FIGURE 4 A

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(54) Title: BUILDING, INTEGRATED DAMPING UNIT, AND METHOD OF DAMPING

(57) Abstract: A building that is susceptible to oscillation in response to an externally induced load, comprising a lateral load-resisting structure, a floor plate, and an interface between the lateral load resisting structure and the floor plate. The interface comprises fluid viscous dampers to dissipate energy, provide damping, and control acceleration of the floor plate. The floor plate acts as a damping mass that oscillates in opposition to oscillation of the lateral load resisting structure to dampen the oscillations of the building. The interface further comprises elastic elements, mounted in parallel to the fluid viscous dampers, to resist static load and control movement of the floor plate relative to the lateral load resisting structure. An integrated building damper unit, and a method of providing damping for a building, is also disclosed.
The present invention relates to a building. In particular, the invention relates to a building, especially a high-rise or tall building, comprising a lateral load-resisting support structure, that oscillates in response to an externally induced load caused by wind or a seismic event. An integrated damping unit and a method of providing damping for a building is also disclosed.

Building structures have typically been designed to resist dynamic loads by increasing strength and stiffness. However, with an improved understanding of the dynamic response of structures to external forces, the merits of providing supplementary damping technologies has been recognised, especially in areas of increased seismic activity and for tall or multi-storey buildings where the effects of wind can be significant.

A common supplementary damping approach is to incorporate a Tuned Mass Damper (TMD) at the top of a building. A TMD involves the use of a mass (usually 0.5-1% of the total mass of the building), which is tuned by means of a spring and a damper to the fundamental natural frequency of the building so that the dynamic response of the building is reduced by vibration in resonance of the tuned mass, thereby creating an equal and opposite force, and by dissipating energy in the damper.

Whilst TMDs are widely accepted, they have a number of drawbacks because they occupy valuable space at the top of the building, which also requires additional strengthening to support the mass. Furthermore, a TMD has to be finely tuned to the frequency of the building, so they can typically only resist dominant wind effects rather than seismic loads. TMDs are also sensitive to changes in the properties of the springs, the dampers or the building itself, and have no redundancy. Although multiple forms of TMDs can be used to control excitations at different frequencies, this type of arrangement becomes complex. Furthermore, performance remains restricted by the size of the mass which consequently limits the amount of damping achievable.

Some of these disadvantages have been addressed by the proprietary 'Damped Outrigger' system developed by the Arup group of companies. Arup's system provides damping by dissipating energy in a series of Fluid Viscous Dampers (FVDs) which connect the end of a stiff outrigger, which cantilevers from the core, to a number of
perimeter columns. As the building sways, energy is dissipated due to differential vertical motion that develops at the perimeter columns. By providing several FVDs, it is possible to create a redundant damping system, which leads to a reduction in the static and dynamic wind loads as well as mitigation of seismic loads.

However, the 'Damped Outrigger' solution also suffers from a number of limitations because, in addition to the need for large outrigger walls which occupy several floors, the perimeter columns are connected only by the FVDs to the outrigger. As FVDs cannot resist static loads, they cannot contribute to the lateral stiffness of the building.

As the building core is the sole lateral resisting element, a restriction is placed on the maximum possible height of the building that can realistically be achieved. Versatility in the design is also limited because the building requires an internal core and large, stiff, perimeter columns.

A method and structure for damping movement of buildings, which corresponds to the 'Damped Outrigger' solution described above, is known from US2009/0211179A1.

The present invention seeks to overcome or substantially alleviate the problems referred to above and to provide an improved building, integrated damping unit and a method of providing damping for a building.

According to the invention, there is provided a building that is susceptible to oscillation in response to an externally induced load, comprising a lateral load-resisting structure, a floor plate, and an interface between the lateral load-resisting structure and the floor plate that comprises fluid viscous dampers to dissipate energy, provide damping and control acceleration of the floor plate, the floor plate acting as a damping mass that oscillates in opposition to oscillation of the lateral load-resisting structure to dampen oscillation of the building, wherein the interface further comprises elastic elements, mounted in parallel to the fluid viscous dampers, to resist static load and control movement of the floor plate relative to the lateral load resisting-structure.

