed stiffer supporting floor structure [13].

In the case of a building with planned underground stories, the surrounding ground at the embedded part is supported by an additional ground protection structure [16] which includes side gaps [24] designed in accordance with the prescribed limit of building base displacement amplitudes during its dynamic response under artificial or earthquake induced ground vibratory effects. For more effective control of structural dynamic response the integral system includes three separate energy absorbing systems where the first represents an energy dissipation system [17] installed in the gap between the lower building peripheral structure [3] and the upper building peripheral structures [4], the second represents an energy dissipation system [18] installed at the building base in combination with the base-isolation system [15], and finally the third one represents an energy absorbing system [25] installed in the gap between the building core structure [2] and both building peripheral structures [3] and [4]. In the same gap installed are soft rubber stoppers or other displacement control systems [23] suitable to effectively avoid eventual collision and generation of severe impulsive-type loading during intensive structural vibrations. The floor structures [19] of the suspended stories are preferably made as

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lightweight construction in order to reduce the effective inertial forces, while the floor structures of the remaining lower stories [20] are alternatively constructed applying the same technology or any common floor construction system. To additionally reduce the total weight of the building, applied are preferably light-weight construction systems of the side and partition walls [22] primarily at suspended [4] and optionally at supported building peripheral structure [3]. In the presented building system, the central space of hollow core structure [21] is used for accommodation of vertical and horizontal building communication systems, electro-installations, main water supply and sewerage systems, and other types of designed sensitive building systems or equipment.

In accordance with the invention the integral building structures or separate building units (modules) are in practice realized based on adopted dominant industrialization of the erection process which enables designers and constructors to apply a very high automatization level in overall building construction technology and to achieve very significant practical advantages mentioned above.

The invention also includes further upgrading of practical applicability of this building system through adopted modular construction of separate building units, Fig. 1, which provide arrangement of very flexible architectural in-plane combinations of separate structural units as shown in Fig. 3 through several characteristic examples expressed in the form of block units [26], diagonal units [27], independent units [28], and complex units [29].

DESCRIPTION OF BUILDING PRINCIPAL COMPONENTS

1. Principal Foundation Structure of the Building
2. Vertical Box-Type RC ductile Building Core Structure
3. Supported Lower Building Peripheral Structure

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- (Base-fixed or Base-isolated)
4. Suspended Upper Light-Weight Building Peripheral Structure
 5. Top-Peripheral Suspension Structure with Joints of Inclined and Vertical Cables
 - 5 6. Top-Central Covering Structure Supporting Cables Network
 7. Top-Central Joint of Cables with Compensation System
 8. Top Vertical and Inclined Bearing Cables
 9. Vertical Cables of Central Suspension System
(Denoted by 9-1 to 9-8 in Fig. 2)
 - 10 10. Vertical Cables of Middle Suspension System
(Denoted by 10-1 to 10-16 in Fig. 2)
 11. Vertical Cables of Side Suspension System
(Denoted by 11-1 to 11-24 in Fig. 2)
 12. Floor Joints of Vertical Cables
 - 15 13. Supporting Floor of Lower Building Peripheral Structure
 14. Lower Support of Base Isolation System
 15. Base-Isolation System of Lower Building Peripheral Structure
 16. Basement Ground Protection Wall with Side Gap
 17. Energy Dissipation/Absorption System Between Lower and Upper
 - 20 Building Peripheral Structures
 18. Base Energy Dissipation/Absorption System
 19. Floor Structures of Suspended Stories
 20. Floor Structures of Supported Stories
 21. Central Space for Accommodation of (Vertical and Horizontal)
 - 25 Building Communication and Installation Systems
 22. Light-Weight Side and Partition Wall Systems
 23. Displacement Control System Installed Between Vertical Core and Two Peripheral Building Structures
 24. Basement Side-Gap
 - 30 25. Energy Absorbing System Installed Between Vertical Core and two Peripheral Building Structures
 26. Plane Arrangement of Block Units (Fig. 3)

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- 27. Plane Arrangement of Diagonal Units (Fig. 3)
- 28. Plane Arrangement of Independent Units (Fig. 3)
- 29. Plane Arrangement of Complex Units (Fig. 3)

