Research Article *ISSN: 2319-507X*
Shashikant Deshmukh, IJPRET, 2013; Volume 1(8): 187-191 *IJPRET*

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SEISMIC RETROFITTING OF BUILDING

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Accepted Date:

27/02/2013

Publish Date:

01/04/2013

Keywords

Building

Seismic

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Abstract

An earthquake causes an unprecedented loss of life and property. In order to reduce this loss retrofitting and restoration of building can be done. Retrofitting is the process of making fit o make improvement in deficient structure for future uncertainty. Restoration is the process o existing damaged buildings bringing back to a former condition. To classify vulnerable building and to carry out a rational retrofitting project, proper analysis is needed, which takes into account the post - elastic response of building. Retrofitting of existing structures with insufficien seismic resistance accounts for a major portion of the total cost of hazard mitigation. Thus, it is o critical importance that the structures that need seismic retrofitting are identified correctly, and an optimal retrofitting is conducted in a cost effective fashion. Once the decision is made, seismi retrofitting can be performed through several methods with various objectives such as increasing the load, deformation, and/or energy dissipation capacity of the structure. Retrofitting o concrete structures has been attracting the attention of researchers over the last two decades Various retrofit options available today include crack injection, steel jacketing, RC carbon jacketing.

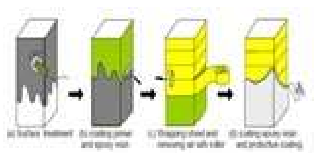


Fig 1: Process of application of AFRP sheet

Also Aramid Fiber wrapping is an effective measure for strengthening of RC structural elements It is based on concept that strength of concrete increases under confinement. Confinement also enhances ductility of material significantly. Strengthening of concrete elements by Aramid Fibe wrapping is comparatively easy to execute but it cannot replace other measures of seismi restoration. The peculiar process of Aramid Fiber Sheet wrapping is done as shown in fig 1. The retrofitting for reservoir is enormously effective for enhancing the strength of reservoir and can be completely done by using Aramid fiber sheet. Its application to reservoir is shown in following figure.

INTRODUCTION:

An earthquake is most deadly catastrophe which strikes within second without any warning. In most of the areas proper precautions were not taken while constructing the buildings. So during future probable earthquake there will be heavy loss of life and property. To avoid this, retrofitting of structure is most important. Construction of new, retrofitting of old and restoration of damaged building requires consideration of all aspects needed for adequate safety and economy. Therefore, depending upon present condition of building the retrofitting measures will have to be adopted.

Fig 2.Retrofiting reservoir

RESPONSE OF BUILDING TO EARTHQUAKE MOTION:

Earthquake causes random motion of ground causing structures to vibrate. The vibration intensity of ground expected at any location depends upon the magnitude of earthquake, depth of focus, distance from epicenter and geological characteristics of foundation strata on which structure stands. The force exerted on a building due to earthquake depends upon the height of building as well as movement of ground. For heavier buildings the force is more and consequently larger damage as comparative lighter roof.

NEED FOR SEISMIC RETROFITTING:

An Existing structure was initially not designed and constructed to resist an earthquake. Further, retrofitting would be essential if the structure was initially designed and constructed to resist an earthquake but.

a) The loading/load carrying parameters have changed since it's construction, due to: the present structural quality being bad due to poor maintenance or aging loads have increased due to change of mode of use alterations/extensions are carried out or are contemplated

b) The design criteria have changed due to: up gradation of seismic zone, importance factors, etc revision in methodology or specifications of structural design/detailing

SEISMIC ASSESSMENT:

Seismic assessment is a natural prerequisite to seismic retrofitting. Ideally, the purpose of a comprehensive assessment should be to "assess the seismic resistance of the structure for the present criteria and to check the feasibility of one or more practical schemes of retrofitting keeping in mind the aspect of economy and convenience to owners". Hence, every task of assessment should pass through a set of well-defined steps, should refer to or create useful references and end with a well-structure report giving recommendations for the schemes of retrofitting along with their merits, demerits and limitations. Primarily, the process of assessment will consist of

Field Work: This will entail collection of data by detailed inspection of structure.

