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Earthquake Resisting Elements and Techniques in High Rise Buildings

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Abstract: - An earthquake resisting elements are the components that are introduced in a structure to improve its seismic resistance and method of application of these elements are said as techniques. Though structures are designed and detailed as per code provision there remains some possibility of damage or failure in strong earthquake. Performance of buildings may be improved using earthquake resistant elements and techniques. An earthquake produces seismic waves on earth surface of earth due to releases of large energy from lithosphere which produces waves in earth surface causing disturbance in structures resulting failure of seismically weak structures. Seismic waves then travels in horizontal and vertical direction. It causes horizontal and vertical ground movement or vibration. These seismic waves cause disturbances in in buildings. The disturbance caused depends on position of building with respect to the center of disturbance called as epicenter. Intensity of these seismic waves is maximum at center and goes on reducing away from epicenter. Generally horizontal waves are of stronger than vertical so buildings are designed to horizontal seismic forces. These valves travel in any direction but from design purpose it is resolved in two orthogonal directions. Few constructional precautions may help to avoid or minimize damage in buildings. Earthquake resistance of building may be improved with proper design and construction of structures. Some earthquake resisting elements like shear wall, moment resisting frame or innovative techniques like base isolation, or energy dissipation system are used in many high rise buildings to avoid or minimize damage and hence loss of lives and properties. Shear walls are RC member generally introduced in a structure during construction in symmetrical manner. Base isolators in the form bearings are placed between sub and super structure to reduce stiffness of structures. Structures are braced with seismic dampers in energy dissipation system. Composites are used by mixing in concrete or as a warp. All these techniques are reviewed herewith with special attention on shear walls.

Keywords: Earthquake resistance, shear wall, base isolation, energy dissipation

I. INTRODUCTION

Seismic resistant building is that building which has designed and constructed as per seismic resistant design and constructed taking all care of avoiding casualties during future possible earthquake.

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Though structures are designed and constructed as per code provision, there are some evidences of failure in past strong earthquake. Strength, stiffness and energy dissipation behaviour are the major areas where improvement can be made to make structures seismic resistant. Several techniques have been developed and also different composite materials are now in use for seismic resistance improvement. This paper gives an insight on seismic behaviour of structure and improvement techniques used for seismic resistance in practice. Behaviour of shear wall having medium height was studied by [1] to know improvement in its seismic performance using different inbuilt bracing maintaining same reinforcement percentage as that of normal reinforced wall and it was observed that there is significant improvement in seismic behaviour of these shear walls using inbuilt bracing without increasing reinforcement.

A study of improvement of behaviour of shear wall with introducing different inbuilt steel sections embedded in concrete was made by [4] and it was investigated that, use of encased profiles in shear wall improves strength, stiffness and ductility if shear wall. Similar experience was for [15] in testing of composite shear wall with encased profile placed in seismic area in numerical analysis of composite shear wall [5] while testing six walls with different encased profiles. Use of steel tube filled with concrete as a embedded columns or truss as a seismic improving arrangement in shear wall was studied by [2] and in this research it was observed that, strength as well as ductility of shear wall increases using that type of arrangement. It also slower the stiffness degradation speed which indicates improved resistance to seismic forces. Study of behaviour of shear walls using light weight concrete with was made by [14]. In this experiment different arrangement of reinforcement was studied and it was found that, placing web reinforcement in diagonal manner improves behaviour of shear wall significantly. This arrangement transfers seismic forces to foundation effectively than normal way of reinforcement. It also reduces the stresses in compression strut in shear wall. Study of behaviour of shear wall adding GFRP in concrete was investigated by [8] in which it was observed that, there is insignificant degradation and reasonable stability of stiffness during reverse cyclic loading. Negligible residual strain and drift within limit was observed using GFRP in shear wall. GFRP concrete experiences god confinement with concrete playing great role in improving ductility of shear walls. FRP shear wall also experiences fewer cracks than reinforced concrete shear wall due to absence of yielding of reinforcement.

Similar observation was reported to [9] in experimental investigation of GFRP reinforced shear wall. It was also observed that GFRP reinforced shear wall attains their flexural capacities as that of ordinary steel reinforced concrete shear wall. Also it behaves in good manner in anchorage to base.

