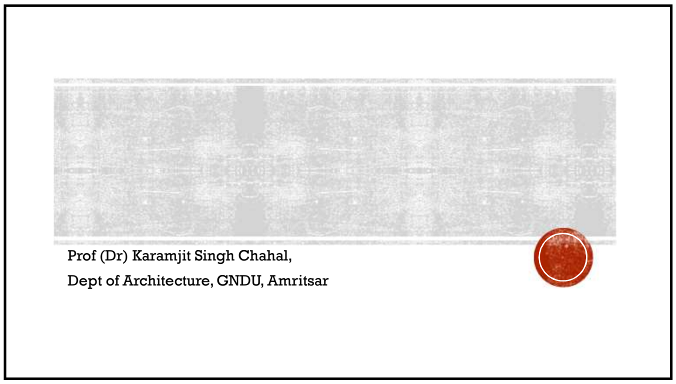
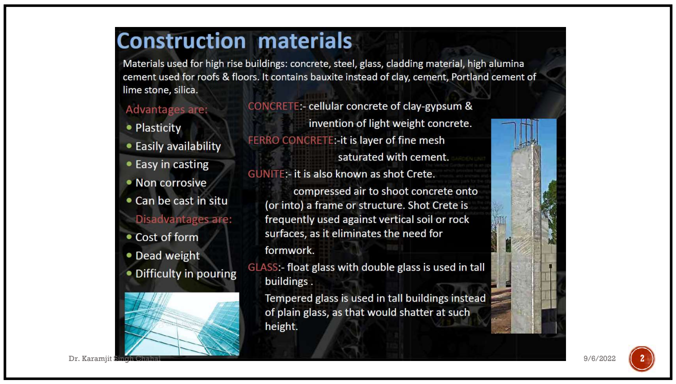


Prof (Dr) Karamjit Singh Chahal,
Dept of Architecture, GNDU, Amritsar



Construction materials

Materials used for high rise buildings: concrete, steel, glass, cladding material, high alumina cement used for roofs & floors. It contains bauxite instead of clay, cement, Portland cement of lime stone, silica.

Advantages are:

- Plasticity
- Easily availability
- Easy in casting
- Non corrosive
- Can be cast in situ

Disadvantages are:

- Cost of form
- Dead weight
- Difficulty in pouring

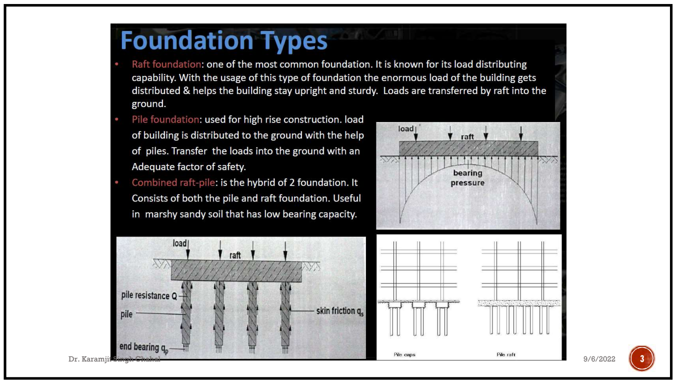
CONCRETE:- cellular concrete of clay-gypsum & invention of light weight concrete.

FERRO CONCRETE:-it is layer of fine mesh saturated with cement.

GUNITE:- it is also known as shot Crete. compressed air to shoot concrete onto (or into) a frame or structure. Shot Crete is frequently used against vertical soil or rock surfaces, as it eliminates the need for formwork.

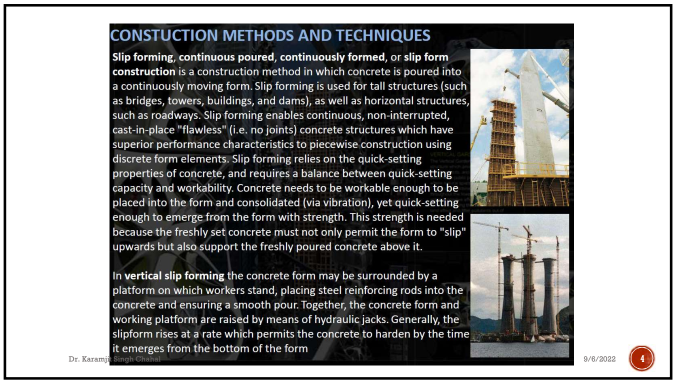
GLASS:- float glass with double glass is used in tall buildings .

Tempered glass is used in tall buildings instead of plain glass, as that would shatter at such height.



Foundation Types

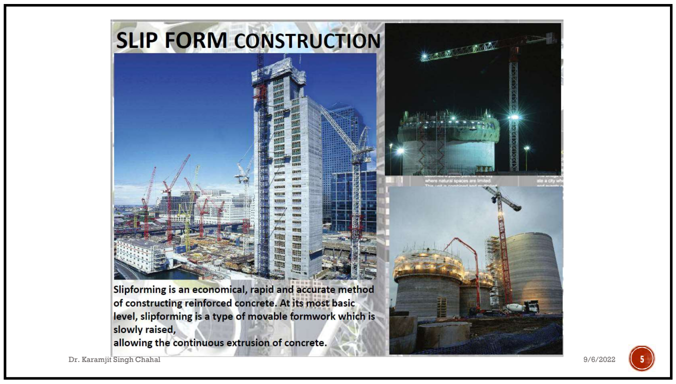
- Raft foundation: one of the most common foundation. It is known for its load distributing capability. With the usage of this type of foundation the enormous load of the building gets distributed & helps the building stay upright and sturdy. Loads are transferred by raft into the ground.
- Pile foundation: used for high rise construction. load of building is distributed to the ground with the help of piles. Transfer the loads into the ground with an Adequate factor of safety.
- Combined raft-pile: is the hybrid of 2 foundation. It Consists of both the pile and raft foundation. Useful in marshy sandy soil that has low bearing capacity.



