JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"SEISMIC RETROFITTING OF BUILDINGS BY VARIOUS METHODS"

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CHAPTER NO 1

INTRODUCTION

1.1 General

The main objective of this paper is to describe the all techniques to give a clear understanding to the readers about repair and retrofitting of RC structures. Such as reinforced concrete jacketing, steel jacketing, fiber reinforced polymer, composite jacketing, steel bracing system, addition of shear walls, seismic isolation system. It is a process of determining the deficiencies in a building which prevent the building from achieving life safety objectives. Evaluation is a process of determining existing structural condition. It is process of identification of unfavorable characteristics of the building. Buildings are evaluated for certain extent of structural damage that is expected in building when subjected to disaster other critical cases.

A structure is supposing various loads like wind, seismic, dead load, live load etc. The reinforced concrete (RC) structures lying in the seismic zones are still being designed only for gravity loads. The conventional approach to earthquake resistant design of buildings depends upon the strength, durability, stiffness and inelastic deformation. In most cases, those structures are highly vulnerable to any moderate or major earthquake. Along with the seismic prone zones like Himalayan region in India, Iran, Turkey, New Zealand and fault regions in US etc., devastations from earthquake have also been seen at the places believed to be seismically not-so-active. We have to provide the retrofitting and strain hardening to the concrete to enhance the compressive strength and tensile strength of concrete structure as to make it less unviable to earthquakes.

Retrofitting means modifying structures with additional or new components or members. It refers to the addition of new technology or features to older system. Retrofitting of a existing building can be more cost effective than the newly constructed building. It adopts new technology and provides better features to older systems. Retrofitting is the modification of existing building to resist seismic activity, soil failure due to earthquakes and grounds motion. The retrofit techniques are also applicable for other natural hazards such as tornadoes, tropical cyclones etc. Many structures were earlier constructed without detailing and reinforcement for seismic protection. After year of research, the retrofit and rehabilitation has been found and used across the world. In retrofitting we have to install a system in building after the construction of building. These systems are heating system, cooling system, integrated design process etc. In retrofitting system we have to upgrade the energy performance of commercial building and improve energy efficiency (reduce the operational costs) or decrease the energy demands. Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. The retrofit techniques outlined here are also applicable for other natural hazards such as tornadoes, tropical cyclones and severe wind from thunderstorm. It is also important to keep in mind that there is no such thing as an earthquake proof structure, although seismic performance can be greatly enhanced through proper initial design or subsequent modifications.

Retrofitting proves to be a better economic consideration and immediate shelter to the problem rather than replacement of building. Many buildings are not adequately the designed to resist earthquakes. The seismic performance of a retrofitted building is aimed higher than that of the original building. According to the Indian earthquake, code (IS1893-2002) many regions of the country have been placed in higher seismic zones. As a result, many buildings designed prior to the revision of the code may fail to perform adequately as per the provisions of the new code. It has, therefore, been recommended that the existing deficient buildings be retrofitted to improve their performance in the event of an earthquake and to avoid large-scale damage to life and property (Dowrick; 2003). The benefits of retrofitting include the reduction in the loss of lives and damage of the essential facilities, and functional continuity of the lifeline structures. For an existing structure of good condition, the cost of retrofitting tends to be smaller than the replacement cost. Thus, the retrofitting of structures is an essential component of long-term disaster mitigation.

India is divided in to four zones according to seismic zones such as zone 2, 3, 4, 5. According to the present zoning map the highest-level seismicity is zone 5 and lowest level of seismicity is zone 2. Retrofitting of the building element should be done at the initial stages of deterioration. In case of deterioration is not attention it leads to be excessive damages and excessive retrofitting cost. Retrofitting is needed where the building is not in good condition as compared to existing building. It aims at strengthening a structure with requirements of current code for seismic design. For an existing structure of good condition, the cost of retrofitting tends to be smaller than the replacement cost. Thus, the retrofitting of structures is an essential component of long-term disaster mitigation.

Retrofitting can be classified into two main types. One is Global-retrofitting techniques and other is Local-retrofitting techniques. Therefore, now we are firstly discuses about Global- retrofitting techniques. The aim of global retrofitting techniques is stiffen the building, by providing additional lateral loads resisting elements, or to reduce the irregularities or mass. Moreover, local retrofitting techniques are the most popular method for strengthening of building columns. The global retrofitting techniques are following below:

The declaration by United Nations (UN) for 1990–2000 as International Decade for Natural Disaster Reduction (IDNDR) brought in front the miseries caused by natural disasters. Stakeholders gauged the problem at the mid-term review of IDNDR in Yokohama, 1994 and highlighted a need for an urgent paradigm shift towards pre-disaster proactive approach rather than post-disaster reconstruction & relief. The Hyogo Framework of Action (2005–2015), most encompassing international accord to date, on disaster risk reduction, had proposed three strategic goals which were integrating Disaster Risk Reduction (DRR) in development, strengthening institutions and including DRR in preparedness and response & recovery at all levels [1]. Post-2015 development agenda, the successor agreement, Sendai Framework for DRR 2015–2030 was taken up by the member states at the third UN world conference. The resilience enhancement included anticipatory preparedness, timely adoption and implementation of modern engineering building codes & standards, early warning and evacuation, emergency response and vulnerability reduction [2].