CLAIMS

1. The global vibro-compensating structural system (GVCS) for industrialized construction of vibro-isolated and seismo-resistant buildings represents a specific building system, characterized in that, the single structural unit of a building module (Fig. 1) is composed of three separate global segments: - the first segment [2] representing a vertical hollow ductile building core structure, acting as the principal building module stabilizer (connected directly to the foundation structure [1] by fixed-type-support or alternatively by appropriate hinge-support with a soft layer and made safe against overturning), with inside space [21] for accommodation of the building communication and installation systems; - the second segment [3] representing a lower peripheral structure (constructed commonly or preferably as light-weight structure with light-weight wall [22] and floor structures [20]), resting on the said foundation structure [1] through appropriate base-isolation system [15] and/or damping system [18] fixed below to their special support [14] and above to a stiff base-floor [13], this segment [3] is separated from the basement protection wall [16] by side gap [24], and from the core structure [2] by inner gap for accommodation of appropriate displacement control [23], and energy absorbing system [25]; - the third segment [4] representing an upper light-weight peripheral structure (constructed in-situ or preferably assembled of prefabricated units), suspended from the said core structure [2] by the system of cables [8], [9], [10] and [11] fixed by floor joints [12] to floor structures [19], and separated from the lower supported peripheral structure [3] by gap for accommodation of an energy dissipating system [17], as well as from the core structure [2] by inner gap for accommodation of appropriate displacement control [23] and energy absorbing system [25];
2. GVCS system, as in claim 1, characterized in that, both building peripheral structures contain at least one story each.

3. GVCS system, as in claim 1, characterized in that, the lower peripheral structure [3] is composed of independent stories, separated by appropriate materials for displacement control and sound and heat isolation between them, as well as between the basement and foundation structure [1].

5

4. GVCS system, as in claim 1, characterized in that, the top central covering structure [6] is constructed alternatively in different geometrical forms, preferably in the form of spherical shell adjusted for safe supporting of the said suspension cables [8].

10

5. GVCS system, as in claim 1, characterized in that, the vertical cables [9], [10] and [11] in Fig. 1, carrying the suspended floors, are fixed to the top peripheral suspended structure [5] which itself is suspended by separate cables [8] to the top central covering structure [6] by an appropriate top central joint with compensation system [7].

15

6. GVCS system, as in claim 1, characterized in that, the mass of the suspended top peripheral structure [5] and/or masses of conveniently chosen suspended floor structures [19] is/are used as a counter mass to act on the said vertical ductile building core structure [2] through an appropriate active (intelligent) control system (not indicated) against the excessive bending of the said building core structure [2] in the case of taller buildings and/or modules without the lower peripheral structure [3].

20

7. GVCS system, as in claim 1, characterized in that, the claimed building module (Fig. 1) is used to arrange appropriate building block unit [26], diagonal unit [27], independent unit [28] and complex units [29], shown in Fig. 3, in which case a common intelligent control system serves against the excessive bending of the said building modules.

25

30

8. A vibration-resistant building system, characterized in that, it comprises the following three structural segments:

- a) a vertical building core structure [2], resting on the building foundation [1] by means of a base-isolation [15] and/or damping system [18] and enclosing an appropriate inner space for the accomodation of installation systems of the building and/or appropriate parts of the building floors,
- b) a lower peripheral structure [3] resting on the building foundation [1] and being arranged around the core structure [2] and
- 10 c) an upper peripheral structure [4] suspended from the core structure [2] by a system of cables [8, 9, 10, 11],

whereby the upper peripheral structure [4] is seperated from the lower peripheral structure [3] by a gap, which comprises energy dissipating devices [17] and the peripheral structures [3,4] are seperated from the core structure [2] by an inner gap, which comprises energy absorbing devices [25] and devices [23] for limiting the displacement of the peripheral structures [3,4] relative to the core structure [2].

9. The vibration-resistant building system of claim 8, characterized in that, at least the upper [4] of the peripheral structures [3,4] is composed of lightweight walls [22] and lightweight floor structures [19].

10. The vibration-resistant building system of claim 8, characterized in that, the base-isolation systems [15] and/or damping systems [18] are fixed to supports [14] at their bottom and to a rigid base-floor [13] of the lower peripheral structure [3] at their top.

11. The vibration-resistant building system of claim 8, characterized in that, a basement protection wall [16] is arranged around the basement floors of the lower peripheral structure [3] and seperated from the lower peripheral structure [3] by a side gap [24].

12. A vibration-resistant building system, characterized in that, it comprises the following structural segments:

5 a) a vertical building core structure [2], resting on the building foundation [1] by means of a base-isolation [15] and/or damping system [18] and enclosing an appropriate inner space for the accomodation of installation systems of the building and/or appropriate parts of the building floors,

b) a peripheral structure [4] suspended from the core structure [2] by a system of cables [8, 9, 10, 11],

10 whereby the peripheral structure [4] is seperated from the core structure [2] by an inner gap, which comprises energy absorbing devices [25] and devices [23] for limiting the displacement of the peripheral structure [4] relative to the core structure [2] and

whereby the peripheral structure [4] is seperated from the building foundation [1] by a gap, which comprises energy dissipating devices and/or
15 bearing devices which take up a part of the weight of the peripheral structure [4].