CONSTUCTION METHODS AND TECHNIQUES

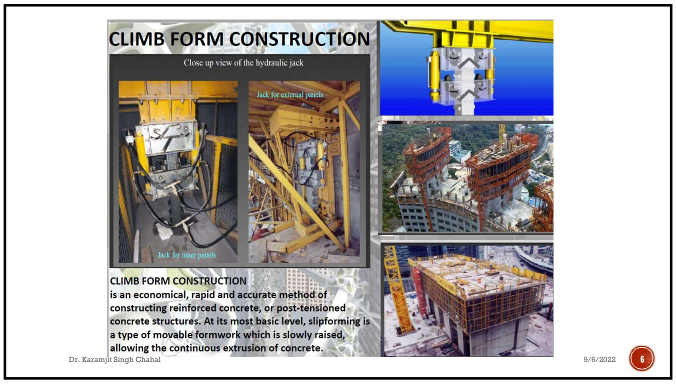
Slip forming, **continuous poured**, **continuously formed**, or **slip form construction** is a construction method in which concrete is poured into a continuously moving form. Slip forming is used for tall structures (such as bridges, towers, buildings, and dams), as well as horizontal structures, such as roadways. Slip forming enables continuous, non-interrupted, cast-in-place "flawless" (i.e. no joints) concrete structures which have superior performance characteristics to piecewise construction using discrete form elements. Slip forming relies on the quick-setting properties of concrete, and requires a balance between quick-setting capacity and workability. Concrete needs to be workable enough to be placed into the form and consolidated (via vibration), yet quick-setting enough to emerge from the form with strength. This strength is needed because the freshly set concrete must not only permit the form to "slip" upwards but also support the freshly poured concrete above it.

In **vertical slip forming** the concrete form may be surrounded by a platform on which workers stand, placing steel reinforcing rods into the concrete and ensuring a smooth pour. Together, the concrete form and working platform are raised by means of hydraulic jacks. Generally, the slipform rises at a rate which permits the concrete to harden by the time it emerges from the bottom of the form



SLIP FORM CONSTRUCTION

Slipforming is an economical, rapid and accurate method of constructing reinforced concrete. At its most basic level, slipforming is a type of movable formwork which is slowly raised,
allowing the continuous extrusion of concrete.



CLIMB FORM CONSTRUCTION

Close up view of the hydraulic jack

CLIMB FORM CONSTRUCTION
is an economical, rapid and accurate method of constructing reinforced concrete, or post-tensioned concrete structures. At its most basic level, slipforming is a type of movable formwork which is slowly raised, allowing the continuous extrusion of concrete.

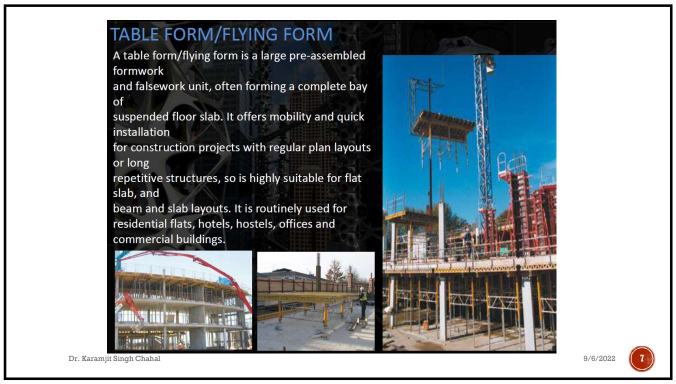
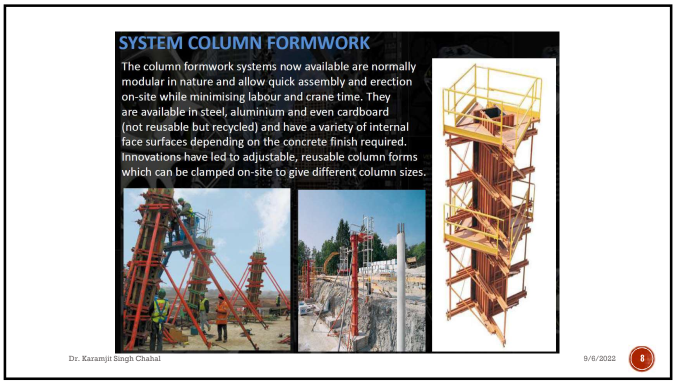


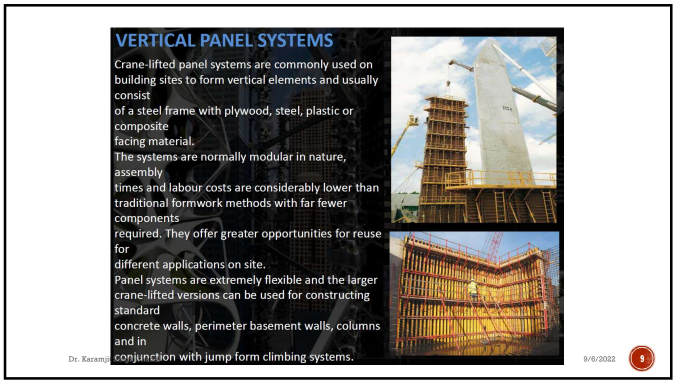
TABLE FORM/FLYING FORM

A table form/flying form is a large pre-assembled formwork and falsework unit, often forming a complete bay of suspended floor slab. It offers mobility and quick installation for construction projects with regular plan layouts or long repetitive structures, so is highly suitable for flat slab, and beam and slab layouts. It is routinely used for residential flats, hotels, hostels, offices and commercial buildings.



SYSTEM COLUMN FORMWORK

The column formwork systems now available are normally modular in nature and allow quick assembly and erection on-site while minimising labour and crane time. They are available in steel, aluminium and even cardboard (not reusable but recycled) and have a variety of internal face surfaces depending on the concrete finish required. Innovations have led to adjustable, reusable column forms which can be clamped on-site to give different column sizes.

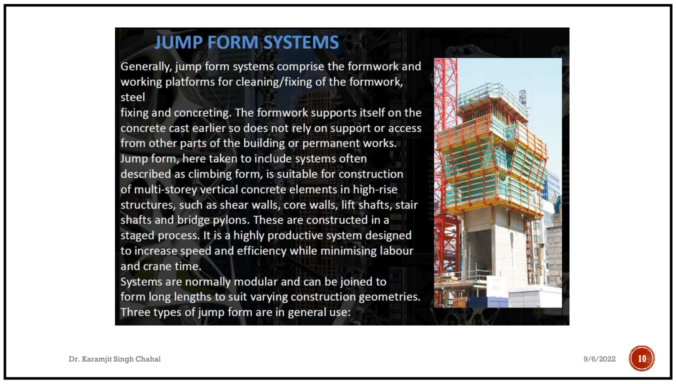


VERTICAL PANEL SYSTEMS

Crane-lifted panel systems are commonly used on building sites to form vertical elements and usually consist of a steel frame with plywood, steel, plastic or composite facing material.

The systems are normally modular in nature, assembly times and labour costs are considerably lower than traditional formwork methods with far fewer components required. They offer greater opportunities for reuse for different applications on site.