The invention recognises the advantages of a TMD but does so without adding supplementary mass to the building. In particular, a proportion of the mass of the building itself is utilized as a damping mass to dampen oscillations of the building.

Whilst a past focus has largely been on preventing building movement, it is the acceleration, rather than the actual movement, of the building which causes concern for
its occupants. Therefore, by allowing a part of the building to move whilst controlling its acceleration using FVDs and elastic elements, that part of the building can be employed as a damping mass without causing discomfort. As the floor plate forms a heavy, integral part, of the building, the inventors have recognised a way in which to mobilize its mass, whilst providing improved levels of damping and static load resistance. The solution requires no additional space and the building does not need to be designed to withstand higher loads that would be needed to support the mass of a conventional TMD. In addition, damping performance can be improved relative to a TMD because the mass of one or more floor plates may be greater than is practically possible compared to the mass of a TMD designed for the same structure.

Each fluid viscous damper and elastic element preferably extends horizontally between the floor plate and the lateral load resisting structure, yet they can also be located transversally or following different alignments depending on the application.

The lateral load-resisting structure may comprise a core. In this case, fluid viscous dampers couple the floor plate to the core to allow lateral movement of the floor plate relative to the core. Similarly, elastic elements may couple the floor plate to the core. The lateral load-resisting structure may comprise a central core. In other embodiments, the lateral load-resisting structure may comprise a plurality of spaced cores and the fluid viscous dampers may then couple the floor plate to each of the plurality of spaced cores.

Each fluid viscous damper may be combined with an elastic member to form an integral damping unit.

The integral damping unit may comprise a first common mount at one end for attachment to the floor plate, and a second common mount at the opposite end for attachment to the lateral load-resisting structure.

The elastic member is preferably a coil spring and the fluid viscous damper may then extend within the coils of the spring.

The integral damping unit may comprise a fluid viscous damper and an elastic member mounted in side-by-side relation.
The floor plate may comprise a floor slab, joists, subflooring, floor finishes and other components that are carried by the slab.

A sliding joint, such as a linear bearing, maybe present between the lateral load-resisting structure and the floor plate to allow lateral movement of the floor plate relative to the lateral load-resisting structure as the elastic elements compress and extend, and fluid viscous dampers stroke. However, in some embodiments a linear bearing may not be necessary. For example, if the elastic elements are steel plates transferring transversal wind loads or if there is an elastic element in that direction, it may be possible to simply maintain a gap between the floor plate and the lateral load-resisting structure.

The building may comprise a support structure to carry gravitational and vertical loads generated by the floor plates. The gravitational and vertical loads may be transferred into the lateral load-resisting structure. Alternatively, the gravitational and vertical loads may be transferred to the foundations of the building directly. The floor plate maybe mounted to the support structure by a sliding joint. The sliding joint may allow movement of the floor plate relative to the sliding joint in all directions.

The building may comprise a first module including a first set of floor plates, and a second module spaced vertically from the first module, the second module comprising a second set of floor plates.

At least some of the floor plates of each of the first and second modules may be coupled to the support structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers. The lowermost floor plate of each of said first and second modules may be immovably fixed to the support structure.

The floor plates of the first module, which are coupled to the support structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers, may be mounted for lateral movement in a direction at right angles to the direction of movement of the floor plates of the second module, which are coupled to the support structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers.
The floor plates of each module may be joined by columns that extend from, and move together with, the floor plates. The columns maybe configured to transfer vertical loads from the floor plates to the support structure, or directly to the foundations of the building. By providing columns that move together with the floor plates in this way, the presence of sliding joints to transfer vertical loads may not be necessary, especially if the columns are close to the lateral load-resisting structure. However, sliding joints may still be necessary in order to transfer transverse loads, unless these loads can be transferred using the elastic element, such as flexible steel plates which act as an elastic element, between the floor plates and the lateral load-resisting structure.

