

Description

[0001] The object of the present invention is a system for disconnection between horizontal elements and supporting structure of a building.

[0002] This system has been purposely designed as an earthquake-proof system with the aim, therefore, of reducing the seismic response of buildings in which it is applied.

[0003] In addition to the traditional method based on the concept of ductility and providing for constraints fixed to the ground, two different approaches are already known in the current state of aseismatic technology.

[0004] The first known earthquake-proof system is based on seismic insulation and provides for separation of the structure of the building from its foundation by means of devices (in particular seismic insulators) positioned at the base of the building or directly below the structures of the first floor.

[0005] For a better understanding of the problems relating to the known technique, this seismic insulation system is illustrated schematically in figure 3 of this description.

[0006] More in particular, in the case of insulation at the base, a building 20 is disconnected from its foundations 22 by the insertion of devices 21 called seismic insulators, which significantly increase the period of the structure of the building 20, causing it to move like a rigid body.

[0007] The accelerations A_i , the inter-storey deformations D_i and the stress in the supporting structure, the latter represented schematically in figure 4 and indicated by S_i , are clearly reduced with respect to the case of a conventional building 20.

[0008] A system of this kind based on seismic insulators has the following disadvantages, however.

[0009] Firstly, seismic insulator systems generate substantial movements of the entire building 20, a fact which requires the use of adequate joints to avoid complications with the passage of electrical and heating systems etc.

[0010] With this kind of earthquake-proof system it is also difficult to locate the building adjacent to other buildings.

[0011] Furthermore, said systems require a double foundation, with consequent increase in costs of at least 10-15% with respect to the conventional building 20.

[0012] A second known earthquake-proof system is based on energy dissipation.

[0013] This system, illustrated schematically in figure 5, provides for the insertion of energy dissipation devices 23, corresponding to parts of the structure 12 of the building 20 subject to relative movement.

[0014] The operating principle of energy dissipation is as follows: in the parts of the building subject to considerable relative movement during the earthquake, devices 23 are inserted designed to dissipate large amounts

of energy.

[0015] The accelerations A_e , the inter-storey deformations D_e and the stress S_e in the supporting structure of the building, the latter shown schematically in figure 6, are reduced following energy dissipation with respect to a conventional building 20.

[0016] This earthquake-proof system also has disadvantages, however.

[0017] Firstly, the energy dissipation system can be applied only to highly deformable structures.

[0018] Moreover, it requires the use of braces and other cumbersome connecting structures.

[0019] From this brief examination of the known technique, it can be seen that there are still problems with the creation of a simple inexpensive earthquake-proof system for buildings.

[0020] The object of the present invention is therefore to produce a system for disconnection between horizontal elements and supporting structure of a building that solves the above-mentioned problems, optimising use of the materials and at the same time limiting production costs.

[0021] Another object of the present invention is to produce an earthquake-proof system that guarantees greater protection of the objects contained in the building and greater safety of persons.

[0022] A further object of the present invention is to produce an earthquake-proof system that reduces the seismic response of buildings in which it is applied.

[0023] These and other objects are achieved by means of a system for disconnection between horizontal elements and supporting structure of a building, where the above building is connected to its foundations and features a number of horizontal elements, in their turn connected to the above-mentioned supporting structure, characterised by the fact that between said supporting structure and the above-mentioned horizontal elements of said building, at least one flexible dissipation device is inserted in order to reduce the seismic response of the above building.

[0024] According to a preferred embodiment of the invention, the dissipation devices can be similar to a unit consisting of a spring and a dissipation element, in which the spring and the dissipation element are coupled in parallel and are arranged to connect the supporting structure to the related horizontal elements of the building.

[0025] According to a preferred embodiment of the invention, the dissipation devices consist of small natural rubber bearings with high damping capacity, in which the natural rubber is reinforced with steel plates.

[0026] Advantageously, by using the system proposed by the invention, it is not necessary to provide large joints and this means that the building can be located adjacent to other buildings.

[0027] Furthermore, the supporting structure of the building can be constructed with conventional methods and, among other things, thanks to the system proposed

by the invention, no conditions are imposed with regard to the deformability of the structure.

