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Aseismic Building Design and Retro Fitting

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ABSTRACT : Earthquake produces large strain energy which travels as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. Shear waves produced by the seismic activity makes the structure to shake upside down and in lateral direction, which results in causing damage or even collapse to the existing structure. Damage to the structure can be reduced by making the superstructure to bend with the shaking of the foundation.

Fluid Viscous Dampers (FVD) in high-rise residential and commercial building prevents the superstructure damage to maximum extent. FVD can be placed either diagonally or in a cross bracings in the frames to absorb the seismic energy and dissipate it as heat. FVD prevents the movement of the shear waves travelling upwards into the structure and reduces the inertia forces. Inertia force makes building to collapse within few minutes. By using Fluid Viscous Damping devices structural damage can be avoided.

An innovative and practical technique for the seismic rehabilitation of beam-column joints using fiber reinforced polymers (FRP) is presented. The procedure is to upgrade the shear capacity of the joint and thus allow the ductile flexural hinge to form in the beam. With Stronger column and weaker beam concept making column beam links more stronger with stainless steel or fibre reinforced plastic prevents the failure in column-beam joints. Reinforcing with FRP or stainless steel in column-beam joints helps the structure to bend without producing damages at the joints. By pre-tensioning and post-tensioning techniques, it is possible to produce the structural members with lesser dimension. Using light weight construction materials produced by pre-stressing techniques, the total weight of the structure can be reduced. Constructing shear walls in the some of the bays of the existing frames with reinforced concrete after earthquake improves the seismic performance of the structure.

All these techniques and its implementation to make the structure to prevent the damage in the structure and retrofitting methods are described in this paper.

I.INTRODUCTION

Earthquake is one of the most dangerous natural disaster. It causes damage to the mankind and buildings. An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface. For hundreds of millions of years, the forces of plate tectonics have shaped the Earth as the huge plates that form the Earth's surface move slowly over, under, and past each other. Sometimes the movement is gradual. At other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free causing the ground to shake. Most earthquakes occur at the boundaries where the plates meet; however, some earthquakes occur in the middle of plates. All buildings can carry their own weight (or they would fall down anyway by themselves). They can usually carry a bit of snow and a few other floor loads and suspended loads as well, vertically; so even badly built buildings can resist some up-and-down loads. But buildings are not necessarily able to resist any lateral loads. By making the entire superstructure to bend forth and back with the shaking of foundation the damage can be prevented. Making the beam column joints stronger by using fiber reinforced plastic or stainless steel, makes the building

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frame to bend without failure. Pre stressing technique produces slabs with lesser thickness which in turn reduce the entire weight of the structure and building damage can be prevented. Another innovative technique is to use fluid viscous dampers in Reinforced concrete framed structure to prevent the damage to the super structure. Fluid viscous damping devices are placed in diagonal positions in the frames. This damping device absorbs the shear energy in the compression and tension forms and dissipate as heat energy into the atmosphere. By this action shear waves are prevented in producing the structural and non-structural damage. Shear wall act as vertical beam to transmit the inertia forces safely to the foundation. Shear wall retrofiting increases the seismic performance of the structures.

II.EARTHQUAKE

Rocks are made of elastic material, and so elastic strain energy is stored in them during the deformations that occur due to the gigantic tectonic plate actions that occur in the Earth [1]. But, the material contained in rocks is also very brittle. Thus, when the rocks along a weak region in the Earth's Crust reach their strength, a sudden movement takes place there opposite sides of the fault (a crack in the rocks where movement has taken place) suddenly slip and release the large elastic strain energy stored in the interface rocks [2-3].

Large strain energy released during an earthquake travels as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. These waves are of two types - body waves and surface waves; the latter are restricted to near the Earth's surface. Body waves consist of Primary Waves (P-waves) and Secondary Waves (Swaves), and surface waves consist of Love waves and Rayleigh waves.