Moderate damage with limit drift, acceptable energy dissipation, and relative small energy dissipation was observed relative to steel reinforced concrete shear wall. In research made by [3] on shear wall to study improvement in its behaviour using additional arrangement of truss in concealed manner in concrete it was observed that, there is improvement in these seismic behaviour of shear wall as compared to shear wall with normal reinforcement. It was also observed that, there is wide distribution and slow development of cracks using this arrangement which is indication of good seismic resistance and prolonged failure. Use of high performance concrete in earth quake resistant structures was studied by [12]. In this research applications like beam end connections, coupling beam and wall with low height etc. which are mainly shear dominated are discussed and came to conclusion that, performance of this concrete is effective in improving seismic resistance of the structures. Study of behaviour of shear wall using smart material called shape memory alloy (SMA) as a composite was made by [7] in shear wall and it found effective in improvement strength, stiffness and energy dissipation. Analysis of light weight shear wall with different web reinforcement was carried by [13] and found these walls with diagonal reinforcement behaves good with improved shear resistance, ductility with satisfactory dissipation of energy. Recent research has focused on the use shear wall, improvement in behaviour with addition of concealed steel profiles in members, advanced fiber composites, energy dissipation and seismic isolation devices for improving behaviour of structural system. All these are discussed in next few paragraphs.

II. RECENT TECHNIQUES USED

A. Shear walls
B. Base isolation
C. Energy dissipation methods
D. Addition of Composite with concrete
E. Addition of any above methods

A. Shear Walls

Shear wall is the wall provided in structures extending from bottom of structure to top at different location in plan preferably along periphery. Shear walls are used in structures to resist seismic and wind forces which are acting on structures in lateral direction. These are designed to resists these forces mainly along the plane. Generally shear wall structures are of rectangular, barbell or L shape and spans to full height of building from foundation to top. They are generally made of reinforcement, steel or timber. Initially they were used for tall buildings but now days these are also used in midrise buildings. These walls are of large dimensions and heavy in weight. Due to this additional property these walls can stabilize moments due to earthquake forces in structure easily.. They are located in pair in plan of buildings such that, no torsion will create after due to external forces on buildings. Main function of shear wall is to improve seismic resistance of structure Well-developed design methods are available in different codes. Shear walls are used for new structures as well for retrofitting purpose. Shear walls are introduced in a structure to improve strength, stiffness and energy dissipation capacity of structures.

Types of shear wall

- Simply rectangular type (Barbell wall):

These walls are of rectangular or barbell shape having enlarged section at its ends and are reinforced horizontally and vertically. Horizontal reinforcement resists shear whereas vertical flexure.

- Coupled shear wall:

If two structural walls are joined together by relatively short spandrel beams, they form coupled shear wall. The stiffness of the resultant wall increases; in addition the structure can dissipate most of the energy by yielding the coupling beams with no structural damage to the main walls. These walls become essential when series of parallel openings are to be provided on shear wall.

- Rigid frame shear wall and in fill walls:

Rigid framed walls are cast monolithically with frame, whereas in filled frames are constructed by casting frames first and in filling it with masonry or concrete block later.

- Column supported shear wall:

These shear walls are discontinued at floor level for architectural reasons or providing wide space at basements. In such column supported shear wall, the discontinuity in geometry at that level should be specially taken care of in the design

- Core type shear wall:

In some building, core walls around elevators or lift cage are constructed to act as shear walls so those are designed as shear wall.

Use of shear walls

Shear walls are constructed in a building mainly to resist lateral forces due to wind or earthquake.

Purpose of shear wall

Shear wall serves following purposes

- It imparts flexural as well as shear strength to the structure there by improving resistance of structures to wind or seismic forces.
- Sometimes it also functions as a wall around stair or lift cage.
- These walls also carry some part of axial load.
- Shear wall improves stiffness of structure
- Improvement in energy dissipation capacity:
- By providing shear wall energy dissipation capacity of structure increases.

