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Seismic Evaluated and Retrofit of Existing Buildings

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Abstract

Most structures in Iraq were designed only for gravity loads, these make buildings present a major quandary for the person or agency concerned with reducing earthquake hazards. Objectives of this research are to develop a computer program for the evaluation existing gravity loads buildings to identify any weak columns in the structure that should need retrofit according to value of damage index . Seismic retrofit techniques are previewed and discussed in this research .

The results identify the location and severity of the damage member, indicate that the sever damage maybe concentrated in the upper stories and can possibly lead to further collapse. According to these results, a minimum retrofit should be considered to reduce the risk of structural collapse.

Keywords: Seismic, Retrofit, Reinforced concrete, Damage

الخلاصة

غالبية الأبنية في العراق مصممة لتحمل قوى الجاذبية فقط مما يشكل حرجا كبيرا تجاه الشخص أو الهيئة التي تحاول تفادي خطر الهزات الأرضية. أن ألغاية من هذا البحث هو عمل برنامج لتقييم الأبنية الموجودة لتعريف ألأعمدة ألضعيفة في ألمنشأ اعتمادا وطبقا ألى قيمة مؤشر الضرر. لقد تم استعراض ومناقشة تقنيات التدعيم تجاه ألهزات ألأرضية .

بينت ألنتائج المواقع المتضررة والخطر و اشار البحث الى ان ألخطر يمكن أن يكون في الطوابق العليا من البناية وهذا يحتمل ان يؤدي ألى ألفشل وطبقا ألى هذه ألنتائج فأنه أصبح من اللازم اجراء التدعيم لتقليص الخطر جراء فشل البناية.

I- Introduction:

The behavior of multistory buildings during story earthquake motion depends on the distribution of mass, stiffness and strength in both the horizontal and vertical planes of the building. The main factors that affect on the behavior of frames subjected to large reversed inelastic deformations are behavior of steel reinforcement , extent of cracks in concrete, bond deterioration and bar slippage , shear deformation and axial force.

Building code requirements for seismic lateral forces for high seismic areas in Iraq have increased in the past years. Improved designer requirements and methods can be expected to reduce damage of newer buildings to acceptable levels in the event of a moderate to strong earthquake. However, most building was constructed prior to any specific requirement to design against earthquakes. These buildings present a major quandary fir person or agency concerned with reducing earthquake hazards. Therefore, retrofit of these buildings was very important.

II- Objectives and Scope:

To retrofit columns structures, first must be evaluated, therefore it should be develop a computer program to be used to evaluate existing buildings resistance (identify damage state in individual elements columns and in the entire structure) to achieve this goal we take the steps in Fig.1, in our consideration.

1- Perform information of the existing building related to configurations, structure and ground conditions.
2- Perform an equivalent static analysis using the Iraqi seismic code conditions ((1)).
3- Compute a damage index in columns and global damage index to be defined later.
4- According to value of damage index, we can estimate the damage state.

As well, as preview and discussed seismic retrofit of gravity load design reinforced concrete existing buildings.

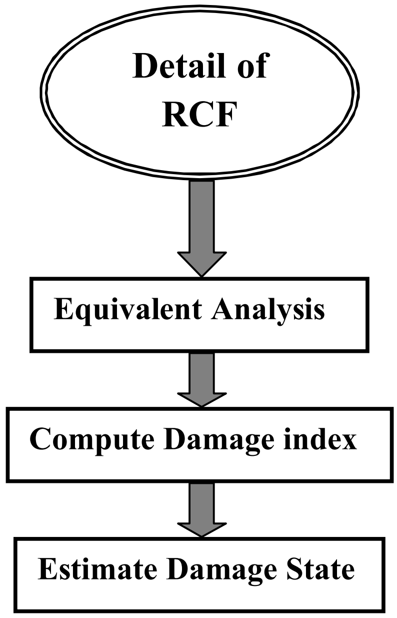


Fig. (1): Out line of program

III-Evaluation:

A-Damage Model:

Park, Ang., and park, et al.… ((2, 3)) provided a formal method for evaluating structural damage of reinforced concrete building under earthquake ground motions. They investigated the statistics of the parameters affecting damage, and calibrated the measure of damage from empirical data.