References: References should comprise original drawings, drawings of extensions, test results.etc as compiled data.

SEISMIC DESIGN FORCE:

To resist the ground motion due to earthquake, seismic design force is required. Some amount of damage is acceptable in structure. If the structure is ductile, it will be able to absorb considerable amount of energy without collapse, and hence, the ductility is effective in reducing the design force requirement on the building. Considerable amount of over strength is introduced in the building during design and construction, that is, the real strength of building is much higher than the design strength due to numerous factors of safety and other factors.

Thus, it is clear that the earthquake resistant building is expected to perform satisfactorily even when subjected to earthquake loads much higher than code-specified design forces. It also mean that in the event of design level earthquake shaking of building may undergo some damage and hence it's inelastic respond is important.

OPTIONS FOR SEISMIC RETROFITTING:

The retrofitting options that can be considered are:

a) Jacketing of columns only, b) Providing additional beams, and

c) Providing both column jacketing and additional beams.

Each of these retrofitting options can be carried out for

1) First storey only,
2) First two storeys only,
3) First three storeys only, and
4) All the four storeys.

Column Jacketing - In the case of column retrofitting, cross- section of 300x300 columns is increased to 500x500. The additional longitudinal steel provided is 1% of the total column area. Jacketing is employed for repairing highly damaged beams and column. Provision of additional beams - In this scheme additional beams are provided along the column lines. The beam is projected 200mm below the slab, and its width is kept as 1146mm so that it flushes with the column head. The bottom bars in the beam are made continuous at the supports by taking them through holes drilled through the column head.

OPTIONS FOR SEISMIC RETROFITTING:

The graphs shows the base shear-drift relationships for different schemes of retrofitting. For the first storeys only - Improvement in strength obtained by the three scheme are almost similar, the lateral stiffness is about the same for the cases involving beam retrofitting alone and column jacketing alone, but the drift capacity is much higher in column retrofitting. Hence, it is obvious that in case only one storey is to be retrofitted, it is better to jacket the columns.

For first two storeys only - Improvement in strength by the three schemes is quite comparable and the beam retrofitting significantly reduces softening caused by sagging hinges. However, in view of the significant higher drift capacity, the column jacketing is still a preferred mode of strengthening. For first three storeys only - Increase in strength due to beam retrofitting alone and column jacketing alone is comparable but much larger due to column plus beam retrofitting. Same is the case when all the four storeys are retrofitted, beam retrofitting alone and column jacketing alone increase the strength. However, if both beam retrofitting and column jacketing are undertaken in all the four storeys, strength increases.

The above results help in deciding one scheme of retrofitting over the other.

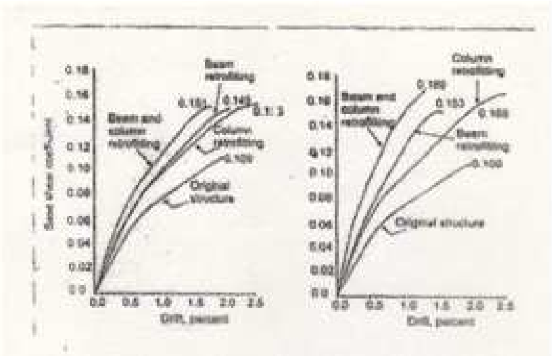


Fig 3 (a).First Storey (b)First Two Storey

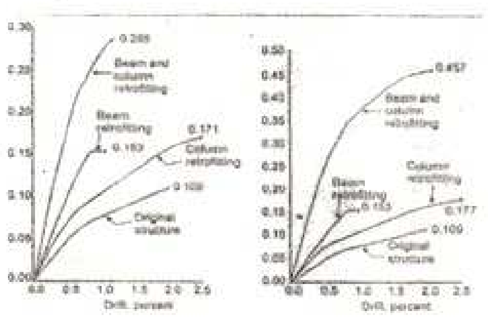


Fig 4. (a)First-3 Storey (b) First-4 Storey

(FORCE-DISPLACEMENT RELATIONS FOR RETROFITTING)

RESTORATION:

Restoration is nothing but the up gradation of structure. It is done for improving the seismic performance of deficient structures, in term of their strength, stiffness and ductility. The deficient structures are either damaged by seismic activity, or are in operation but designed for lower level of seismic design specifications. Damage to structure in the event of earthquake can occur due to deficiencies in the superstructure or due to deficiencies in foundation system or due to due to geological hazard.