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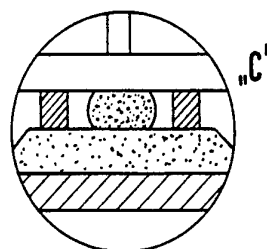
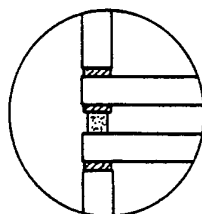
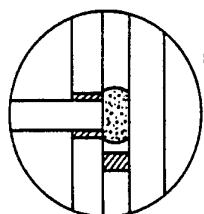
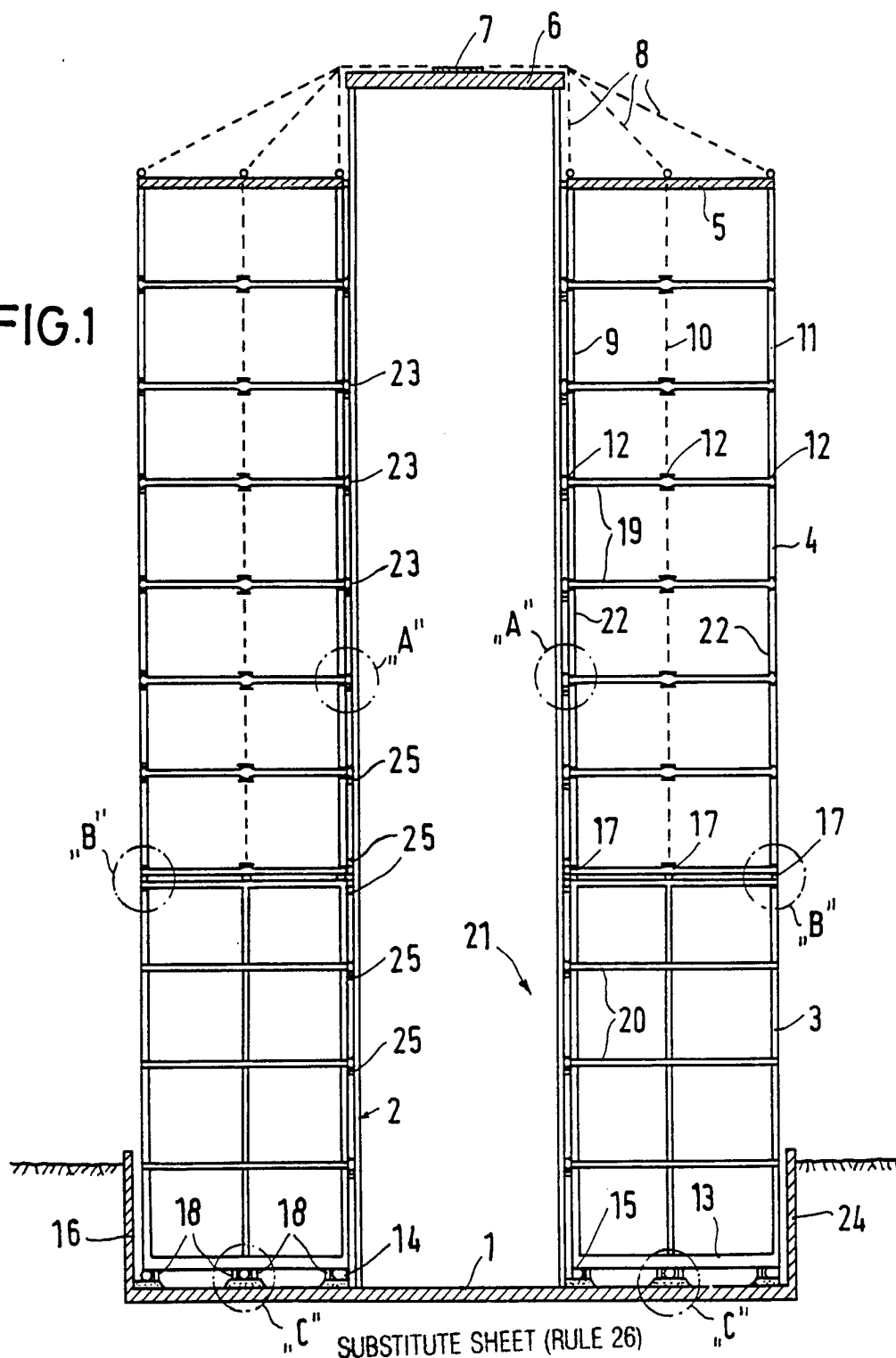