Panel systems are extremely flexible and the larger crane-lifted versions can be used for constructing standard concrete walls, perimeter basement walls, columns and in conjunction with jump form climbing systems.



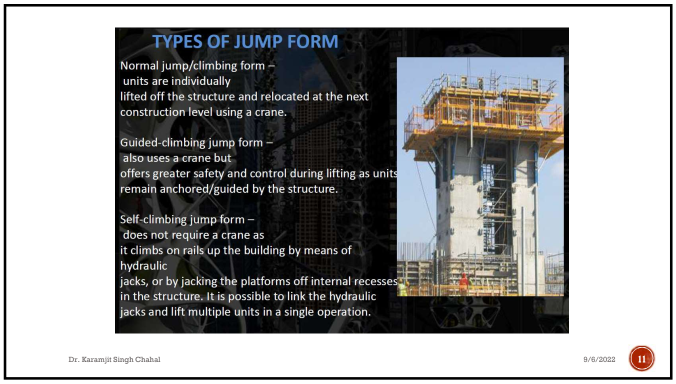
JUMP FORM SYSTEMS

Generally, jump form systems comprise the formwork and working platforms for cleaning/fixing of the formwork, steel fixing and concreting. The formwork supports itself on the concrete cast earlier so does not rely on support or access from other parts of the building or permanent works.

Jump form, here taken to include systems often described as climbing form, is suitable for construction of multi-storey vertical concrete elements in high-rise structures, such as shear walls, core walls, lift shafts, stair shafts and bridge pylons. These are constructed in a staged process. It is a highly productive system designed to increase speed and efficiency while minimising labour and crane time.

Systems are normally modular and can be joined to form long lengths to suit varying construction geometries.

Three types of jump form are in general use:

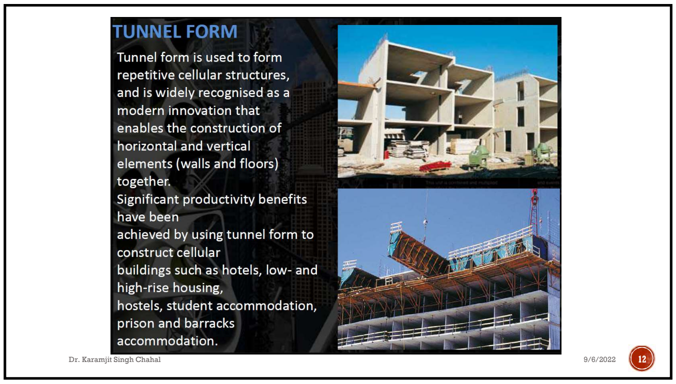


TYPES OF JUMP FORM

Normal jump/climbing form – units are individually lifted off the structure and relocated at the next construction level using a crane.

Guided-climbing jump form – also uses a crane but offers greater safety and control during lifting as units remain anchored/guided by the structure.

Self-climbing jump form – does not require a crane as it climbs on rails up the building by means of hydraulic jacks, or by jacking the platforms off internal recesses in the structure. It is possible to link the hydraulic jacks and lift multiple units in a single operation.



TUNNEL FORM

Tunnel form is used to form repetitive cellular structures, and is widely recognised as a modern innovation that enables the construction of horizontal and vertical elements (walls and floors) together.

Significant productivity benefits have been achieved by using tunnel form to construct cellular buildings such as hotels, low- and high-rise housing, hostels, student accommodation, prison and barracks accommodation.

WHAT IS A DAMPER?

IN STRUCTURES:

A **DAMPER** is a device that deadens, restrains, or depresses structures that are or may be subjected to dynamic loading..

- A device that damps oscillation in **RADIO MASTS AND Buildings** for better protection against storms.
- A device mounted in structures to prevent discomfort, damage or structural failure by vibration. (tuned mass dampers)

STRUCTURAL DAMPERS-AN OVERVIEW:

- Structural damping is critical parameter for all structures that are or may be subjected to dynamic loading.
- Structural dampers are implemented in buildings to deal with the dynamic excitation.
- Dampers are efficient in the sense that they dampen the energy input due to dynamic loading through various mechanisms.
- The energy gained due to dynamic loading is dissipated through the various mechanism as heat or as deformation i.e elastic strain energy.
- There are many types of dampers such as the frictional dampers, metallic dampers, viscoelastic dampers, Tuned Mass Dampers, Tuned Liquid Dampers.
- A recent development has lead to damping by magnetic induction.

SOURCES OF VIBRATION AND RESONANCE:

- ➢EARTHQUAKES
- ➢MECHANICAL HUMAN SOURCES
- ➢WIIND

DUE TO EARTHQUAKES:

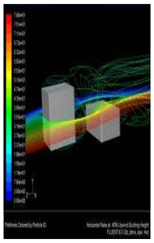
- The seismic waves caused by an earthquake will make buildings sway and oscillate in various ways depending on the frequency and direction of ground motion, and the height and construction of the building.
- Seismic activity can cause excessive oscillations of the building which may lead to structural failure.

DUE TO MECHANICAL HUMAN SOURCES:

- Masses of people walking up and down stairs at once, or great numbers of people stomping in unison, can cause serious problems in large structures like stadiums if those structures lack damping measures.
- Vibration caused by heavy industrial machinery, generators and diesel engines can also pose problems to structural integrity, especially if mounted on a steel structure or floor.
- Large ocean-going vessels may employ tuned mass dampers to isolate the vessel from its engine vibration.

DUE TO WIND:

- The force of wind against tall buildings can cause the top of skyscrapers to move more than a metre.
- This motion can be in the form of swaying or twisting, and can cause the upper floors of such buildings to move



THE ST. FRANCIS SHANGRI-LA PLACE

- The St. Francis Shangri-La Place, also known as The St. Francis Towers 1 & 2 are twin-tower residential condominium skyscrapers in Mandaluyong City, Philippines.
- The towers are the 3rd tallest building in Metro Manila and in the Philippines, and are currently the tallest residential skyscraper and tallest twin towers in the Philippines surpassing Pacific Plaza Towers with a height of 212.88 metres from the ground to its architectural spire

The first ever building to use the STRUCTURAL DAMPERS

- The building has 60 floors above ground, including a podium which connects the two towers, and 5 basement levels for parking, and are considered one of the most prestigious residential buildings in the Philippines.
- Due to the tower's location being close to an active fault in a highly seismic region and also subjected to typhoon winds, the St. Francis Shangri-La Place was the first building in the world to feature a revolutionary 'damping' system designed by an international engineering company Ove Arup & Partners.