According to another aspect of the invention, there is provided an integrated building damper unit to provide an interface between a lateral load resisting structure and a movable floor plate of a building, the integrated building damper unit comprising a fluid viscous damper and an elastic element mounted in parallel with each other, a first common mount for attachment of one end of the fluid viscous damper and the elastic element to the floor plate, and a second common mount for attachment of the opposite end of the fluid viscous damper and the elastic element to the lateral load-resisting structure.

The elastic member is preferably a coil spring and the fluid viscous damper extends within the coils of the spring.

The fluid viscous damper, and an elastic member, may be mounted in side-by-side relation.

According to another aspect of the invention, there is provided a method of providing damping for a building that is susceptible to oscillations in response to an externally induced load, comprising a lateral load resisting structure and a floor plate, wherein the method comprises coupling the floor plate to the lateral load-resisting structure using:

(a) fluid viscous dampers so that the floor plate acts as a damping mass that oscillates in opposition to oscillations of the lateral load resisting structure to dampen oscillation of the building; and

(b) elastic elements, mounted in parallel to the fluid viscous dampers, to resist static load and control movement of the floor plate relative to the lateral load-resisting structure.
The method of damping does not require tuning the elastic elements to match the natural frequency of the building. Although tuning may be carried out to provide an even greater improvement to the extent to which the building is damped.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIGURE 1 is a visualisation of one possible embodiment of a building that may be constructed in accordance with the invention;

FIGURE 2 is a floor plan of the building as shown in Figure 1 to indicate the position of the trusses;

FIGURE 3 is a schematic cross-section through one module of the building in Figure 1;

FIGURE 4A illustrates a first floor plan of the building shown in Figure 1;

FIGURE 4B illustrates a second floor plan of the building shown in Figure 1;

FIGURE 4C shows an enlarged view of the circled part of the plan view shown in Figure 4A;

FIGURE 5 is a typical plan view of a different type of tower, with central core, showing the movable floor plate with respect to the core;

FIGURE 6 is a typical fluid viscous damper (FVD) that provides the interface between the floor plate and the lateral load-resisting support structure;

FIGURE 7 shows a first embodiment of an integral FVD/elastic element damper unit; and

FIGURE 8 shows a second embodiment of an integral FVD/elastic element damper unit.

With reference to Figure 1, a visualisation of a building according to an embodiment of the invention is shown. The building 1 has a lateral load-resisting structure 2 which, in the illustrated embodiment, is formed by four concrete, L-shaped, vertical communication cores 2a (only two of which are visible in Figure 1), situated at each corner to provide column-free office space on each floor. The building 1 further includes a support structure for transferring gravity and vertical loads from a floor plate 3. The support structure can be steel trusses connecting the four cores 2a, as represented by the arrows marked γ in Figure 2. The trusses provide vertical support for the floor plate 3, or for a set of floor plates 3, as will become apparent from the below.

In the embodiment of Figure 1, the building 1 is divided into five independent and vertically stacked modules 4, each of which cantilever from a central square in two
orthogonal directions. Each module 4 comprises a number of floor plates 3 (ten, as shown in the embodiment of Figures 1 and 3). Each individual floor plate 3 includes structural elements, components, facades, floor finishes and other parts of the building that are carried by that floor plate 3. The floor plates 3 are supported by columns 5 that may run continuously top to bottom through the movable floor plates 3. The columns of each module are supported at the bottom by the trusses T, which transfer the load to the lateral load-resisting structure 2. The lowermost floor plate 3a of each module 4 may be fixed to the truss T so that only the floor plates 3 above the lowermost floor plate 3a can move differentially. The columns 5 play no role on the lateral stability of the floor plates 3 and so allow the floor plates 3 to move freely, as indicated by arrows 'X' in Figure 3.

The vertical cross-section through a module 4 of Figure 3 shows that all the floor plates 3 in one module 4, except for the bottom floor plate 3a, are connected to the lateral load-resisting structure 2 to allow differential movement of the floor plates 3 relative to the cores 2a of the lateral load resisting structure 2 in a lateral direction in the horizontal plane, marked 'X'. In Figure 3, the lateral load resisting structure 2 is represented as fixed points 2b. The connection that allows such differential movement of the floor plates 3 will be described below.