Commonly used up-gradation strategies are

Local modification of components:

This includes measures like improvement of connections or component deformation capacity. This is economical when only a few components of a building are deficient but not the overall building. Measures like filling up of cracks, shotcreting are adopted.

Removal of existing irregularities:

This is effective if the condition assessment of the structure shows that the irregularities result in inability of the building to meet selected structural performance level. Expansion joints can be introduced to divide a single building having an irregular shape in to suitable structure.

Global mass reduction:

It is useful when the outcome of seismic re-evaluation attributes the deficiencies to excessive mass or unbalanced building mass, global structural flexibility or global structural weakness.

Global structural stiffening:

It is applicable when the condition assessment indicates deficiencies attributable to excessive lateral deflection of structure, and when critical component do not have adequate stiffness to withstand the resulting deformation.

Enhancement of structural ductility:

Ductility of the structural is its ability to absorb energy in the inelastic range. Ratio of deformation at collapse to that at yield point is often taken as ductility ratio.

Energy dissipation:

It is effective when seismic re-evaluation shows that the structure is not generally deficient but the earthquake hazard level is higher than that considered during original design.

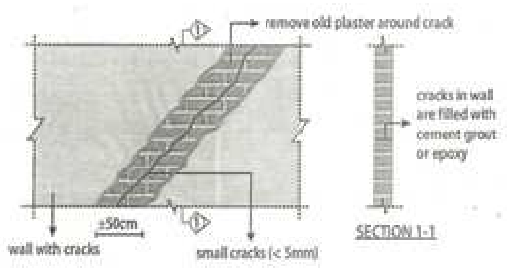
Structural strengthening:

It is most commonly used. It is of two types, Global Structural Strengthening (GSS) and Local Structural Strengthening (LSS). GSS is achieved by providing supplemental strength to such a lateral force - resisting system so as to raise the threshold of ground motion at which the damage occurs. LSS denotes repairing / strengthening or replacement of damaged or deteriorated structural element to augment their capacities. Repairing or strengthening of damaged and deteriorated structural element can either be done by adopting the conventional method of using similar material such as reinforcement, concrete, and structural steel; or by fiber wrapping.

RESTORATION MEASURES:

Crack Filling:

The formation of crack is the most common type of damage in buildings. Cracks in RC structural elements are filled up by injecting grouts when concrete and reinforcement are not damaged. Injection of cement grout, epoxy resin, compatible polymers, etc. is common for repairing cracks having width more than 0.75mm but less than 6mm. Cracks of width less than 0.75mm may not be repaired.



Shortcrete:

Shortcrete is a method of applying a combination of cement-sand mortar, which is mixed pneumatically and conveyed in a dry state to the nozzle of a pressure gun, where water is mixed just prior to expulsion. The material bonds perfectly to properly prepared surfaces of any material. It can be effectively applied to curved or irregular surfaces. It's high strength after application and good physical characteristics, make it an ideal means to achieve added structural capability in walls and other elements- There are some restrictions of clearance, thickness, direction of applications, etc, which need to be understood and followed.

JACKETING:

Jacketing is employed for repairing highly damaged beans and columns or strengthening inadequate structural elements. Since it increases the capacity of structural elements, jacketing is really a strengthening procedure, although it can also provide local repairing. It is performed by means of additional reinforced concrete, a steel profile skeleton or steel encasement. One of the basic assumptions of strengthening by jacketing is that the newly-introduced RC portion will act monolithically with the existing portion of the element. To ensure the monolithicity, dowel bars should be provided, in case of structural elements having large cross-sections. It is suggested to provide dowels when any side of a cross-section of a damaged member is more than 350mm long after removal of loose materials.