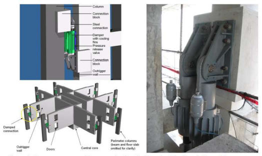
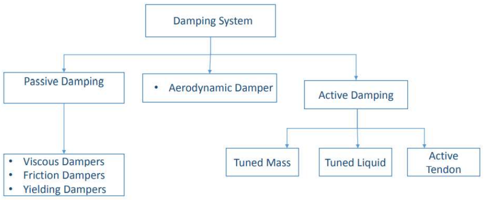


Figure 4 – Dampers conceptual lay-out and as installed into the Saint Francis Shangri-La towers.

DAMPING SYSTEMS IN HIGH-RISE BUILDINGS



- Damping System
  - Passive Damping
    - Viscous Dampers
    - Friction Dampers
    - Yielding Dampers
  - Aerodynamic Damper
  - Active Damping
    - Tuned Mass
    - Tuned Liquid
    - Active Tendon

DAMPING SYSTEMS IN HIGHRISE BUILDINGS

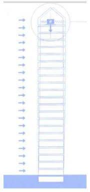
- Minimizing the effects of wind –induced vibrations and earthquake shaking on tall buildings as well as non structural architectural elements and mechanical components.

ACTIVE DAMPING SYSTEM:

- Requires power for motors sensors and computers control.
- Constant external power is required and may be undependable during a seismic event on disruption of power supply.
- more suitable for tall buildings: where wind induced loading rather than the unpredictable cyclic loading caused by earthquake.

SEMI ACTIVE DAMPING SYSTEM:

- Use of controlled resistive force to reduce motion
- They are fully controllable yet require little input power



- More useful in reducing sway during storm.
- Less satisfactory for building deflections during seismic event

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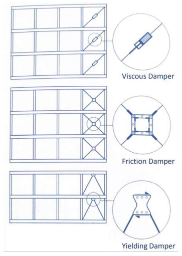
PASSIVE DAMPING SYSTEMS

- Absorb a portion of wind induced or seismic energy
- reducing the need for primary structural elements to dissipate energy.
- A metallic yielding damper (MYD) is **a type of hysteretic damper made of metal that utilizes the plastic deformation of hysteretic materials, such as mild steel, to dissipate the input seismic energy**



PALL FRICTION DAMPERS (PFD)

- Damping using frictional dampers is considered to be the most effective and economical solution for seismic upgrade
- In the late seventies, frictional dampers were developed inspired by the principle of friction brakes in automobiles.
- Nowadays, several frictional dampers are being used. They are available for tension cross bracing, single diagonal bracing and chevron bracing.
- They consist of a series of steel plates specially treated to develop the most reliable friction. The plates are clamped together with high-strength steel bolts.

- During severe seismic excitations, friction dampers slip at a predetermined optimum load before yielding occurs in other structural members and dissipate a major portion of the seismic energy. This allows the building to remain elastic or at least yielding is delayed to be available during maximum credible earthquakes.
- Another feature of friction damped buildings is that their natural period varies with the amplitude of vibration. Hence the phenomenon of resonance is avoided.

ADVANTAGES

- Simple and foolproof in construction.
- Friction dampers possess large rectangular hysteresis loops, with negligible fade over several cycles of reversals. For a given force and displacement in a damper, the energy dissipation of friction damper is the largest compared to other damping devices.
- The maximum force in a friction damper is pre-defined and remains the same for any future ground motion. Therefore, the design of bracing and connections is simple and economical. There is nothing to yield and damage, or leak. Thus, they do not need regular inspection, maintenance, repair or replacement before and after the earthquake.
- Friction dampers are also compact in design and can be easily hidden within drywall partitions.

METALLIC DAMPERS

- Metallic damper is a popular (and inexpensive) choice for an energy dissipation device because of its relatively high elastic stiffness, good ductility and its high potential for dissipating energy in the post-yield region.

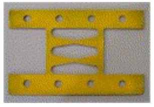
Single round hole metallic damper and double X shaped metallic damper are commonly used.

SINGLE ROUND HOLE DAMPER

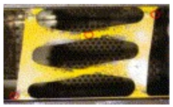
BEFORE DEFORMING

AFTER DEFORMING

DOUBLE X SHAPED DAMPER



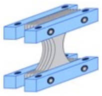
BEFORE DEFORMING

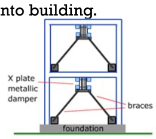


AFTER DEFORMING

X-SHAPED METALLIC PLATE DAMPER:

- IT is used where two braces meet.
- One type, the X-shaped Plate Damper, is used where two braces meet.
- As the building vibrates, the braces stretch and compress, pulling and pushing the damper sideways and making it deform. They are designed to deform so much when the building vibrates during an earthquake that they cannot return to their original shape.
- This permanent deformation is called inelastic deformation, and it uses some of the earthquake energy which goes into building.





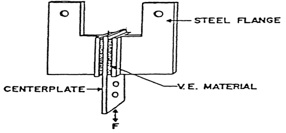
2 storey steel frame
with metallic dampers in position

ADVANTAGES

- These are inexpensive.
- No complicated technology is required to manufacture them.
- They can easily be integrated into structures; they show stable behavior in earthquakes.
- No environmental factors (like temperature, humidity etc.) affect their performance.
- These dampers increase the stiffness of structures in addition to increasing energy dissipation capacity in them. After earthquakes, these dampers can easily be replaced to strengthen the structure for future earthquakes.

VISCOELASTIC DAMPERS

- The typical viscoelastic damper consists of viscoelastic layers bonded with steel plates or solid thermoplastic rubber sheets sandwicthed between steel plates .
- The viscoelastic solid materials are used as a means to dissipate energy in viscoelastic dampers. The viscoelastic materials generally used are co-polymers or glassy substances .
- The energy is dissipated through shear deformation of the viscoelastic layers . Its behaviour depends upon vibration frequency , strain levels and temperature.
- While in active state , the relative motion between central and outer plates gives rise to shear deformations in the viscoelastic fluid between these interfaces and consequently the energy is dissipated leading to seismic response mitigation.



TYPES OF FORCES IN VISCOELASTIC DAMPERS

The force generated in the viscoelastic damper comprises of two components : elastic force and damping force.

1. The elastic force is proportional to the relative displacement between the connected floors of a building in which it is used .
2. The damping force is esentially proportional to the relative velocity of the piston head with respect to the damper casing .

USE OF VE DAMPERS IN SEISMIC ENGINEERING.