[0028] Another important advantage of the above system is that there is no generation of concentrated stress at particular points of the structure.

[0029] Finally, it should be noted that in order to produce the system proposed by the invention, no large interface elements are required and it is not necessary to alter the architectural appearance of the building.

[0030] The above-mentioned advantages are obtained without significantly increasing the cost of the work and the construction times.

[0031] The devices relating to the system proposed by the invention are inexpensive, not particularly invasive, easy to install and replace and do not require maintenance.

[0032] Further characteristics of the present invention are defined in the other claims.

[0033] Further objects and advantages of the present invention will become clear from the following description and attached drawings, provided as a non-restrictive example, in which:

- figure 1 shows a schematic view of a conventional building;
- figure 2 shows a diagram of the stress S_c on said conventional building;
- figure 3 shows a schematic view of a building with insulation at the base according to the known technique;
- figure 4 shows a diagram of the stress S_i on the building of figure 3;
- figure 5 shows a schematic view of a building provided with a number of energy dissipators, according to a further system belonging to the known technique;
- figure 6 shows a diagram of the stress S_e on the building of figure 5;
- figure 7 shows a schematic view of a building provided with the system for disconnection between horizontal elements and supporting structure, according to the present invention;
- figure 8 shows a diagram of the stress S_d on the building of figure 7;
- figure 9 shows, in an axonometric view, a floor to which the system for disconnection between horizontal elements and supporting structure of a building is applied, according to the present invention;
- figure 10 shows a diagram illustrating the operation of the system proposed by the invention; and
- figure 11 shows a comparative graph of the maximum response of a structure with and without the system proposed by the invention.

[0034] With particular reference to the figures mentioned, the system for disconnection between horizontal elements and supporting structure of a building according to the present invention is indicated overall by refer-

ence number 10.

[0035] It concerns a new system designed to significantly reduce the seismic response of any building 20 by insertion between the supporting structure 12 of the building 20 and its horizontal elements 13 of one or more flexible dissipation devices 14 made in any way.

[0036] For a better understanding of the operation of the system 10, it should be observed that, during an earthquake, the ground imparts to the foundations 22 of the structures accelerations that are amplified as the elevation of the building 20 increases.

[0037] As a result of these accelerations, inside the structures inertial forces are generated, proportional to the local acceleration, which depend on the mass distribution.

[0038] Considering the phenomenon with reference to the structure (and not the ground), we can imagine that it is deformed by a system of distributed forces which, for the sake of simplicity, can be considered concentrated in the largest parts, typically the floors.

[0039] In a conventional building 20, such as the one given as an example in figure 1, said forces increase as the elevation increases (we therefore have $F_{c2} \gg F_{c1}$, where F_{c1} indicates the force on the general i -nth horizontal element).

[0040] Furthermore said forces are almost always all in phase, contributing to serious deformation of the supporting structure, with consequent danger of accidents, even serious or fatal to persons 24, and probable damage or destruction of objects 25.

[0041] It should be noted, incidentally, that the extent of said deformations can contribute to triggering off a sense of panic which can amplify the danger impending on persons 24.

[0042] In a building 20 provided with the system 10 proposed by the present invention, on the other hand, the forces generated in the floors increase more slowly as the elevation increases (we therefore have $F_{d2} > F_{d1}$) and they are not in phase.

[0043] The supporting structure is therefore subject to lower deformation ($D_d \ll D_c$) and, consequently, to less stress ($S_d \ll S_c$).

[0044] Moreover, the accelerations of the floors are clearly lower than those of the conventional case ($A_d \ll A_c$), guaranteeing greater protection of the objects contained 25 and greater comfort for persons 24.

[0045] The effectiveness of the system 10 proposed by the invention has been ascertained both numerically and experimentally on a two-storey metal frame representing a prototypical portion of a real building.

[0046] Initially, the frame was modelled numerically with the finite element method and subjected to non-linear dynamic analysis, designed to assess the seismic response in different ground and intensity conditions.