Park and Ang´s model is,

$$D_e = \frac{\theta_{\max}}{\theta_u} + \frac{\beta}{M_y \theta_u} \int_t E \qquad ((1))$$

Where θ_{max} and θ_u are the maximum required rotation and rotational capacity of the member, with θ_u which refers to monotonic loading conditions, M_y is the member yield moment capacity (if the maximum moment, M_u is the smaller than M_y, M_y is replaced by M_u) and

$$\beta = \left(-0.447 + 0.73\frac{l}{d} + 0.24 n_o + 0.314 \rho_t \right) * 0.7^{\rho_w}$$

Where l/d= shear span ratio (replaced by 1.7 if l/d <1.7); n_o =normalized axial stress (replaced by 0.2 if n_o<0.2), ρ_t =longitudinal steel ratio as a percentage replaced by 0.75% if ρ_t<0.75% ρ_w =confinement ratio.

It is pointed out that equation ((1)) , is expressed more convenient (for analysis purposes) from of rotations , while the original Park-Ang index is based on displacement (δ), which is more convenient to us when test results are evaluated. For global damage index, Park and Ang suggested to combine the individual member damage indices, using the dissipated energies as weighting factors,

$$D_g = \sum_i \frac{D_e^i E_i}{\sum_i E_i} \qquad ((2))$$

Where D_g = global damage index, E_i = total energy dissipated by ith member and D_e^i = local damage index for ith member.

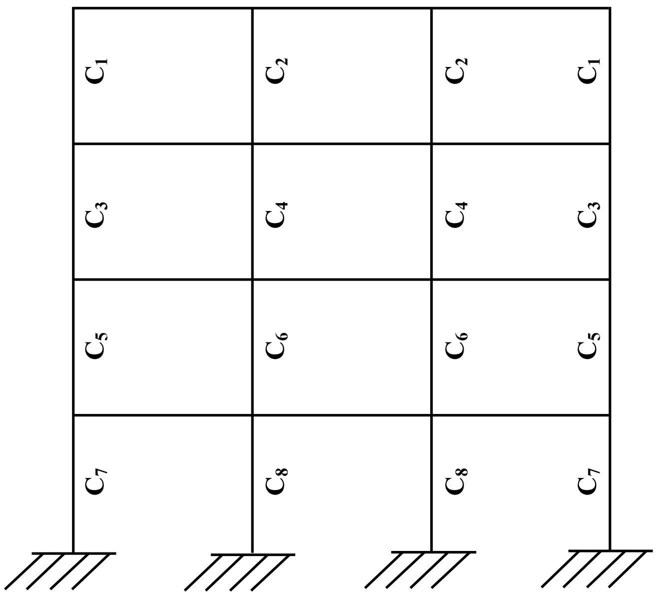
The previous damage index is formulated between 0.1 and 1.0 , indicating elastic behavior , and absolute collapse respectively, the damage index and damage states are calibrated ((2)) , and their correlation is shown in table ((1)). Individual performance indicators are established for individual members and for story levels. Each indicator is valuable to shown damage distribution and concentrations. More details are described in Ref.((2)).

Table ((1)): Correlation of damage indices and damage states ((2,3))

Usability	Degree of damage	Damage (service) static	Limit state damage index	Appearance
		Undamaged		Undeformed/ uncracked
			0.00	
usable	Slight	Serviceable		Moderate to severe cracking
			0.2-0.3	
	Minor	Repairable		Spalling of concrete cover
Temporary – Unusable	Moderate		0.5-0.6	
	Severe	Irreparable		Buckled bars , exposed core
			>1.00	
Unusable	Collapse	Collapse		Loss of shear/ axial capacity

B- Application and Result of Analysis:

Detail of structure that have analyzed shown in Fig. ((2)). this structure has been designed to resist the gravity loads only. The lateral forces were determined in accordance V=2.5ZIKSW, the structure were located in sever seismic zone 3 , z = 0.09 , I = 1.0 for occupancy – importance factor , k = 1.0for ductile moment resisting space frames S= $0.5471XT^{-1.304}$ characteristic of soil , w = 3686 kn for total weight , the fundamental period of this frame is approximately T = 0.254 sec , The maximum roof displacement 0.019 m , maximum interstory drift = 0.01 m , results of analysis shown in Fig (3). Fig (3c) display calculated damages in the vertical column. The dashed line represents the limit of repairable damages, thus any point to the right of the dashed line represents damage is beyond repair. This plots easily identify the location and severity of the damage member, they indicate that the sever damage may be concentrated in the upper stories and can possibly lead to further collapse. A Comparison of the performance indicators are shown in table (2).



Elevation-Frame spacing 5 m, with height 3 m For each stories.

	d (m)	As% (m^2)	As% (m^2)	b (m)	h (m)	ρ_w
C_1, C_2, C_3	0.340	0.10	0.10	0.300	0.390	1.04%
C_4, C_5	0.340	0.17	0.17	0.300	0.390	1.2%
C_6, C_7	0.410	0.18	0.18	0.390	0.460	1.24%
C_8	0.410	0.19	0.19	0.390	0.460	1.18%

Fig. ((2)): Detail of example office building.