FIG.1



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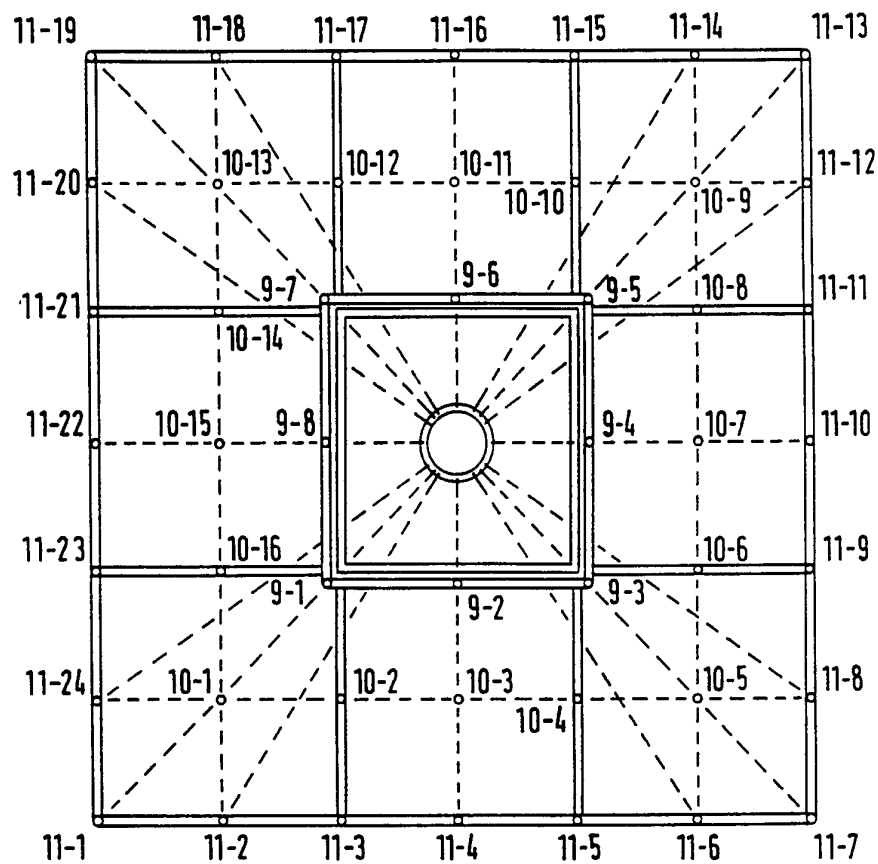


FIG. 2

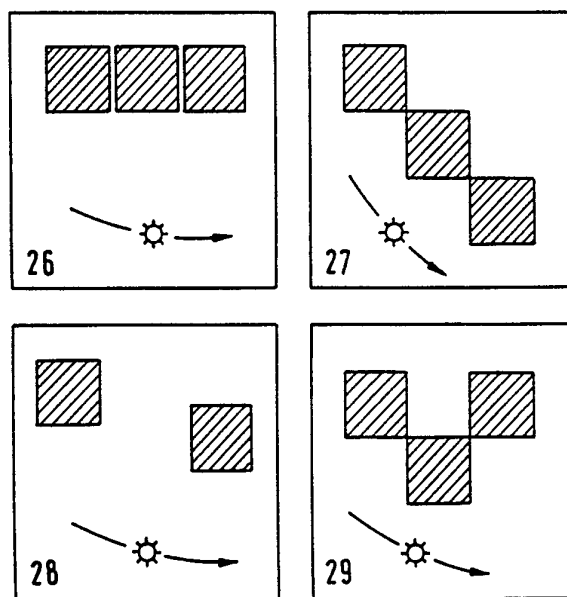


FIG. 3

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INTERNATIONAL SEARCH REPORT

Internat. Application No.
PCT/EP 95/01606

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E04H9/02 E04B1/34

According to International Patent Classification (IPC) or to both national classification and IPC

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IPC 6 E04H E04B

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE-C-33 25 783 (POLENSKY & ZÖLLNER GMBH & CO.) 13 September 1984 see the whole document ---	1
A	GB-A-1 065 281 (SUSPENDED STRUCTURES INCORPORATED) 12 April 1967 see the whole document ---	1
A	DATABASE WPI Week 8448 16 January 1985 Derwent Publications Ltd., London, GB; AN 84-299030 [48] & SU,A,1 033 681 (KAZA CONS METAL REI) , 7 August 1983 see abstract --- -/--	1

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A	US,A,3 396 502 (J. CONTEVITA) 13 August 1968 see the whole document -----	1

INTERNATIONAL SEARCH REPORT

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