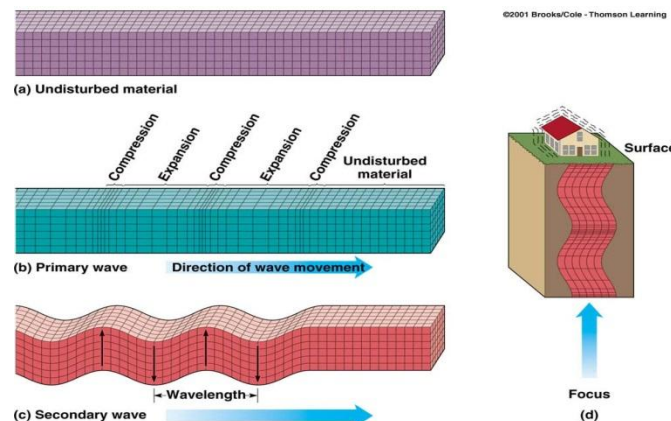


Fig 1 : Different Waves

Under P-waves, material particles undergo extensional and compressional strains along direction of energy transmission, but under S-waves, oscillate at right angles to it. Love waves cause surface motions similar to that by S-waves, but with no vertical component. Rayleigh wave makes a material particle oscillate in an elliptic path in the vertical plane (with horizontal motion along direction of energy transmission). P-waves are fastest, followed in sequence by S-, Love and Rayleigh wave. S-waves do not travel through liquids. S-waves in association with effects of Love waves cause maximum damage to structures by their racking motion on the surface in both vertical and horizontal directions. When P- and S-waves reach the Earth's surface, most of their energy is reflected back. Some of this energy is returned back to the surface by reflections at different layers of soil and rock. Shaking is more severe (about twice as much) at the Earth's surface than at substantial depths [4].

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III. MAGNITUDE

Magnitude is a quantitative measure of the actual size of the earthquake. An increase in magnitude (M) by 1.0 implies 10 times higher waveform amplitude and about 31 times higher energy released. For instance, energy released in a M7.7 earthquake is about 31 times that released in a M6.7 earthquake, and is about 1000 ($\approx 31 \times 31$) times that released in a M5.7 earthquake [5]. Most of the energy released goes into heat and fracturing the rocks, and only a small fraction of it (fortunately) goes into the seismic waves that travel to large distances causing shaking of the ground en-route and hence damage to structures. Annual average number of earthquakes across the Earth in each of these groups is also shown in the table; it indicates that on an average one Great Earthquake occurs each year [6].

Table 1: Magnitude of Earthquake

Group	Magnitude	Annual Number	Average
Great	8 and higher	1	
Major	7 – 7.9	18	
Strong	6 – 6.9	120	
Moderate	5 – 5.9	800	
Light	4 – 4.9	6,200 (estimated)	
Minor	3 – 3.9	49,000 (estimated)	

Earthquake resistant structures

Its possible to construct a structure to resist the effects of earthquake entirely but it is difficult to construct and it is too expensive too. Damages of buildings to resist earthquakes involve controlling the damage to acceptable levels at a reasonable cost. Instead of earthquake proof buildings it is possible to make the buildings which can resist the effects of the ground shaking but would not collapse during the strong earthquake [7]. Thus , safety of people and contents is assured in earthquake-resistant buildings, and thereby a disaster is avoided. This is a major objective of seismic design codes throughout the world.

IV.FLUID VISCOUS DAMPERS

When ground seismic waves reach up and start to penetrate a base of a building, their energy flow density, due to reflections, reduces dramatically: usually, up to 90% [8]. However, the remaining portions of the incident waves during a major earthquake still bear a huge devastating potential. After the seismic waves enter a superstructure it is possible to control them in order to minimize their damaging effect and improve the building's seismic performance. Passive fluid viscous damping systems are generally well suited to vibration control of civil structures subject to seismic excitation [9].

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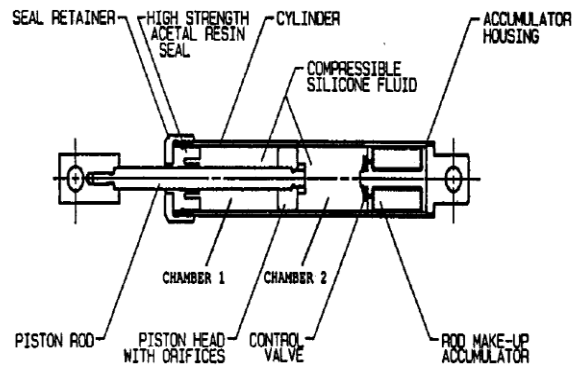