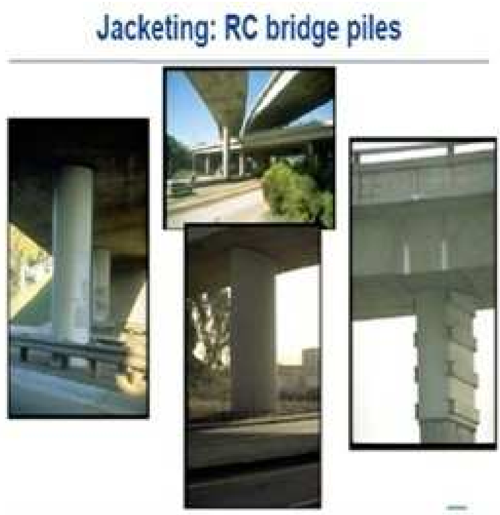


Fig 5. JACKET: Computer-Contorl Robot wraps Concrete Column with carbon fibers.

Steel Jacketing:

In this method, which was originally formulated for circular columns, two half-shells of steel plate, rolled to the column radius oversized by about 25mm are positioned over the column to be retrofitted, and are site-welded up the vertical seams. The gap between the jacket and the column is grouted with a non-shrink cement grout after flushing with water.

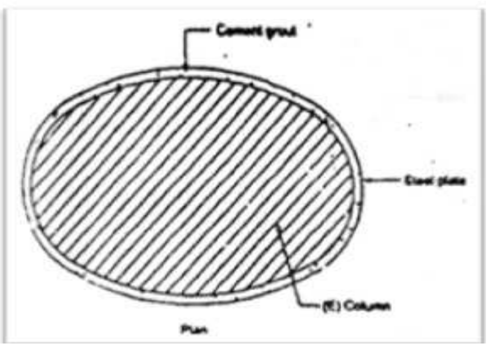


Fig.6 : Steel jacket for concrete column

Typically, a space of about 50mm (2 inch) is provided between the jacket and any supporting member (footing or column below or beam) to avoid the possibility of the jacket acting as compression reinforcement. The jacket is effective in providing passive confinement. The behavior of the steel jacket is analogous to that the continuous hoop reinforcement. For rectangular columns, the behavior of an oval jacket, which provides a continuous confining action similar to that for a circular column, would be superior. The space between the jacket and the column is filled with concrete. Rectangular columns so retrofitted have also performed exceptionally well in flexure and shear. Attempts to retrofit rectangular columns using rectangular jackets are not as effective, have been less successful, but are used; In this case four corner steel angles are provided with a steel plate tying these angles. The low effectiveness of rectangular jackets is due to the fact that the confining action of the rectangular jackets comes into play only after the lateral bending of the jacket sides (plates), which is a very flexible action in comparison to the membrane tension action developed in an oval jacket. Similar lines to column jacketing, complete with additional stirrups may be provided. This may require propping of the adjacent slabs.

Shear Wall: Walls is a common measure for strengthening of a structure. Two important aspects are to be considered in engineering this measure -

a) New shear walls must be appropriately located in order to avoid significant torsion

b) The connections between the new shear walls and existing structure are of great importance.

Infill Walls:

Introduction of new infill walls is an effective measure for removal or lessening of irregularities as well as global strengthening of structure. Like shear walls, two aspects that need to be taken care of in engineering of new infill walls are avoidance of torsion and appropriate connection between new walls and existing structures.

Removal of Weakness Caused By Openings:

Openings for doors and windows are often a source of weakness of the wails. Filling the opening, if permissible, is an easy approach to overcome this weakness. Filling of openings can be engineered following the same methods as for shear walls and infill walls.