In an optimized arrangement, the top two modules 4 are independently mounted to the support structure 2 with the lowest floor plate 3a of each module 4 being fixed to the trusses T and the remaining floor plates 3 of each module 4 being individually mounted for differential movement relative to the lateral load resisting structure 2. Not all floor plates 3 within a module 4 have to be mounted in this way, and instead of being individually mounted so that each floor plate 3 of one module 4 moves relative to each of the other floor plates 3 of that same module 4, two or more floor plates 3 of the same module 4 may be coupled so that they move together as a single body.

To enable differential movement of each of the floor plates 3 relative to the load-resistant support structure 2, they may each be connected to the lateral load-resisting structure 2 by a sliding joint or bearing 6 or other system to allow relative movement between the floor plates 3 and the load-resistant support structure 2, to transfer transversal wind loads. However, the columns 5 that move together with the floor plates 3 may be sufficient to transfer vertical load to the truss, a fixed or ground floor.
Differential movement of each of the movable floor plates 3 relative to the lateral load resisting structure 2 is controlled by a number of fluid viscous dampers (FVDs) 7. Preferably, a separate fluid viscous damper 7 extends laterally between each floor plate 3 and each of the four communication cores 2a, or other load resisting structure 2, as shown in Figures 4A and 4B, and in the enlarged view of Figure 4C.

A typical FVD 7 is illustrated in Figure 6. A FVD 7 dissipates energy by pushing fluid through an orifice 8 in a piston head 9 to produce a damping pressure which generates a force. The fluid flows through the orifice 8 at high speed as the piston head 9 strokes. When the FVD 7 strokes in compression, fluid flows from a first chamber 10 to a second chamber 11 through the orifice 8. When the FVD 7 strokes in tension, fluid flows from the second chamber 11 to the first chamber 10. The high pressure drop across the orifice 8 produces a pressure differential across the piston head 9, which creates a damping force. A number of factors affect the damper coefficient. For present purposes, the damper coefficient values are relatively small, so the FVD 7 may have a reduced diameter.

By attaching one or more of the floor plates 3 to the support structure 2 with FVDs 7 so that the floor plates 3 can move laterally relative to the support structure 2, oscillation energy is damped in the FVDs 7 that also serve to control the accelerations of the movable floor plate 3. The floor plate 3 acts as a damping mass that oscillates in opposition to oscillation of the lateral load-resisting structure 2 to further dampen oscillation of the building 1. The floor plate 3, or more specifically the mass of the floor plate 3, fulfils the function that would have otherwise been provided by a separate mass, had a TMD been employed.

As FVDs 7 cannot resist static loads, such as the wind applied to the movable part of the building 1, elastic elements 12 are placed in parallel with the FVDs 7 that connect the floor plate 3 to the support structure 2, as most clearly shown in Figure 4C, which is an enlarged partial view of part of Figure 4A. It is envisaged that there will be the same number of elastic elements 12 as there are FVDs 7, although there may be differing numbers of FVDs 7 and elastic elements 12 depending on the application. The stiffness of the elastic element 12 determines the degree of differential movement that occurs between both parts of the building 1, and also represents the parameter determining the amount of damping generated. Damping is generated by the differential motion of both ends of each FVD 7, such that the larger the motion the larger the damping.
Each elastic element 12 may take the form of a spring, but the elastic element 12 can be formed by any body that is at least capable of some elastic deformation. For example, the elastic element 12 can be a beam or plate working in bending. In this configuration, the aforementioned sliding joint 6 connecting each of the floor plates 3 to the core 2a may no longer be required, as transversal forces can be transferred through the elastic element 12, which may be a plate or series of plates that act as elastic elements and which extend between the core 2a and the floor plate 3.

It is envisaged that the elastic elements 12 may be designed so that they deform within their elastic range under normal load conditions, but exceed their elastic range and deform inelastically or non-linearly when the building 1 experiences an extraordinary seismic event, such as during a major earthquake. Yielding of the spring so that it behaves plastically may allow further differential displacement, thereby increasing the level of damping and the resistance of the building 1 to damage. Assuming that a floor plate 3 can be provided with sufficient lateral stability, it is also possible to design the elastic element 12 so that it will fail in cases of extreme seismic events, thereby allowing the floor plate 3 to move by a larger distance to provide more damping.