[0047] In the numerical analyses, various types of systems according to the present invention were considered, parameterizing the mechanical characteristics, in order to assess the best combination of lateral flexi-

bility and energy dissipation of the devices.

[0048] The solution judged to be the most effective and economic consists in the use of small natural rubber bearings with high damping capacity reinforced with steel plates.

[0049] These devices, indicated by reference number 14, are inserted between supporting frame and floor, as can be seen in figure 9, which shows in axonometry a node relating to a supporting frame consisting of a pillar 28 and a beam 29, on which the devices 14 are applied, in their turn connected to the floor 13.

[0050] Furthermore, the devices 14 can be schematised with a spring 26 and a dissipator element 27 coupled in parallel.

[0051] The operating principle of the system 10 proposed by the invention can be briefly expressed as follows: the inertial forces (F) generated during the earthquake in the larger parts of the building 20 are not in phase with each other and therefore result in lower accelerations (A), inter-storey deformations (D) and stress on the supporting structure (S) than those occurring in a conventional building.

[0052] After completing the numerical analysis of the frame and device 14 applied to it, laboratory tests were carried out on the entire structure.

[0053] The tests were performed on a vibrating table, applying to the structure, both in the conventional configuration and in the one provided with system proposed by the invention, real and artificial earthquakes, characteristic of different types of ground, up to the maximum intensity permitted by the vibrating table.

[0054] In all test conditions, the structure protected with the system 10 proposed by the invention always reacted much better than the conventional structure, both in terms of acceleration on the floors 13 and deformations and tensions of the supporting structure 12.

[0055] Figure 11 shows a graph illustrating the experimental comparison between the maximum response of the structure with and without device.

[0056] In particular, the light-coloured histograms represent the response of the building 20 without the devices 14 and the dark-coloured histograms show the response of the building 20 to which the devices 14 were applied.

[0057] Moreover, the various quantities represented in the graph of figure 11 are: Lloy = horizontal deformation of the structure on the first storey in transverse direction; Ai = horizontal acceleration of the structure on the i-nth storey; Agi = horizontal acceleration of the floor on the i-nth storey.

[0058] It is therefore noted that, with application of the devices 14, all the parameters that define the seismic response of the building 20 are clearly reduced.

[0059] The numerical and experimental activity performed on the system proposed by the invention therefore permits formulation of the following conclusions.

[0060] The disconnection devices 14 used demonstrated excellent behaviour during seismic tests on a vi-

brating table, confirming the results obtained during the static qualification tests.

[0061] The innovative constraint proposed was effective right up to large deformations, was easy to install and replace and was inexpensive.

[0062] The experimental tests on the vibrating table highlighted a considerable reduction in acceleration of the horizontal elements 13 (equal to at least 50%) compared to the configuration without devices 14, with logical improvement in comfort and reduction or absence of damage to the partitions, equipment etc.

[0063] Another aspect highlighted by the tests is the considerable reduction in inter-storey deformations of the frame, with consequent further reduction in the probability of damage to the elements contained.

[0064] It should be noted that this contributes to the safety of persons 24 and objects 25.

[0065] Examination of the hysteresis cycles of the device measured during the tests on the vibrating table highlights the great dissipation capacity of the insulation system, confirmed moreover by the reduction in acceleration.

[0066] Incidentally, it should be noted that said fact demonstrates the particular and advantageous performances that can be guaranteed by use of the present invention.

[0067] The description provided clearly illustrates the characteristics of the system for disconnection between horizontal elements and supporting structure of a building, subject of the present invention, and likewise the advantages thereof.

[0068] The final considerations made herebelow serve to further specify said numerous advantages.

[0069] With the introduction of the system 10 proposed by the invention, the disconnected parts of the building behave like inertial masses which, since they do not move in phase, significantly reduce the amplitude of the response of the supporting structure 12 of the building 20 and deform the device, dissipating considerable quantities of energy.

[0070] This means, firstly, that the acceleration, both of the horizontal elements 13 and of the supporting structure 12, is significantly reduced with respect to the configuration without devices.

[0071] Secondly, the deformations of the supporting structure 12, and therefore the stress on the beams and columns, are drastically reduced with respect to the configuration without devices.