- When carrying out dynamic analyses using commonly used linear analysis , the resulting force-deformation relationship of the VE damper is linear without any phase lag and its peak force value is less than the maximum damper force .
- Viscoelastic (VE) dampers are dependent on both relative velocity and displacement to dissipate energy.
- VE damping system in Twin Towers is a double-layer shear damper using a 3M material, which is a rubber derivative, glued to steel plate and angle irons.
- This material will carry some load (which is temperature-dependent and would be less than the two-bolt connection as shown) as it displaces.

FUNCTIONS :

- It develops continuity moment at the end of joist girder, that is, the joist girders will behave as partial continuous members under Dead and Live load. It is partially restrained under Wind load.
- It restrained the lower chord of the joist girder (in the direction perpendicular to the plane of the joist). Therefore it stabilizes the concrete diaphragm. Note that for a 4-inch thick concrete slab spanning 60 feet, it would buckle if there were no joist girder. It also transfers compression load through bottom chord.
- Joist girder-column connection is a moment connection.
- It reduces the energy to be absorbed by the joist girder and the columns under Wind load.

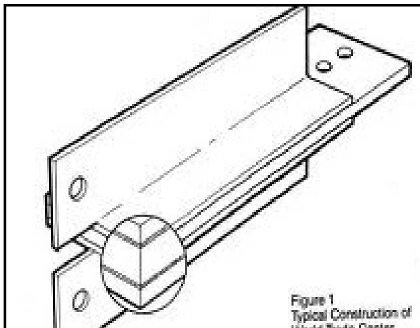


Figure 1
Typical Construction of
World Trade Center
Damper

TYPICAL CONSTRUCTION OF WORLD TRADE CENTRE DAMPER

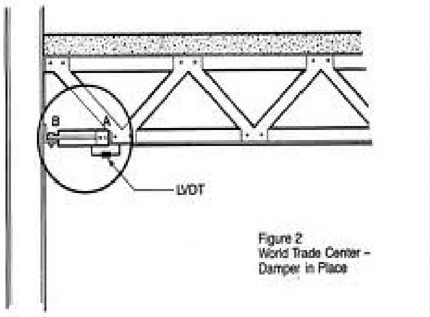


Figure 2
World Trade Center –
Damper in Place

WTC DAMPER

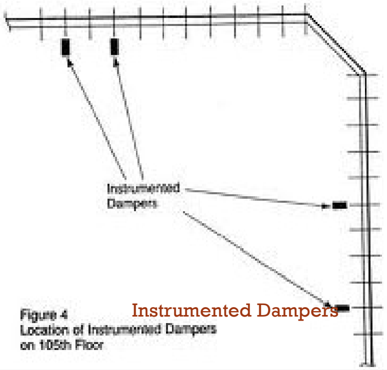


Figure 4
Location of Instrumented Dampers
on 105th Floor

Instrumented Dampers

TUNED MASS DAMPERS (TMDS)

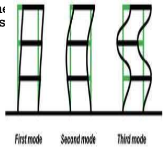
Tuned Dampers
- Tuned Mass Dampers
- Tuned Liquid Dampers
- Tuned Liquid Column Dampers

- It is a passive damping system.
- Utilizes a secondary mass attached to a main structure through spring and dashpot.
- Secondary mass system has a natural frequency closed to the primary structure which depends on its mass and stiffness.

- The excess energy that is built up in the structure can be transferred to a secondary mass and is dissipated by the TMD.
- By specifying the mass ratio of the secondary mass to the primary body, the optimum frequency ratio between the two masses and the optimum damping ratio of the secondary mass can be obtained.
- This secondary mass can be made of any material such as concrete or steel, while damping is generally provided by viscous damping devices.

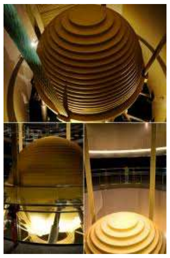
WORKING DURING AN EARTHQUAKE:

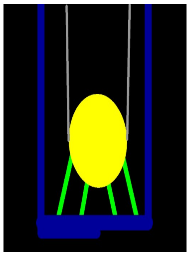
- During an earthquake, TMD will move against the direction of main structural vibration and an inertia force will be acted on the structure to reduce the response of the structure.
- One TMD can attenuate only the first mode response of a structure with its frequency tuned to the fundamental frequency of the structure.
- First several modes of a high rise structure are primary and th anticipated response reduction cannot be achieved if only the firs mode is controlled.
- Li and Wang presented the method of using multiple TMDs to control multiple modes of structures and got obvious results of vibration reduction.

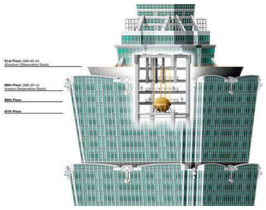


USE OF TMD IN TAIPEI FINANCIAL CENTRE, TAIPEI, TAIWAN

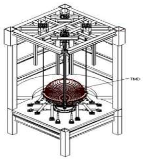
- It is also known as "Taipei 101 Tower".
- Its height is 508 meters which is the tallest building in the world



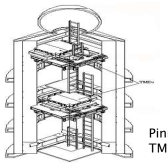




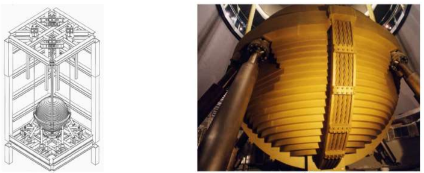
- The mass of TMD pendulum type is 660 tons
- The mass of two TMDs Pinnacle type weighs 4.5 tons each which was installed in 2002.
- Furthermore, the passive TMD systems were installed in many structures such as Bloomberg Tower in New York, Gran Canyon Skywalk in Arizona, USA and Shenzhen Bridge in Hong Kong, China.



TMD Pendulum type



Pinnacle TMD



a) b)

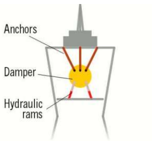
Figure 1 – Taipei 101: TMD general configuration (a) and primary viscous dampers (b).

TUNED MASS DAMPERS

- Consist of a huge mass of concrete or steel suspended from a cable-like pendulum mounted on tracks in the upper stones of a building.
- Lateral force -> swaying in the building - > computer senses the motion and signals the motor to move the weight in an opposing direction and neutralize the motion.

ACTIVE TENDON DAMPING SYSTEM:

- Uses a conceptualized controller that responds to the building moment
- Adjust member which is connected to an array of steel tendons disposed of adjacent to the structure's main support members.



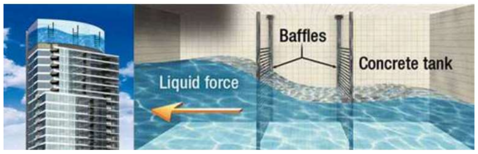
Where it dangles: Taipei 101
Diameter: 18 ft.
Weight: 730 tons
Cable thickness: 3 1/2 in.
Protects against: Earthquakes, high winds, oversize gorillas.