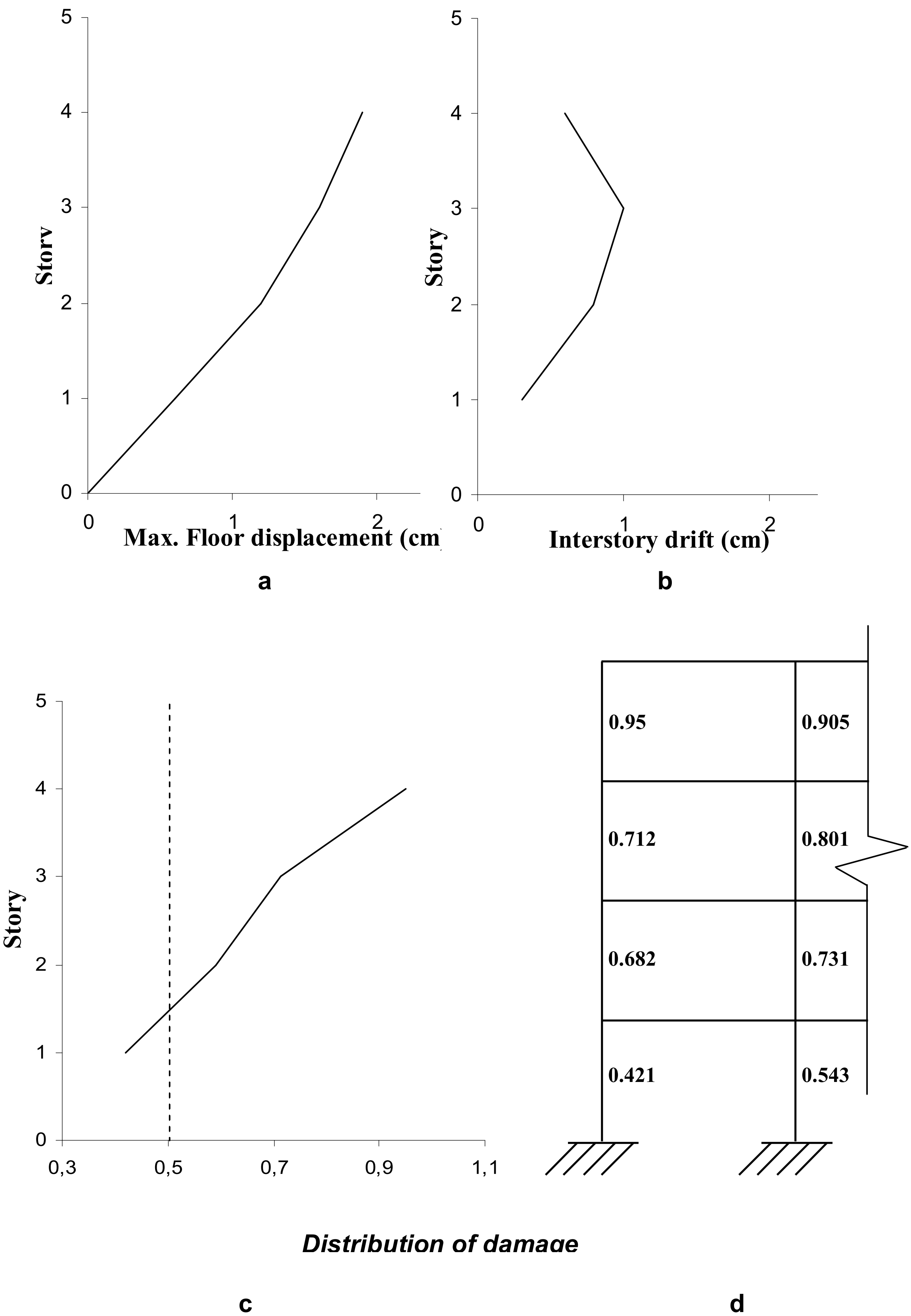


Fig. ((3)): Results of analysis

Table ((2)): Performance Indicators for Seismic Force.

Damage	**Index**	**Damage**		**State**
		Usability	Degree of damage	Damage state
First story interior	0.543	Temporality unusable	Moderate	Repairable/Irreparable
structure	0.46	Usable	Minor	Repairable

The damage index shows usable minor degree of damage repairable damage state for the structure, and temporarily unusable moderate degree of damage irreparable damage state for the interior column. The over all (global) damage index does indicate sever damage. But not complete collapse, since some of the structure elements are not severely distressed, Therefore a multiple of indices are required to characterize the structural damage near collapse.

IV- Retrofit:

Seismic retrofit becomes necessary if it is shown that through a seismic performance evaluation; the building does not meet minimum requirements up to the current building even collapse during a seismic event. Therefore, redesign and retrofit of critical structural elements to adequately resist minimal level of seismic force demand and distribute damage from columns to, more desirable locations, such as beam – slabs.

A- Seismic Retrofit Techniques For Individual Structural Elements:

Selection of any technique must be based on correcting the weak links in the structure as well as satisfying other factors, including desired performance level, economy, and esthetic. Existing gravity load design reinforced concrete frame structures are identified as weak-columns/strong –beams structures, failure, found in gravity load design reinforced concrete columns are due to lack of conferment, insufficient lateral reinforcement and inadequate reinforcement splicing. To reconfigure the structural failure mode should be select as suitable seismic retrofit to reconfigure the distribution of strength rather than adding ductility.

A.1- Steel and Concrete Jacketing Techniques:

Some of successful techniques being used for seismic retrofit of RC bridge and building structures are steel and concrete jacketing techniques ((4,5,6,7)). These techniques aim to add ductility without significantly affecting strength.

External prestressing technique tested modified concert jacketing technique tested by Joseph, Rainborn and Mander ((8)) , shown in Fig.(4) consist of a: encasing existing columns in a concrete Jacket with additional longitudinal and transverses reinforcement) providing reinforced concrete fillet around the un reinforced concrete fillet around the un reinforced beam-column Joint , c) post – tensioning the added longitudinal column reinforcement .

Analytical and experimental studies have shown that columns retrofitted with external prestressing exhibited improved retrofit by external prestressing system not only improve the strength, also increase the stiffness of column. Increasing the column stiffness is not desirable as the stiffened columns now attract or are subjected to higher seismic loads.