[0072] Furthermore, the system 10 proposed by the invention increases safety and provides indirect economic benefits as the building is more likely to survive the earthquake and remain in service, since the seismic load on the supporting structure 12 is reduced, therefore reducing the seismic response.

[0073] Moreover, with the system 10 the inter-storey deformations of the structure are considerably reduced and overall behaviour of the structure improves.

[0074] Finally, damage to the elements contained

(partitions, electrical and heating systems etc., equipment etc.) is reduced or even eliminated and comfort increases in the sense that persons 24 and objects 25 are not thrown from one side to the other of the building 20 during the earthquake.

[0075] At the same earthquake intensity, the safety coefficient of a construction protected by the system proposed by the invention is greater.

[0076] In other words, also this parameter indicates that damage to the structure and elements contained is reduced and the level of comfort is increased.

[0077] Vice versa, at the same safety coefficient, i.e. level of protection, by adopting the system proposed by the invention it is possible to reduce the dimension of the structural elements, with considerable economic saving.

[0078] Finally, it is clear that many variations can be made to the system for disconnection between horizontal elements and supporting structure of a building, subject of the present invention, while remaining within the principles of novelty inherent in the inventive idea.

[0079] In practical implementation of the invention, the materials, forms and dimensions of the details illustrated can be of any type according to requirements and the same may be replaced with other technical equivalents.

Claims

1. System (10) for disconnection between horizontal elements (13) and supporting structure (12) of a building (20), in which the above-mentioned building (20) is connected to its foundations (22) and features a number of horizontal elements (13), in their turn connected to the above-mentioned supporting structure (12), **characterised in that** it provides for insertion between said supporting structure (12) and said horizontal elements (13) of the above-mentioned building (20) of at least one dissipative type flexible device (14) in order to reduce the seismic response of the above-mentioned building (20).
2. System (10), as in claim 1, **characterised in that** the above-mentioned devices (14) are comparable to a unit consisting of a spring (26) and a dissipator element (27), in which the above-mentioned spring (26) and the above-mentioned dissipator element (27) are coupled in parallel, and are arranged so as to connect the above-mentioned supporting structure (12) to the related horizontal elements (13).
3. System (10), as in claim 1, **characterised in that** the above-mentioned devices (14) are inserted between the supporting frame belonging to the above-mentioned supporting structure (12) and the horizontal elements (13) of the above-mentioned building (20).
4. System (10), as in claim 1, **characterised in that** the above-mentioned devices (14) consist of small natural rubber bearings with high damping capacity, in which the above-mentioned natural rubber is reinforced with steel plates.
5. System (10), as in claim 1, **characterised in that** the devices (14) are positioned in such a way that the forces generated in the above-mentioned horizontal elements (13) increase more slowly as elevation from the ground of said horizontal elements (13) increases.
6. System (10), as in claim 5, **characterised in that** the devices (14) are positioned in such a way that the forces generated in the above-mentioned horizontal elements (13) are not in phase with each other, thus producing considerably lower accelerations, inter-storey deformations and stress in the above-mentioned supporting structure (12) than in a conventional building (20).
7. System (10), as in claim 5, **characterised in that** the devices (14) permit reduction of the accelerations in the above-mentioned horizontal elements by at least 50% compared to a traditional building (20).