The floor plates 3 may be isolated from the lateral load-resisting system 2 to act as a movable mass in other types of buildings, and as such it is not limited to any specific typology or building configuration. For example, Figure 5 shows a floor plan of a building having a lateral load-resisting structure in the form of a central core 13 with an external floor plate 14 acting as a movable mass with respect to the central core 13. For this case, the FVDs 7 and elastic elements 12 may be hidden within the ceiling by placing them underneath the floor plate 14 which they are coupling to the central core 13, so that they do not take any usable space from the floor plate 14.

In any embodiment, each of the elastic elements 12 extends between the support structure 2 and the floor plate 3 separately to the FVDs 7. However, an elastic element 12 may be combined with an FVD 7 to form an integrated damping unit 15. For example, the elastic elements 12 may be helical springs. As shown in Figure 7, each FVD 7 may extend axially through the helical spring 12, similar to the way in which a spring surrounds a car shock absorber. A common mounting plate 16 at one end enables attachment of the integrated damping unit 15 to a floor plate 3, whilst a common
mounting plate 17 at the opposite end enables attachment of the integrated damping unit 15 to one of the cores 2a or other lateral load resisting structure 2.

In another embodiment, illustrated in Figure 8, the FVD 7 and elastic element 12 may extend parallel to each other and an end of the FVD 7, and a corresponding end of the elastic element 12, may both be connected to a first common mounting member 18 for fixed attachment to the floor plate 3, whilst the opposite end of the FVD 7, and corresponding opposite end of the elastic element 12, may be coupled to a second common mounting member 19 for attachment to the lateral load-resisting structure 2, thereby forming an integral damping unit 15. Respective ends of the FVD 7 and elastic element 12 may each be attached to the first and second common mounting members 18, 19 by bolts or similar fasteners 20.

Although reference has been made to placing the integrated damping unit 15 so that the axis of the FVDs 7 and elastic elements 12 extends horizontally, it will be appreciated that the integrated damping unit 15 may also be placed parallel, perpendicular or in diagonal depending on each specific application.

Figures 4A shows a first plan view at a first height through the uppermost module 4 of the building 1 of Figure 1, and 4B shows a second plan view at a second height through the module 4 directly below the uppermost module 4. In Figure 4A, a floor plate 3 of the uppermost module 4 is shown mounted to the cores 2a for movement in the direction of arrow M, whereas in Figure 4B, a floor plate 3 of the lower module 4 is shown mounted to the cores 2a for differential movement in the direction of arrow H. The floor plates 3 of each module 4 move in one orientation only; the floor plates 3 of the uppermost module 4 move, in direction M, at 90 degrees to the direction of movement H, of the floor plates 3 of the lower module 4, to ensure that the building 1 will generate damping in all directions by means of just using the two top modules 4 as part of the damping system. The location of the FVDs 7, and elastic elements 12 in parallel with the FVDs 7, is apparent from each Figure.

Besides the advantages of not occupying any floor, rather integrating within it, and not adding any additional mass, a building 1 according to the invention has several FVDs 7 and elastic elements 12 provided at each floor plate 3, and so forms a redundant arrangement that still functions despite failure of some of the FVDs 7. Beyond using the system to provide damping for serviceability and thus reduce the accelerations at the
top of a building 1, it can also be used to reduce the seismic loads as well as the static and dynamic wind loads on the building 1. This not only avoids any necessary increase in the sizes of the structural elements to an increased load, but also permits significant reductions due to the mitigation of applied loads.

When compared to a TMD, the system is far less dependent on the frequency characteristics of the building 1 or the system itself, and provides a far more robust response. As the mass ratio increases, the system is not only able to control the response in the fundamental natural frequency, but also in other higher modes, and thus is able more readily to deal with seismic loads.

Utilisation of the floor plate mass removes the requirement of the FVD 7 and the elastic element 12 to be tuned to match the natural frequency of the building 1, and is thus less reliant on changes in properties of the building 1 or the dampers. However, even if not necessary and may not usually be the target, it is envisaged that even further damping may be achieved by adjusting the elastic element 12 to match the main natural frequency of the building 1.