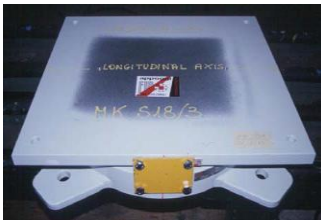
B. Base Isolation

Isolators are the devices which are installed between foundation and superstructure.

Base isolators work like suspensions in vehicles which protects the passengers form shock. Base isolation is one of the best tool controls vibration or shaking of buildings in earthquake in passive manner [18]. Base isolation system is used for improving seismic resistance as an effective system [10]. It is one of the effective methods of reducing stiffness of the building to resist earthquake forces.

Base isolation has made it possible to medium rise masonry or concrete

a) Elastomeric bearing



b) Low friction bearing

Fig. 2 Bearings used in stiffness reduction [6]

Structures capable of withstanding earthquake. Buildings are less likely to be damaged if its natural frequency is less than earthquake frequency. Isolators reduce natural frequency of structures by reducing stiffness of structure. Failure in buildings with fixed base is more than base isolated buildings. Base isolated structures are supported by series of bearing pads which are placed between building and its foundation. Stiffness of building may be reduced by inserting bearings. Fig. 2 shows bearings used in stiffness reduction [6]. Four types of bearings or isolators which are mostly in use named friction bearing, roller bearing, elastomeric bearings and spring bearing. Fig.2 shows two categories named elastomeric and sliding. Elastomeric performs well in large buildings with heavy axial loads and sliding for small building with light load. Elastomeric bearings and low-friction bearings function as the devices for stiffness reduction. The elastomeric bearing and low friction bearing can also call as seismic isolators. All these bearings are made of heavy metals. Base isolation is suitable for low or mid - rise buildings or bridges and generally for new structures and strengthening of old structures.

C. Energy Dissipation System

Another way to seismic strengthening is to use energy dissipation devices called dampers. In this method structures are equipped with additional devices called seismic dampers which have high damping capacity which can greatly decrease the seismic energy entering in buildings and minimizes building damage. Different type of energy dissipation devices is available commercially and many numbers are in development. Generally they are made of metals heavy metals to suit for particular load. There are many type of energy dissipation devices available in market and choice of particular type depends on nature of structure. These devises dissipates seismic energy and protects structures during earthquakes. These devices limits the deformations of structural member thereby reduce damage. Their effectiveness depends on properties of structure [17]. In one concept named damage control system, additional

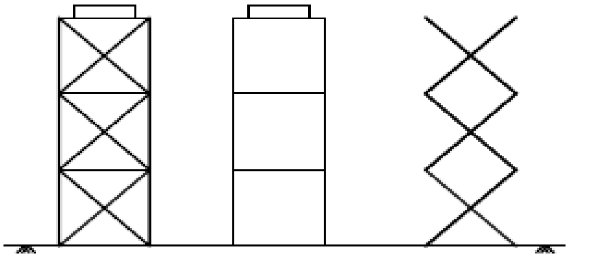


Fig. 4 Damage controlled structure [6]

structure is introduced in buildings to control damage in main structure while earthquake[6]. System controls damage in buildings with energy dissipation. This system consists primary structure and secondary structure. Structure is pre strengthened with secondary structures called as seismic dissipaters. In earthquake damage occurs to only to secondary supporting system which can be repaired with minimum cost and time. Main structures remains intact without causing any damage. One of the arrangements is as shown in Fig. 4 in which main structure equipped with such a seismic resisting system and separate primary and secondary system is shown.

D Addition of composite to concrete

Addition of composite materials is another technique of improving seismic resistance of structures. These composite materials are added in concrete to improve its structural behaviour if structural members. Composites are mixtures of two or more materials so as to form new material which is superior to primary material. Recently different composite materials are available are in practice for improving behaviour of normal concrete. It is made if two materials, one of which bulk material like glue and other are having reinforcing properties as fibers. These two form composite material [11]. One of the materials, called the reinforcing phase, is in the form of fibres, sheets, or particles, and is embedded in the other materials called the matrix phase.