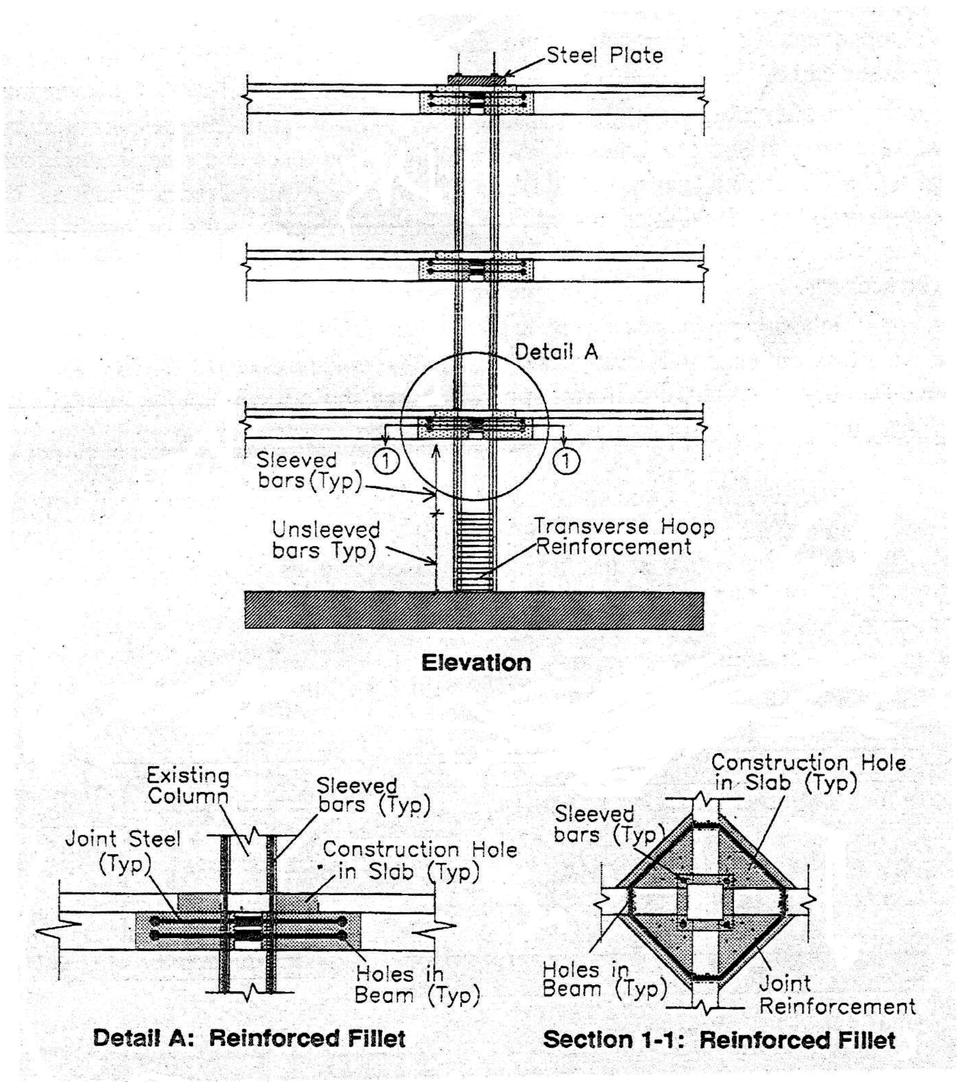


Fig. ((4)): Prestressed concrete jacketing technique.

A.2- Partial Masonry to Fill Technique:

Partial masonry in fill technique shown in Fig. ((5)), these techniques also increasing the strength and stiffness of structure((9)).