It will be appreciated that performance will be dependent on many factors. However, performance of the specific building 1 shown in Figure 1 and described in more detail above, using the floor plates 3 of the top two modules 4 of the building 1 as movable masses, has been assessed in order to provide an indication as to likely performance levels. In this assessment, a response was determined for two elastic element stiffness levels, allowing up to either 25mm or 250mm of differential displacement (representing relatively low or high situations) under 10 minutes mean wind load for a 50-year return period according to a European code of practice. It should be noted that a 250m high building 1 could be designed to accommodate up to 500mm displacement at the top. It was concluded, based on the assessment, that for a 25mm displacement, it was possible to obtain about 1.8% additional damping, and for 250mm displacement it was possible to achieve 24% additional damping.

Following European design standards, and using the obtained damping levels for the specific case study considered, it was possible to reduce the mean wind load by 25% for the case of small displacement (1.8% additional equivalent damping), and by 45% for the case of large displacement (24% additional equivalent damping). Additionally, if the response of the building 1 is studied further in a wind-tunnel test, following typical
assumptions and previous assessments, the reduction in the dynamically-induced wind forces could be estimated to be in the range of a 40% reduction for the 25 mm maximum differential displacement and of 65% reduction for the 250 mm maximum differential displacement. The dynamically-induced wind loads will depend on every specific case, but it has been concluded that it would be possible to reduce considerably the loading induced in the building 1 to allow its design to be optimized. The same structure was also examined using 7 different earthquake excitations, consistent with a European codified scenario, and it was found that it was possible to reduce the response of the building 1 during a seismic event by an average of 19% for the small displacement case.

Upon further analysis, the inventors have also established that, by implementing the system, it was possible to reduce the response of the building 1 during a seismic event to 47% for the large displacement case.

A graph showing the response of the case study in which the system was tested against a series of 7 earthquake records is shown below (Graph 1). In the graph each seismic event is identified by their number in the NGA earthquake database. A substantial reduction in peak displacement can be noticed.

Graph 1 illustrates a reduction in the top displacement versus damper coefficient values for the 7 considered earthquake records, for the case of a maximum differential displacement of 250mm.
Besides the above-discussed benefits, the assessment demonstrated that it was possible to control the accelerations of the building 1. These reductions in the wind loads, seismic loads and accelerations would lead to substantial savings in material both in the superstructure and in the foundations, and thus resulting in a far more efficient and optimized design with minimum disruption and maximum space usage of the building 1.

Motion amplification systems may also be used to increase the performance of the system, yet their suitability will also depend on each specific application.

Reference is made to a "building", and the invention is particularly applicable to tall and high-rise structures or towers such as skyscrapers, which are susceptible to seismic and other loads. However, reference to a "building" should also be taken to include other tall structures, such as wind turbines.

The term "floor plate" is used to define a slab which makes up each floor of the building 1. Such slabs are usually formed of concrete although other materials may also be envisaged. The floor plate 3 may also be taken to include associated joists, structure, subflooring, floor finishes and other components that are associated with, or carried by, the floor plate 3. Employing the floor plates 3 as damping masses is advantageous due to their substantial weight. Multiple floor plates 3 may be used as part of the system so that they each act to provide a damping mass. It is envisaged that each floor plate 3 will move independently of the other floor plates 3. However, in some circumstances it may be beneficial to combine two or more floor plates 3 into a single unit so that they will move as one.

It will be appreciated that the foregoing description is given by way of example only and that modifications may be made to the present invention without departing from the scope of the appended claims.
Claims

1. A building that is susceptible to oscillation in response to an externally induced load, comprising a lateral load-resisting structure, a floor plate, and an interface between the lateral load-resisting structure and the floor plate that comprises fluid viscous dampers to dissipate energy, provide damping and control acceleration of the floor plate, the floor plate acting as a damping mass that oscillates in opposition to oscillation of the lateral load-resisting structure to dampen oscillation of the building, wherein the interface further comprises elastic elements, mounted in parallel to the fluid viscous dampers, to resist static load and control movement of the floor plate relative to the lateral load-resisting structure.