Fibre Wrapping:

It is an effective measure for strengthening of RC structural elements. It is based on concept that strength of concrete increases under confinement. Confinement also enhances ductility of material significantly. Strengthening of concrete elements by fiber wrapping is comparatively easy to execute but it cannot replace other measures of seismic restoration

Until a few years ago, the only available techniques for upgrading vertical structural elements were those presented in the previous sections. Only recently, have fiber reinforced polymers (FRP) been recognized as an effective strengthening technique for degraded or inadequate reinforced concrete members. The remarkable properties of FRP, such as high specific strength, and mostly also high specific stiffness, low thickness and weight, and resistance to corrosion, allow them to be applied in a construction site without serious difficulties. Normally carbon fiber and/or fiberglass are used, sometimes also aramid-fibers like Kevlar ¥ or Twaron ¥, in combination with a resin matrix, usually epoxy. Numerous combinations can be made, which is one of the main advantages of FRP jackets. Experimental studies and pilot applications have demonstrated that, by wrapping vertical elements with FRP jackets placed on one or more layers, a confining action on the concrete is obtained that enhances both strength and ductility of the whole element. In the case of columns, FRP composite jacketing techniques have been shown to have performance capabilities comparable to and in some cases better than columns retrofitted through the application of the above-presented conventional methods.

The confinement action so obtained is of the "passive" type, that is, it develops only consequent to the transverse dilation of the compressed concrete core that stretches the confining device, which thus,

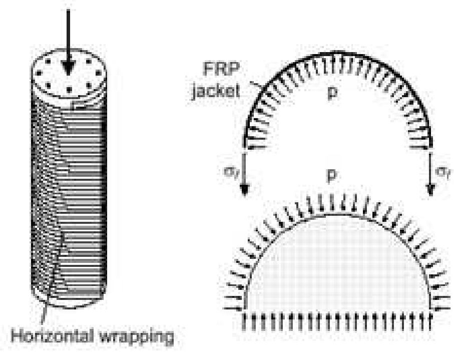


Fig 7: Confining columns with FRP

taking advantage of the transverse dilation of the compressed concrete core under axial load.

SEISMIC RETROFITTING TECHNIQUES USING

FIBRE COMPOSITES

1) Fibre Sheet Wrapping:

After preparation of the surface a low viscosity primer is applied on the concrete surface to improve bond between the fiber sheet and the concrete, fiber sheets are cut to required sizes,. An allowance for the length of lap joint must be given while cutting the sheets. The lap length is determined based on test results in the laboratory and the precision that can be maintained in construction. The cut fiber sheets are rolled on a circular spindle to make them easy for wrapping.

It is very important to choose the right epoxy resin for wrapping application. The resin must be viscous enough to hold the fibers in place. On the other hand, the resin must wet the fiber thoroughly and there should not be any dry pockets. The viscosity of the resin, therefore, is a tradeoff between these two contradicting requirements. The resin is usually a two-part mix. The mixing of the parts must be thorough. The resin should not entrap air during mixing. Therefore, the speed of the stirrer and extremely important parameters. The mixed epoxy resin is applied on to the concrete surface that is to be wrapped.

There are two methods of laying-dry layup and wet layup. In the dry layup, the dry fiber sheet is applied on the concrete surface freshly coated with epoxy resin. In the wet layup, the fiber sheet is wetted with epoxy resin before wrapping. Although wet layup ensures a better wetting. It is not always convenient to use wet layup, especially in the hot climate of Gujarat. Therefore, dry layup has been used in the present work, the sheet should not be slack at the time of wrapping and care must be taken to maintain the intended fiber direction. The sheet is rolled by serrated Teflon rollers, so that the resin oozes out though the sheet and wets the sheet properly. Rolling must always be in the direction of fiber. The wrapped ends must be pressed thoroughly to avoid any defect in bond Spreading some extra resin on the lap area is a good idea. The wrapping must be completed within the pot life period of the resin that is usually 20 to 30 minutes. Therefore, it is advisable to mix small quantities of resin at a time. A thin coat of resin is applied after the wrapping is over. After the resin is completely cured (usually 24 hours), the wrap is inspected to rule out any defect. A micaceous polyoxide top coat is applied on the wrapped surface to protect the resin from deterioration from exposure to ultraviolet rays.

Aramid fibers :

After some years of investigation aramid fibers have been manufactured by extruding a polymer solution through a spinneret, resulting in fibers with high thermal stability, high strength and high stiffness. . Typical useable temperature for aramid fibers range from -200 to +200 degrees. Since ultraviolet rays degrade aramid fibers, the fibers should be embedded in a protective resin matrix if exposed to sunlight.