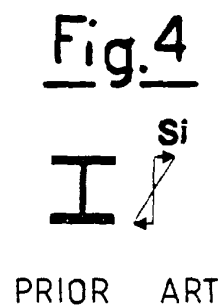
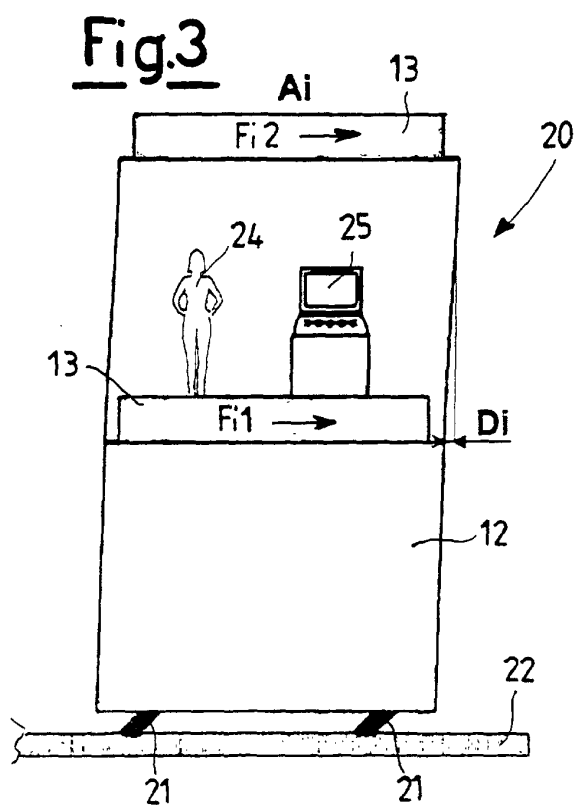
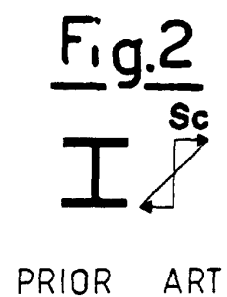
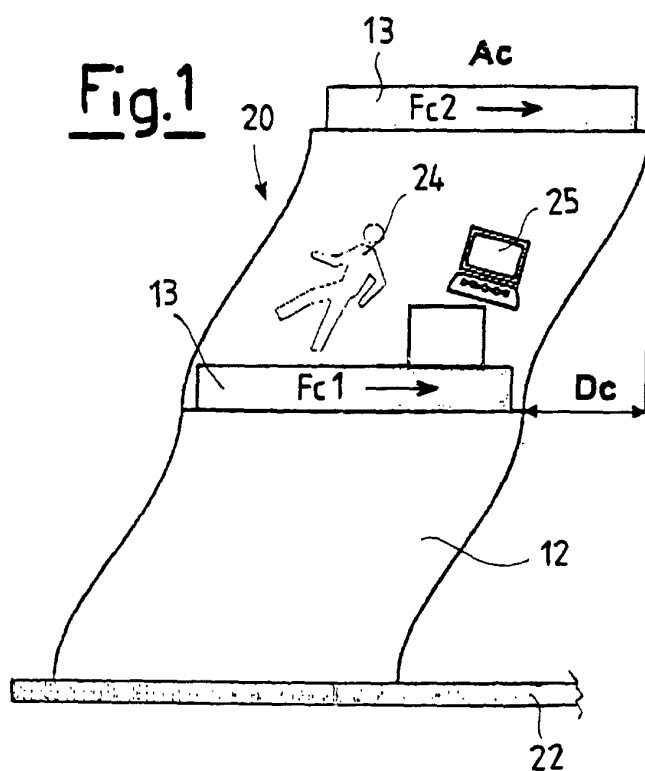