TUNED LIQUID DAMPERS (TLDS)

- A dynamic vibration absorber proposed for existing water tanks on the building in particular.
- TLD utilizes the motion of shallow liquid in a partially filled container to dissipate the vibration energy.
- The configuration of the TLDs is also designed to have a frequency close to the fundamental frequency of the structures.
- The frequency of the liquid is determined by their length and depth of the liquid.
- When the TLDs are excited, the liquid inside sloshes and energy is dissipated from the viscous action and wave-breaking.
- If the frequency of the sloshing motion is properly tuned to the natural frequency of a dominant mode of vibration of the structure, the sloshing motion imparts an inertia force that acts against the structural vibration. This effect leads to a reduction in the structural response, and, consequently an increase in the effective damping of the structure.

TUNED LIQUID DAMPERS

- To increase the energy dissipation of the sloshing liquid, flow-damping devices such as screens or posts in the container are required.
- Different shapes of containers, such as rectangular or circular can be used as TLD implementations.
- The tank moves back and forth in the opposing direction transferring its momentum to the building and counteracting the effect of wind vibration.
- Note: Unlike a circular type, a rectangular type has two different frequencies in two orthogonal directions.



EFFFETIVENESS OF TLD

- TLD when properly tuned to natural frequency of structure is more effective in controlling the vibration.
- The damping effect of TLD is sharply decreases with mistuning of TLD.
- TLD is more effective when it is placed at the top storey of the structure.

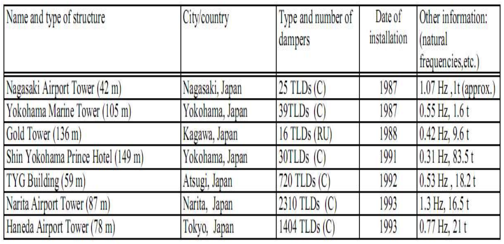
Circular Type TLD

USE OF TLD IN SHIN YOKOHAMA PRINCE HOTEL IN YOKOHAMA, JAPAN:

- The TLD's configuration of multi-layer stack of 9 circular (2 m dia.) fiber reinforced plastic containers, each 0.22 m high, was installed in 1991.
- It was found that the RMS accelerations in each direction were reduced 50% - 70% by the TLD at wind speeds over 20 m/s .
- Furthermore, TLDs system was implemented on other structures such as Gold Tower in Kagawa, Narita Airport Tower in Narita, Japan.

Shin Yokohama Prince Hotel

Table 2: Tuned Liquid Dampers (TLDs) for vibration mitigation of large structures.



Name and type of structure	City/country	Type and number of dampers	Date of installation	Other information: (natural frequencies,etc.)
Nagasaki Airport Tower (42 m)	Nagasaki, Japan	25 TLDs (C)	1987	1.07 Hz ,1t (approx.)
Yokohama Marine Tower (105 m)	Yokohama, Japan	39TLDs (C)	1987	0.55 Hz, 1.6 t
Gold Tower (136 m)	Kagawa, Japan	16 TLDs (RU)	1988	0.42 Hz, 9.6 t
Shin Yokohama Prince Hotel (149 m)	Yokohama, Japan	30TLDs (C)	1991	0.31 Hz, 83.5 t
TYG Building (59 m)	Atsugi, Japan	720 TLDs (C)	1992	0.53 Hz , 18.2 t
Narita Airport Tower (87 m)	Narita, Japan	2310 TLDs (C)	1993	1.3 Hz, 16.5 t
Haneda Airport Tower (78 m)	Tokyo, Japan	1404 TLDs (C)	1993	0.77 Hz, 21 t

C = Circular Sloshing Type , RU = Rectangular - Unidirectional

TUNED LIQUID COLUMN DAMPER (TLCD)

- TLCD are special type of TLD.
- Used for controlling vibration of structure under various dynamic loading.

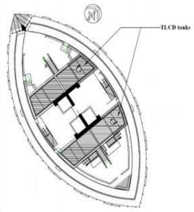
Tunabe Liquid Column Damper

PRINCIPLE OF TLCD

- Tuned Liquid Column Dampers (TLCDs), dissipates structural vibration by combined action involving the motion of the liquid mass in the tube.
- where the restoring force is due to the gravity acting upon the liquid and the damping effect as a result of loss of hydraulic pressure due to the orifice (s) installed inside the container

Structural Features:

- Comprised of two vertical columns of liquid connected by a horizontal crossover duct of the same width, enclosed in a custom U-shaped tank.
- A variation of these with a cross-over duct difference in width is denoted as a liquid column vibration absorber (LCVA).



Cross-sections of One Wall Centre

- The U-shaped tank is configured to have a natural frequency that optimally matches one or more of the structure's natural frequencies.
- The natural frequency of the tank is determined by its "effective length", and this is related to the geometry of the tank and particularly to the ratio of the cross-section areas of the vertical columns and the cross-over duct.
- Damping is dependent on the opening ratio of the orifice inside the TLCDs tank.

Note: A single TLCD can provide damping along a single building axis.

ADVANTAGES OF TLCD

- TLCDs are relatively are easy to install in new and existing buildings, because they can take any arbitrary shape.
- They do not interfere with the vertical and horizontal load paths, as other passive devices do.
- It's easy to adjust their frequencies and they can be combined with an active control mechanism.
- Do not require large space for stroke length.
- The water in the tank can be used for fire fighting.
- Set-up cost, as well as maintenance cost, is comparatively low

USE OF TCLD IN IN ONE WALL CENTRE IN VANCOUVER, BC, CANADA:

- A wide elliptical footprint with a 7:1 slenderness ratio.
- Two Tuned Liquid Column Dampers were installed to control wind-induced vibrations.
- Each TLCD contains 230 tons of water tuned to the proper frequencies.


One Wall Centre

USE IN COMCAST CENTER OR ONE PENNSYLVANIA PLAZA, PHILADELPHIA, USA:

- Contains the largest TLCD in the world.
- Its height is 297 meters of 57 floors.
- The TLCD water mass is 1,300 tons.