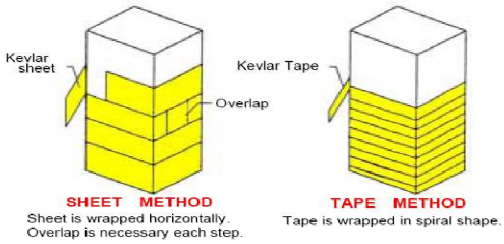


Fig 8 WRAPPING Methods for AFRP Sheets

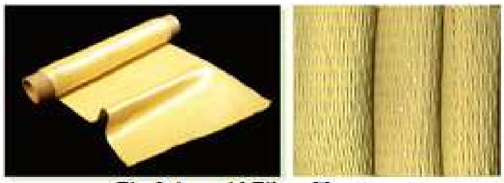


Fig 9 Aramid Fiber Sheets

Table No.1 Specifications of the Reinforcing materials

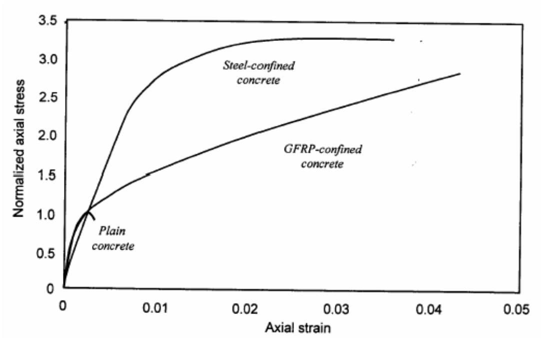
	Type	Weight (g/m^2)	Thickness (mm)	Width (mm)	Tensile strength (N/mm^2)	Young's modulus ($\times 10^3$ N/mm^2)
Aramid 1	40tf	280	0.193	300	2060	118
	60tf	415	0.286			
	90tf	623	0.430	300		
Aramid 2	40tf	235	0.169	500	2350	78
	60tf	350	0.252			
	90tf	525	0.378			

Fig 10. Applications of AFRP Sheets in Building Structures

Fig 11. (a) Strengthening of Slab (b) Strengthening of Beam

COMPARISON BETWEEN STEEL AND FRP-CONFINED CONCRETE

Figure no 10 and 11(a,b) shows the axial stress-strain behavior of a steel-confined concrete tubes together with the typical axial stress-strain behavior of a GFRP-confined concrete tubes, which is being compared to unconfined plain circular concrete [Samaan et al 1998]. Both curves are different due to the opposite nature of the modulus of elasticity, containing high value for steel and low value for GFRP. Because of high modulus of steel, confinement of the concrete core set off a relatively low load levels, as only a small lateral strain in concrete is needed to develop significant hoop (circumferential) stresses, resulting in a confining pressure. Conversely, the GFRP-confined concrete is insensitive to small lateral expansion which displays a similar curve to the unconfined concrete curve up to the unconfined strength fc', primarily due to the low hoop modulus of the GFRP jacket. After reaching fc', the curve (tangent stiffness) stabilizes at a constant value until the ultimate strength is reached from fiber rupture. This can be explained from when the unconfined strength is being approached, major micro cracking develops that leads to high lateral expansion that will result in activation of the FRP jacket. This induces variable lateral confining pressure which leads to a continuous increase up to rupture of the fibers; the increase is due to the linear FRP characteristics. As it was mentioned already, the behavior for steel tubes (jackets) is totally different from FRP tubes. Steel jackets induce a constant confining pressure which is not dependant of the lateral expansion of concrete, once yielding of the steel occurs at low strain level [Mirmiran, 1995].



Above graph shows the Stress-strain response of GFRP-confined concrete versus steel-confined concrete (Samaan et al., 1998)

CONCLUSION:

Now days the earthquakes give rise to grow awareness among people and consulting engineers. Thousands of structures in major metropolitan areas and elsewhere may need seismic assessment and retrofitting. The concept of seismic assessment and retrofitting is comparatively new and requires lot of standardization. It is fairly possible at a reasonable cost to remove many of the constructional defects and introduce enough strength to meet the future earthquake resistance requirement by applying retrofitting.

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