Fig.5

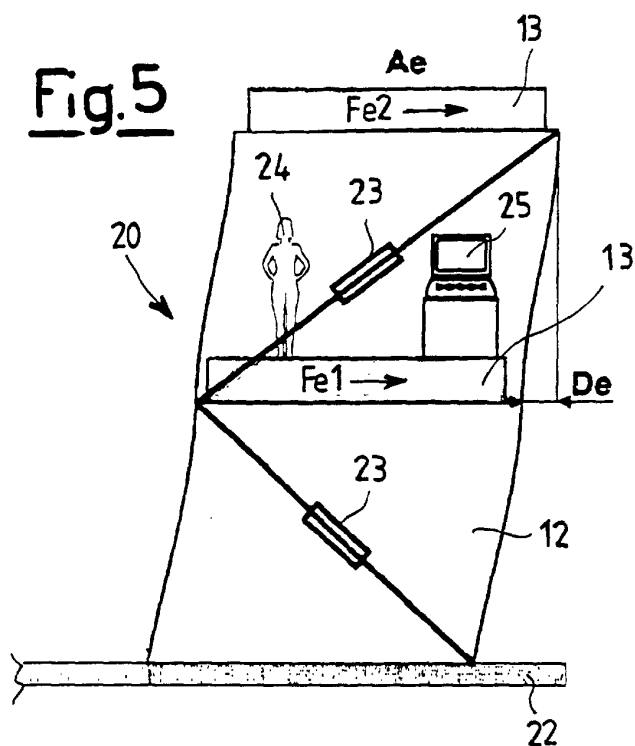


Fig.6

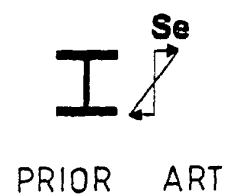


Fig.7

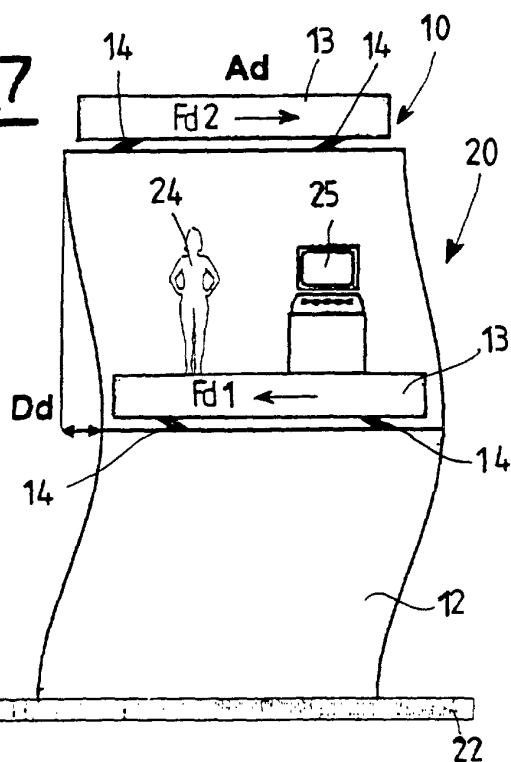


Fig.8



Fig.9

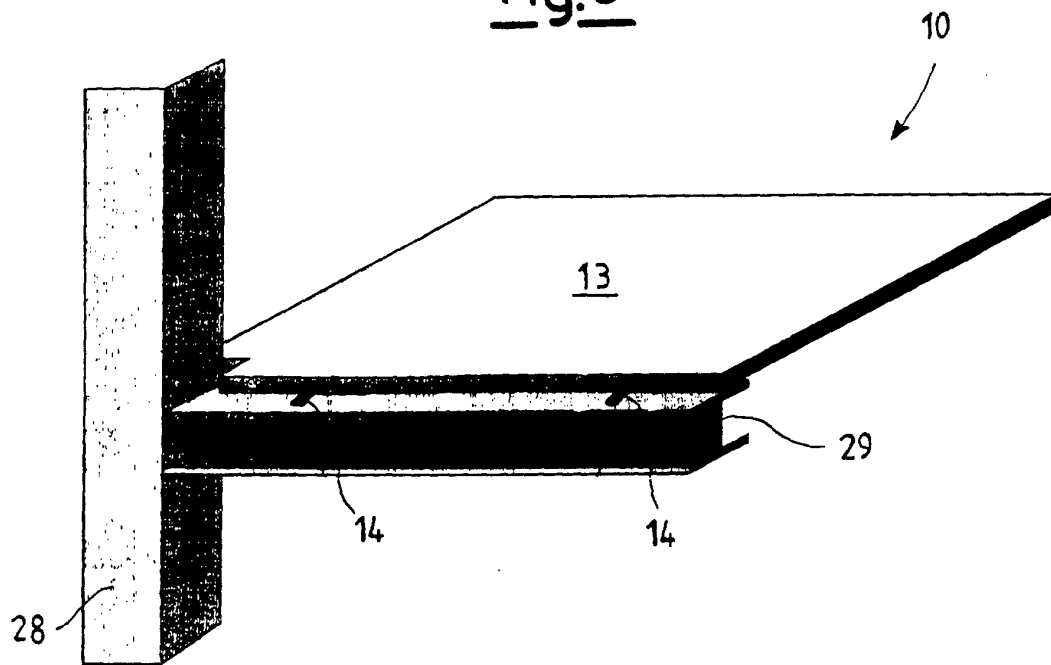


Fig.10

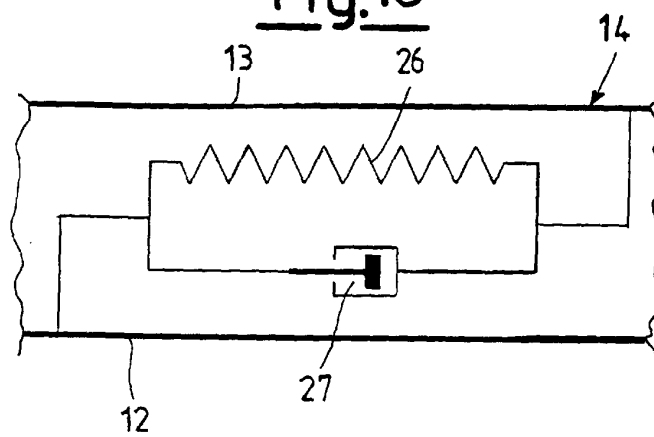
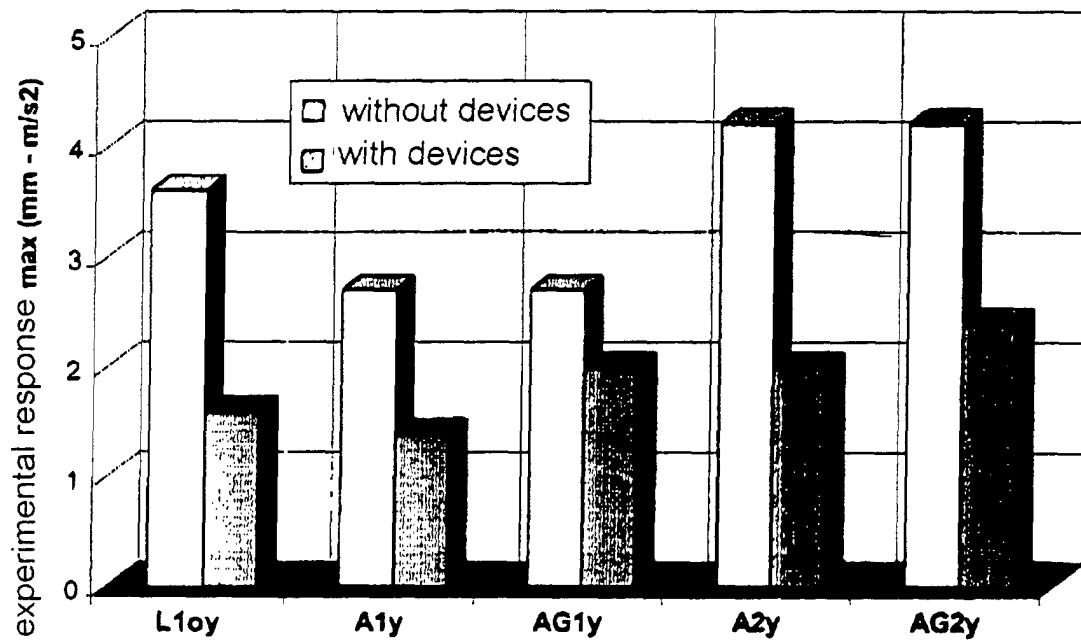


Fig.11



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 01 20 1875

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 09, 30 July 1999 (1999-07-30) -& JP 11 107575 A (JDC CORP), 20 April 1999 (1999-04-20) * abstract; figures * ---	1-7	E04H9/02
X	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 08, 29 August 1997 (1997-08-29) & JP 09 100648 A (OHYAYASHI CORP), 15 April 1997 (1997-04-15) * abstract * -----	1-7	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			E04H
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 July 2001	Examiner Delzor, F
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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25-07-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 11107575 A	20-04-1999	NONE	
JP 09100648 A	15-04-1997	NONE	

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