Comcast Center

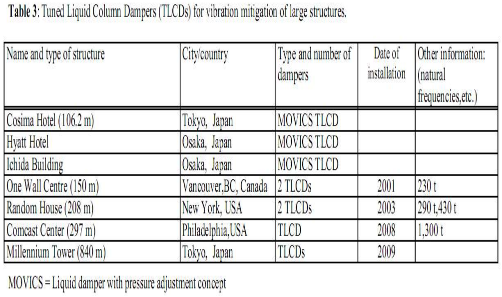


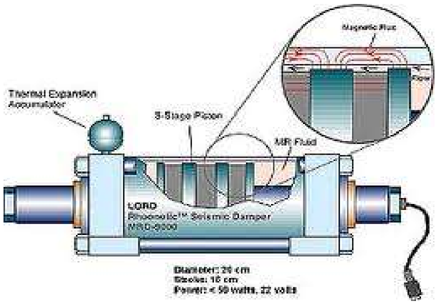
Table 3: Tuned Liquid Column Dampers (TLCDs) for vibration mitigation of large structures.

Name and type of structure	City/country	Type and number of dampers	Date of installation	Other information: (natural frequencies,etc.)
Cosima Hotel (106.2 m)	Tokyo, Japan	MOVICS TLCD		
Hyatt Hotel	Osaka, Japan	MOVICS TLCD		
Ichida Building	Osaka, Japan	MOVICS TLCD		
One Wall Centre (150 m)	Vancouver,BC, Canada	2 TLCDs	2001	230 t
Random House (208 m)	New York, USA	2 TLCDs	2003	290 t,430 t
Comcast Center (297 m)	Philadelphia,USA	TLCD	2008	1,300 t
Millennium Tower (840 m)	Tokyo, Japan	TLCDs	2009	

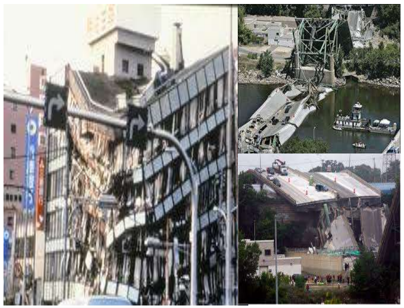
MOVICS = Liquid damper with pressure adjustment concept

MAGNETORHEOLOGICAL (MR) DAMPER

- MR damper is one of the most promising new devices
- MR dampers uses MR fluids to produce a controllable damping force
- MR damper is developed from MR fluid for reason that this microscopic shift can macroscopically induce great changes in the damping force of the MR damper.



ADEVERSE EFFECTS IF STRUCTURAL DAMPERS ARE NOT USED:



CONCLUSION

- Now-a-days there is an increasing trends to construct tall structures, to minimize the increasing space problems in urban areas.
- These structures are often made relatively light & comparatively flexible, possessing quite low damping, thus making the structure more vibration prone.
- Besides increasing various failure possibilities, these are also creating problem from service point of view, due to cladding and partition problem.
- So to ensure functional performance of tall buildings, it is important to keep the frequency of vibrational motion level bellow threshold.
- Various methods are there to overcome these problems like Aero dynamic design, structural design, Auxiliary damping device.
- But recently it is found that use of dampers is the best to overcome this problem.

EARTHQUAKE RESISTANCE TECHNIQUES

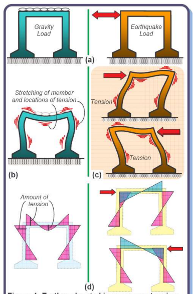


Figure 4: Earthquake shaking reverses tension and compression in members – *reinforcement is required on both faces of members.*

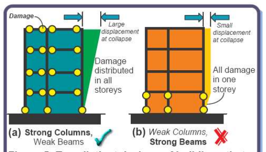


Figure 5: Two distinct designs of buildings that result in different earthquake performances – *columns should be stronger than beams.*

EARTHQUAKE RESISTANCE TECHNIQUES

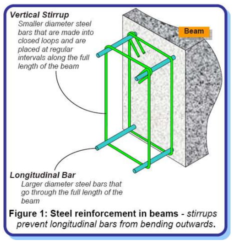


Figure 1: Steel reinforcement in beams - *stirrups prevent longitudinal bars from bending outwards.*

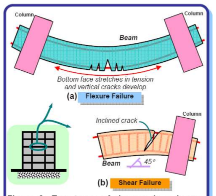


Figure 2: Two types of damage in a beam: *flexure damage is preferred. Longitudinal bars resist the tension forces due to bending while vertical stirrups resist shear forces.*

EARTHQUAKE RESISTANCE TECHNIQUES

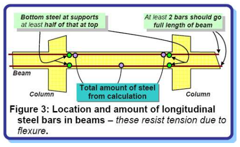


Figure 3: Location and amount of longitudinal steel bars in beams – *these resist tension due to flexure.*

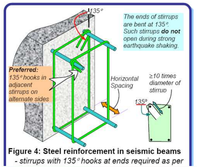


Figure 4: Steel reinforcement in seismic beams - *stirrups with 135° hooks at ends required as per*

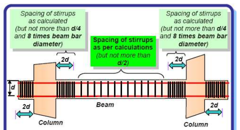


Figure 5: Location and amount of vertical stirrups in beams – *IS:13920-1993 limit on maximum spacing ensures good earthquake behaviour.*

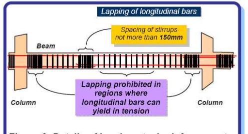


Figure 6: Details of lapping steel reinforcement in seismic beams – *as per IS13920-1993.*

EARTHQUAKE RESISTANCE TECHNIQUES

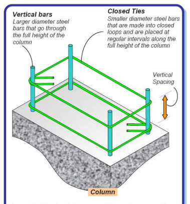


Figure 1: Steel reinforcement in columns – *closed ties at close spacing improve the performance of columns under strong earthquake shaking.*

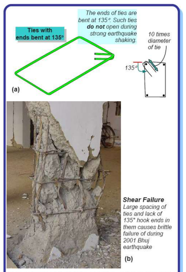


Figure 2: Steel reinforcement in seismic columns – *closed ties with 135° hooks are required as per Indian Ductile Detailing Code IS:13920-1993.*

EARTHQUAKE RESISTANCE TECHNIQUES

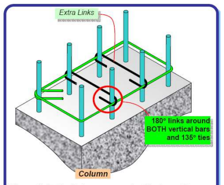


Figure 3: Extra links are required to keep the concrete in place – *180° links are necessary to prevent the 135° tie from bulging outwards.*

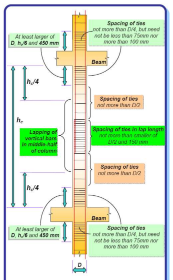


Figure 4: Placing vertical bars and closed ties in columns – *column ends and lap lengths are to be protected with closely spaced ties.*

EARTHQUAKE RESISTANCE TECHNIQUES

Figure 1: Ground storeys of reinforced concrete buildings are left open to facilitate parking – *this is common in urban areas in India.*

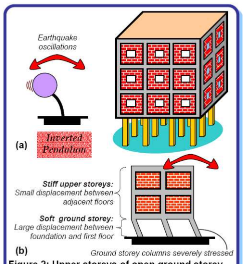


Figure 2: Upper storeys of open ground storey buildings move together as a single block – *such buildings are like inverted pendulums.*

EARTHQUAKE RESISTANCE TECHNIQUES


Photo Courtesy: The EERI Annotated Slide Set CD, Earthquake Engineering Research Institute, Oakland (CA), USA, 1998.