Fig.2 : Fluid Viscous Damper

Fluid visous dampers that operate on the principle of flow through orificing exhibit high levels of energy dissipation density. During a seismic event, the input energy from the ground acceleration is transformed into both kinetic and potential (strain) energy which must be either absorbed or dissipated through heat. The inherent energy dissipation capacity of the structure will eventually withdraw all of the seismic input energy from the structure. The damper consists of a stainless steel piston with a bronze orifice head and a piston rod make-up accumulator. The damper is filled with a thin silicone oil having a kinematic viscosity of 100cSt. High strength seals are utilized to maintain closure over the design life of the damper. The piston head orifices are designed such that the fluid flow is altered according to the fluid speed resulting in a force output which is essentially proportional to the relative velocity of the piston coming from the concatenation of fluid .The force generated by the damper is a result of a pressure differential across the piston head. When the damper is subjected to a compressive force, the fluid volume is reduced by the product of travel and piston rod area. Since the fluid is nearly incompressible , the reduction in fluid volume results in the development of a restoring force. This is prevented by the use of a rod make-up accumulator and control valve. An alternate construction of this device is with a run-through rod in which the rod enters the damper, is connected to the piston head, and then continues out through the opposite end of the damper. This arrangement avoids changes in fluid volume and then continues out through the opposite end of the damper. This arrangement avoids changes in fluid volume and therefore prevents the development of a restoring force. The construction of large size dampers for structural control applications typically includes a run-through rod rather than an accumulator. The flow of fluid through the piston head orifices is compensated according to the temperature such that the mechanical properties remain relatively stable over a wide temperature range (-40 to 70 deg celcius). Figure below shows a three storey structure with fluid viscous damping devices placed in diagonal and cross bracings. These dampers when placed in multi-storey structures absorbs the seismic energy coming through the base of the building and reduces the impact of seismic waves passing further above the building. By this action the impact of inertia force are also decreased and seismic performance is improved.

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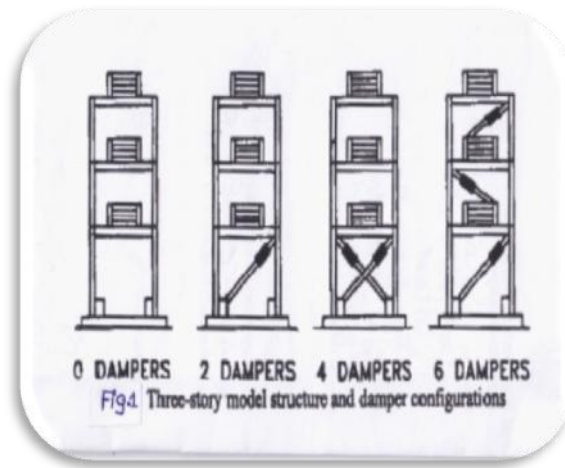


Fig 3: A three storey structure with fluid viscous damping devices placed in diagonal and cross bracings

Prestressed concrete

The function of prestressing is to place the concrete structure under compression in those regions where load causes tensile stress. Tension caused by the load will first have to cancel the compression induced by the prestressing before it can crack the concrete. Prestressing can be accomplished in three ways: pre-tensioned concrete, and bonded or unbonded post-tensioned concrete. In pre-tensioned members the prestressing strands are tensioned against restraining bulkheads before the concrete is cast. After the concrete has been placed, allowed to harden and attain sufficient strength, the strands are released and their force is transferred to the concrete member. Prestressing by post-tensioning involves installing and stressing prestressing strand or bar tendons only after the concrete has been placed, hardened and attained a minimum compressive strength for that transfer.

Pre-tensioned concrete

Pre-tensioned concrete is cast around already tensioned tendons. This method produces a good bond between the tendon and concrete, which both protects the tendon from corrosion and allows for direct transfer of tension. The cured concrete adheres and bonds to the bars and when the tension is released it is transferred to the concrete as compression by static friction. However, it requires stout anchoring points between which the tendon is to be stretched and the tendons are usually in a straight line. Thus, most pre-tensioned concrete elements are prefabricated in a factory and must be transported to the construction site, which limits their size. Pre-tensioned elements may be balcony elements, lintels, floor slabs, beams or foundation piles.

Bonded post-tensioned concrete

Bonded post-tensioned concrete is the descriptive term for a method of applying compression after pouring concrete and the curing process (in situ). The concrete is cast around a plastic, steel or aluminium curved duct, to follow the area where otherwise tension would occur in the concrete element. A set of tendons are fished through the duct and the concrete is poured. Once the concrete has hardened, the tendons are tensioned by hydraulic jacks that react against the concrete member.

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itself. When the tendons have stretched sufficiently, they are wedged in position and maintain tension after the jacks are removed, transferring pressure to the concrete. The duct is then grouted to protect the tendons from corrosion. This method is commonly used to create monolithic slabs for house construction in locations where expansive soils (such as adobeclay) create problems for the typical perimeter foundation. All stresses from seasonal expansion and contraction of the underlying soil are taken into the entire tensioned slab, which supports the building without significant flexure. Post-tensioning is also used in the construction of various bridges, both after concrete is cured after support by falsework and by the assembly of prefabricated sections, as in the segmental bridge.

Unbonded post-tensioned concrete

Unbonded post-tensioned concrete differs from bonded post-tensioning by providing each individual cable permanent freedom of movement relative to the concrete. To achieve this, each individual tendon is coated with a grease (generally lithium based) and covered by a plastic sheathing formed in an extrusion process. The transfer of tension to the concrete is achieved by the steel cable acting against steel anchors embedded in the perimeter of the slab. The main disadvantage over bonded post-tensioning is the fact that a cable can destress itself and burst out of the slab if damaged.