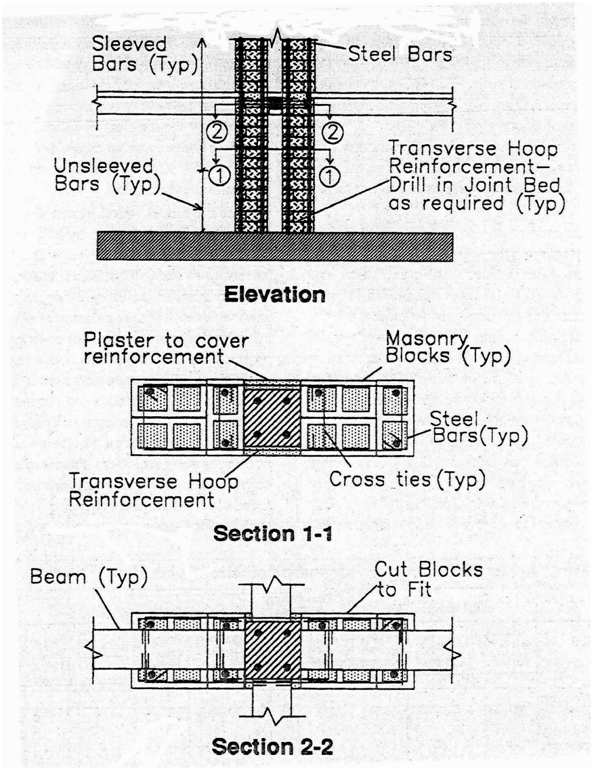


Fig. ((5)): Partial masonry infill technique.

A.3- Carbon Fiber Reinforced Plastic Jackets:

Advanced composite materials such as carbon fiber reinforced plastic (CFRP) is much stronger and lighter than steel. The inherent non-corrosive characteristic of CFRP makes CFRP reinforcement every effective alternative to steel reinforcement for reinforced concrete structures, especially when reinforcement corrosion is a main concern for the performance and durability of the structure. Analytical and experimental ((10, 11, 12)), results have shown that columns with CFRP sheets improve their strength, ductility and energy dissipation capacity without adding stiffness to the elements. Ease of installation, which is similar to putting up wallpapers, makes the use of CFRP sheet, every efficient alternative in the seismic retrofit of existing buildings.

B- Other Seismic Retrofit For Existing Buildings:

While passive damping device such as friction dampers and viscous dampers reduce the overall seismic demand upon the structural system of building, the use of carbon fiber reinforced plastic, partial masonry or external prestressing improves the performance of individual structural elements.

B-1 Friction Damper:

Friction damper, consisting of especial coated steel plates being bolted together, is usually part of a steel brace system that is mounted within a column-beam frame. The commonly used friction damper systems are in the form of an X (friction damper being at the middle of the X) or a diagonal (friction damper being a long the diagonal) inside a rectangular column –beam frame through connections at the column-beam joint. Friction damper system's friction is similar that of a shock-absorbing system in a car. Earthquake release energy through ground shaking motions, which induce seismic loads to a building structure. Friction dampers absorb the earthquake-induce energy (for load) when the steel plates slide against each at other at pre-determined slip load, i.e. Dissipating the earthquake-induced energy through friction-generated heat energy. Adding friction dampers to an existing building increase the seismic load carrying capacity of the building structure by means of reducing the demand of seismic resistance capacity upon the building's existing load carrying elements.

B-2 Fluid Viscous Damper:

Similar in function to that of friction dampers, fluid viscous dampers is another type passive device that can be used in the seismic retrofit of existing buildings. Retrofitting an existing building with viscous dampers results in reduction of seismic demand upon the structure element of the existing buildings.

VI- Conclusions:

Based on the results of this study the following conclusions can be drawn :-

1- Gravity load designed reinforced concrete buildings in the sever seismic zone ш is susceptible to sever damage , concentrated in the upper stories and can possibly lead to further collapse .

2- Retrofit should involve strengthening and adding ductility to selected columns to avoid the undesirable column side – sway mechanism .

3- We can use steel , concrete jacketing techniques and partial masonry to fill technique to seismic retrofit of existing buildings in low to moderate seismic zones because of , relatively inexpensive techniques , not only improve the strength also increase the stiffness of column , increasing the column stiffened columns now attract or subjected to higher seismic loads .

4- Carbon fiber reinforced plastic jackets improve their strength and ductility without adding stiffness to the columns, but the use of this technique is very coast effective and alternative in the seismic retrofit of existing building in sever seismic zone .

Note: without such test, predication of structural response may not be very reliable when compared with an actual response .

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