(a) 1971 San Fernando Earthquake


(b) 2001 Bhuj Earthquake

Figure 3: Consequences of open ground storeys in RC frame buildings – *severe damage to ground storey columns and building collapses.*

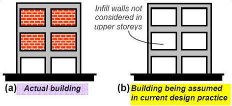


Figure 4: Open ground storey building – *assumptions made in current design practice are not consistent with the actual structure.*

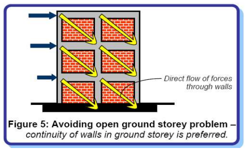


Figure 5: Avoiding open ground storey problem – *continuity of walls in ground storey is preferred.*

EARTHQUAKE RESISTANCE TECHNIQUES

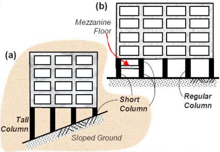


Figure 1: Buildings with short columns – *two explicit examples of common occurrences.*

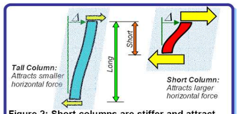


Figure 2: Short columns are stiffer and attract larger forces during earthquakes – *this must be accounted for in design.*

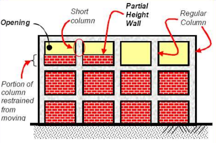


Figure 3: ***Short columns effect*** **in RC buildings when partial height walls adjoin columns –** *the effect is implicit here because infill walls are often treated as non-structural elements.*

EARTHQUAKE RESISTANCE TECHNIQUES

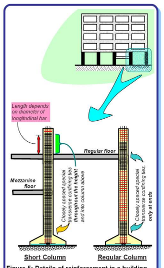


Figure 5: Details of reinforcement in a building with short column effect in some columns – *additional special requirements are given in IS:13920-1993 for the short columns.*

EARTHQUAKE RESISTANCE TECHNIQUES

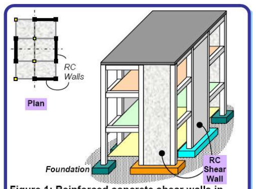


Figure 1: Reinforced concrete shear walls in buildings – *an excellent structural system for earthquake resistance.*

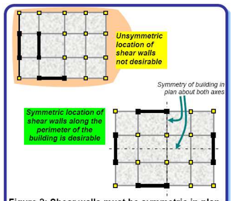


Figure 2: Shear walls must be symmetric in plan layout – *twist in buildings can be avoided.*

EARTHQUAKE RESISTANCE TECHNIQUES

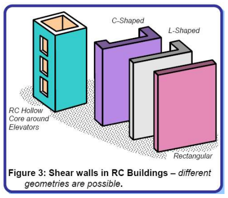


Figure 3: Shear walls in RC Buildings – *different geometries are possible*.

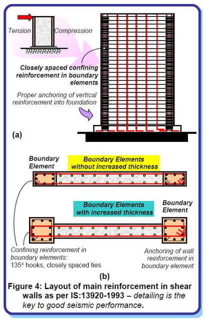


Figure 4: Layout of main reinforcement in shear walls as per IS:13920-1993 – *detailing is the key to good seismic performance*.

EARTHQUAKE RESISTANCE TECHNIQUES

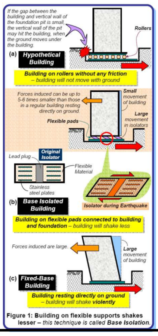


Figure 1: Building on flexible supports shakes lesser – *this technique is called* **Base Isolation**.

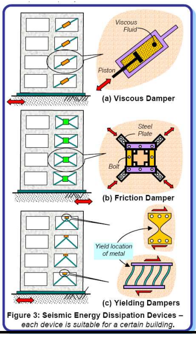


Figure 3: Seismic Energy Dissipation Devices – *each device is suitable for a certain building*.

EARTHQUAKE RESISTANCE TECHNIQUES

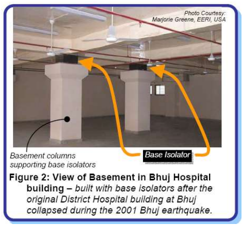


Figure 2: View of Basement in Bhuj Hospital building – *built with base isolators after the original District Hospital building at Bhuj collapsed during the 2001 Bhuj earthquake.*

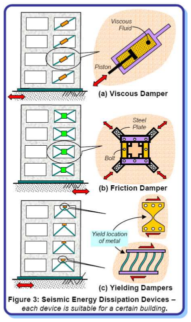
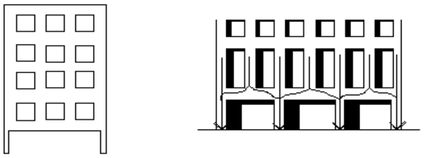


Figure 3: Seismic Energy Dissipation Devices – *each device is suitable for a certain building*.

SOFT STORY

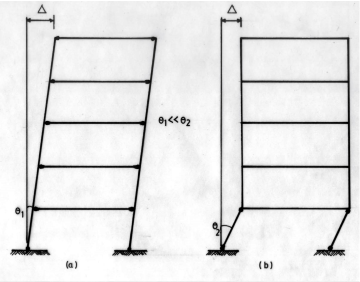
Generally structural or nonstructural walls above.

Soft story & discontinous load path



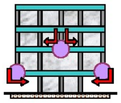
- During earthquake forces tend to be concentrated in the weaker floor or at the point of discontinuity.

ACTIONS OF SOFT FIRST STORY

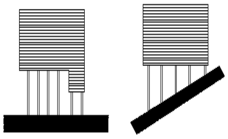


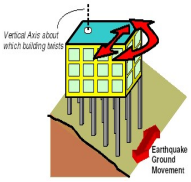
SOFT STORY

Soft Story & Vertical Discontinuity



SHORT COLUMNS





Unequal height columns along the slope causes ill effects like twisting and damage in shorter columns.

Short Columns

Hammering in Buildings

Straddling Pendulum

swinging device technology