Advantages of prestressing

Prestressed concrete is the predominating material for floors in high-rise buildings and the entire containment vessels of nuclear reactors. The advantages of prestressed concrete include crack control and lower construction costs; thinner slabs - especially important in high rise buildings in which floor thickness savings can translate into additional floors for the same (or lower) cost and fewer joints, since the distance that can be spanned by post-tensioned slabs exceeds that of reinforced constructions with the same thickness. Increasing span lengths increases the usable unencumbered floorspace in buildings; diminishing the number of joints leads to lower maintenance costs over the design life of a building, since joints are the major focus of weakness in concrete buildings. By reducing the size of the structural members and the materials used, less weight materials can be produced. These less weight structural members withstand the high load and provides less damage during earthquake.

V.FIBRE REINFORCED POLYMERS

The functional requirement of a joint, which is the zone of intersection of beams and columns, is to enable the adjoining members to develop and sustain their ultimate capacity. The demand on this finite size element is always severe especially under seismic loading [10]. The joints should have adequate strength and stiffness to resist the internal forces induced by the framing members. FRP can be applied to strengthen the beams, columns and slabs in buildings. It is possible to increase strength of these structural members even after these have been severely damaged due to loading conditions. For strengthening beams, two techniques are adopted. First one is to paste FRP plates to the bottom (generally the tension face) of a beam. This increases the strength of beam, deflection capacity of beam and stiffness (load required to make unit deflection). Alternately, FRP strips can be pasted in 'U' shape around the sides and bottom of a beam, resulting in higher shear resistance. Columns in building can be wrapped with FRP for achieving higher strength. This is called wrapping of columns. The technique works by restraining the lateral expansion of the column. Slabs may be strengthened by pasting FRP strips at their bottom (tension face). This will result in better performance, since the tensile resistance of slabs is supplemented by the tensile strength of FRP. In the case of beams and slabs, the effectiveness of FRP strengthening depends on the performance of the resin chosen for bonding. The FRP rods provide flexural strengthening, whereas the lay-up laminates provide confinement and shear strengthening the RC frames, designed without seismic provisions, are often characterized by an unsatisfactory structural behavior due to the low available ductility. For example in a column, the lack of appropriate size and spacing of ties, which does not guarantee the required level of confinement, can cause the collapse of the column end, resulting in crushing of the not confined concrete, instability of the steel reinforcing bars in compression

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and pull out of those in tension. A critical region in an RC frame is the beam-column connection, where different constructive details can originate local failures, such as the shear collapse of the panel due to the lack of transverse reinforcement. Moreover, either for the scarce stirrup reinforcement or for the extreme loads due to a seismic event a beam can show a shear failure

Fibre reinforced polymers (FRP) having a great potential for strengthening of reinforced concrete structure by laying up laminates externally bonded to a concrete member which increases the flexural and shear capacity and provide concrete confinement.

Shear walls

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads .

Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane must be provided along the other direction to resist strong earthquake effects. Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net crosssectional area of a wall at an opening is sufficient to carry the horizontal earthquake force.

Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings They could be placed symmetrically (as shown below) along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

Reinforcement Bars in Shear Walls

Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section. Such walls, when adequately anchored into the surrounding frame using various types of connections like shear keys, dowels, chemical anchors not only increase the lateral stiffness of the building significantly, but also relieve the existing non-ductile frames from being subjected to large lateral force demands. The critical issue in prediction of the seismic performance of a building strengthened with shear walls is the distribution of lateral earthquake forces to the walls and the frame.

VI.CONCLUSION

Earthquake resistant design is therefore concerned about ensuring that the damages in buildings during earthquakes are of acceptable variety, and also that they occur at the right places and in right amounts. The advanced technique.

of Fluid Viscous Dampers (FVD) can be implemented either diagonally and as cross bracings in a reinforced concrete frames to control the structural damage. With pre-stressing techniques, it is possible to produce lesser dimension members

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and thereby decreases the self weight and reduces the effect of damage. It is possible to modify the strength of the joints by the use of Fibre Reinforced polymers wrapping. In doing this, the design of retrofitting could be oriented to induce a favourable collapse mode of the upgraded frame. Formation of new shear walls by infilling some of the bays of the existing frames with reinforced concrete infill walls. These shear wall transmits the inertial forces safely to the foundation and improves the performance of the damaged structure. Earthquake-resistant design of building costs money, but to prevent the worse damage of earthquake, these techniques have to be adopted

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