2. A building according to claim 1, wherein each fluid viscous damper and elastic element extend horizontally between the floor plate and the lateral load-resisting structure.

3. A building according to claim 1 or 2, wherein the lateral load-resisting structure comprises a core, and wherein fluid viscous dampers couple the floor plate to the core to allow lateral movement of the floor plate relative to the core.

4. A building according to claim 3, wherein the lateral load-resisting structure comprises a plurality of spaced cores, and wherein fluid viscous dampers couple the floor plate to each of said plurality of spaced cores.

5. A building according to claim 3 or 4, wherein elastic elements couple the floor plate to the, or each core.

6. A building according to any preceding claim, wherein each fluid viscous damper is combined with an elastic member to form an integral damping unit.

7. A building according to claim 6, wherein the integral damping unit comprises a first common mount at one end for attachment to the floor plate, and a second common mount at the opposite end for attachment to the lateral load-resisting structure.

8. A building according to claim 7, wherein the elastic member is a coil spring and a fluid viscous damper extends within the coils of the spring.
9. A building according to claim 7, wherein the integral damping unit comprises a fluid viscous damper and an elastic member mounted in side-by-side relation.

10. A building according to any of claims 1 to 9, wherein the floor plate comprises a slab, joists, subflooring and other components that are carried by the slab.

11. A building according to any preceding claim, comprising a sliding joint, such as a linear bearing, between the lateral load-resisting structure and the floor plate to allow lateral movement of the floor plate relative to the lateral load-resisting structure.

12. A building according to any preceding claim, comprising a support structure to carry gravitational and vertical loads from the floor plates.

13. A building according to claim 12, wherein the floor plate is mounted to the support structure by a sliding joint.

14. A building according to claim 12 or 13, comprising a first module including a first set of floor plates, and a second module spaced vertically from the first module, the second module comprising a second set of floor plates.

15. A building according to claim 14, wherein at least some of the floor plates of each of the first and second modules are coupled to the lateral load-resisting structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers.

16. A building according to claim 15, wherein a lowermost floor plate of each of said first and second modules is fixed to the support structure.

17. A building according to any of claims 14 to 16, wherein the floor plates of the first module, which are coupled to the lateral load-resisting structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers, are mounted for lateral movement in a direction at right angles to the direction of movement of the floor plates of the second module, which are coupled to the support structure via fluid viscous dampers and elastic elements in parallel with said fluid viscous dampers.
18. A building according to any of claim 12 to 17, wherein the floor plates of each module are joined by columns extending from, and which move together with, the floor plates, said columns being configured to transfer vertical loads from the floor plate to the support structure.

19. An integrated building damper unit to provide an interface between a load-resistant support structure and a movable floor plate of a building, the integrated building damper unit comprising a fluid viscous damper and an elastic element mounted in parallel with each other, a first common mount for attachment of one end of the fluid viscous damper and the elastic element to the floor plate, and a second common mount for attachment of the opposite end of the fluid viscous damper and the elastic element to the load-resistant support structure.

20. An integrated building damper unit according to claim 19, wherein the elastic member is a coil spring and the fluid viscous damper extends within the coils of the spring.

21. An integrated building damper unit according to claim 19, wherein the fluid viscous damper and an elastic member are mounted in side-by-side relation.

22. A method of providing damping for a building that is susceptible to oscillations in response to an externally induced load, comprising a lateral load-resisting structure and a floor plate, the method comprising coupling the floor plate to the lateral load-resisting structure using:

   (a) fluid viscous dampers so that the floor plate acts as a damping mass that oscillates in opposition to oscillations of the lateral load resisting-structure to dampen the oscillations of the building; and

   (b) elastic elements, mounted in parallel to the fluid viscous dampers, to resist static load and control movement of the floor plate relative to the lateral load resisting structure.

23. A method according to claim 22, including tuning the elastic elements to the natural frequency of the building.
A. CLASSIFICATION OF SUBJECT MATTER
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ADD.

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
E04B E04H F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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