Reinforcement + Matrix = Composite

These composite materials have superior properties than their individual properties to suit their application at different use. Two materials do not mix each other but act as a single material. Fiber-reinforced polymer composite are extensively used in various industries from many years and now it has become a predominant material from past some decades in civil engineering in seismic resistance improvement, repair, strengthening and retrofitting due to its qualities like high strength, low cost, corrosion resistance, lightweight etc. [16]. FRP composite materials are widely used in improving strength of particular members due to their added properties like strength and ductility. These materials are extremely strong with high ultimate strain. They are chemically inert and corrosion resistant.

Moreover, they are very light and that facilitates easy implementation at site with fewer supporting structures. These materials consist of fibers of different type and the most used are Glass fiber reinforced polymer, aramid fiber reinforced polymer and carbon fiber reinforced polymer. FRP composites now days used in variety of applications ranging from addition of few percentages to complete replacement of steel in concrete replacement of steel.

FRP composites are also used in structural elements to be used where problem of conjugation is arises in partial replacement of reinforcement in heavily reinforced members. Majority used fibers in various industries are basalt, carbon, glass and aramid. Some other type viz. asbestos, steel, polyester quartz etc. are also widely in use. The main function of these fibers is to carry axial load along their length and imparting strength to structural members. These are also used in new structures as well as retrofitting of failed structural members. They are lighter in weight and are having good strength. Glass fibers are used widely and become common as they are cheaper, available in different form, and good properties to use in structures. Carbon fibers can be of many type or grades according to their constituent. These are costly than glass fibre but have high tensile strength, modulus of elasticity and low density and thermal coefficient. Aramid fibers are polymeric fibers they are made rigid for using them in composite. The main characteristics of these fibers are their high strength, resistant to impact, moderate elastic modulus and low density. Basalt fibers are obtained from melting of crushed lava deposits they are having good properties to use as composite materials. Basalt fibers are fire resistant and having good acoustical properties than glass fibres and are of low cost. All these FRP are used as external warping or by mixing in concrete.

III. RESULTS

As per study of different seismic resistant elements and techniques following results are recorded.

Table – I: Findings of seismic resistant elements and techniques

Particulars/ Elements & technique	Location	Material	Applicability and use
Addition of Shear wall	Preferably along periphery of building	Reinforcement concrete, steel or timber	Tall and, mid-rise buildings improving strength, stiffness and ductility to structure
Base isolators	Between sub and super structure	Generally of steel, rubber or composite	For low or mid- rise structure by controlling horizontal acceleration due to earthquake force, reduces stiffness
Energy dissipaters	Every storey as a braces	Steel or addition of any suitable metal	For heavy and all height structures, by damping seismic forces, dissipates seismic energy
Addition of Composite with concrete	At any height, at any part	Fibers and matrix	Decorative works, thin members, by improving ductility and energy dissipation, controls opening and extension cracks

IV. CONCLUSION

Different techniques are currently available for improving seismic resistance of structure which improves stiffness, strength and/or ductility. These techniques include the use of shear wall, base isolation system, energy dissipation system or use of composite materials. Seismic resistance RC structures can successfully improve with use of concealed steel profiles, by using advanced techniques or composite materials. The addition of shear walls can be suitably done as per requirement to improve strength, stiffness and ductility of structures. FRP composites can be used effectively for improvement of seismic behaviour of structure which helps to increase ductility, control opening and widening of cracks and to reduce stiffness and strength degradation. Energy dissipaters dissipate energy of seismic wave thereby reducing seismic effect on structure. Base isolator reduces stiffness of structures which controls damage during earthquake. Each seismic resistant technique works with technique and different principle to resist earthquake or wind load. These techniques may be used individually or in combination of any two or more method. Finally it can be concluded that though possibility of damage or failure of structures during earthquake can be reduced by using proper seismic resistant elements and techniques. Structures can be made seismic resistant with addition of shear wall, using advanced constructional techniques and using advanced composites materials to show superior performance over conventional methods.

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- Analysis of structures using Finite element
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Sanjivan Mahadik, S. R. Bhagat, “ Use of composite materials in seismic retrofitting of RC shear wall”, International Journal of Recent Technology & Engineering(IJRTE), Blue Eye Intelligence Engineering & Science Publication Pvt. Ltd., Volume- 4, Issue- 6, pp 4751, Jan 2016.

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