Many countries with moderate-to-severe seismic hazard, landslide prone areas, cyclones or floods prone areas are vulnerable to multi hazard risks. Architects and Engineers deal with safety against natural hazards when designing all new buildings and finalizing the construction strategies, materials and services. But, all of the old existing building stock constructed without engineering supervision did not follow mandatory hazard resistant design. Proper evaluation, modeling, and assessment of the effects of multiple concurrent, cascading, or non-concurrent hazards (e.g., earthquakes and tsunamis, earthquakes and fires, hurricane wind and storm surge, wind and earthquake, earthquake and scour, earthquake and blast, fire and explosion) are fundamental to ensure the desired performance and safety of non-engineered or engineered structural systems. Ample amount of technical expertise and specialized data on safe built environment is available with the civil engineering community but yet not handy in the public domain. Also, this technical knowledge may not be applicable to local housing typologies. The risks get intensified by people's low perception of the extent of damage to buildings and along these lines, there is no or low levels of readiness.

A proactive approach by Municipal Corporations (MC) in mitigating weaknesses can save significant sums of money and decrease disruption or total breakdown. The MCs can impose mandatory insurance for all the buildings irrespective of the size, location and typology under a suitable insurance policy even if there is no mortgage, so that the property can be restored to the state it was before the occurrence of a hazard. The insurance may be on market value or reinstatement value and depreciation with age may also be included. Third parties affected by the destruction can also be compensated according to the terms of the policy. The insurers will have to however, ensure condition of the building and compliance to building codes before issuing cover policy. The liability of structural defects due to design flaws or inferior materials/workmanship etc can be levied on the construction firm.

Also, buildings are large consumers of natural resources, energy and water with energy sector being the biggest contributor to greenhouse gases. Issues relating to climate change, buildings' energy usage, GHG emissions have long been highlighted in many international events since the Stockholm Agreement in 1972. United Nations Climate Change

Chapter 2
LITERATURE RIVEW

2.1 The lateral force capacity of an existing building may be increased by adding new structural elements to resist part or all of the seismic or wind forces of the structure. The newly added elements may be shear and/or wing walls in a frame or skeleton structure. The choice of the number and size of the added elements depends on the particularities of the existing structure and the functional layout of the building.
El Samny,M.K., Abbas, H.& El Sebai, A. (1997) presented an analysis of the location and detailed design of added shear wall to existing buildings to improve the seismic performance. In particular, the location of the shear wall in relation to the overall symmetry of the building is critical because non symmetrical shear wall locations will tend to increase the torsional response of the building.
Abou- Elfath. H, Ghobarah. and Aziz. T. S (1997) investigated the seismic response of a 3-story nonductile reinforced concrete building retrofitted using concentric steel bracing. The reinforced concrete members were modeled using a beam-column element that is capable of representing the nonductile behavior characteristics of these members including strength softening after reaching a specified level of deformation. The state of damage of the building before and after retrofitting was assessed by calculating the actual deterioration in stiffness and in the load carrying of the building. Three brace designs were considered. The response of the building was determined using El Centro earthquake ground motion record. The results indicate that steel bracing can provide nonductile buildings with improved seismic performance. **Ghobarah.A, Abbas.H and El Samny. M. K (1997**) stated that the evaluation of the seismic capacity of existing structures and their deficiencies is essential for the design of an appropriate rehabilitation system. The aim of structural rehabilitation is their collapse prevention to ensure safety of the occupants or to control the damage to ensure the continuity of operation after an earthquake. The performance of the structure is evaluated in terms of its lateral load resistance, maximum base shear; inter story drift and potential damage. The lateral load resisting capacity of existing structure can be determined using empirical rules, nonlinear static pushover analysis or dynamic analysis. The various approaches for the evaluation of the lateral load resisting capacity of existing structures are reviewed. In terms of damage analysis, the performance of the structure can be defined in terms of five ranges of damage states. The defined performance levels and their relationships to drift are correlated with force-drift relationship form a pushover analysis for use as a performance evolution procedure. It is concluded that the pushover analysis is promising approach for the evaluation of the capacity of large class of structures. Damage indices are powerful indicators of potential damage to the structure.

K Soudki, T Alkhrdaji - Structures Congress 2005: Metropolis and …, 2005 - ascelibrary.orgThis paper reports on the key features of the" Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures" issued by theAmerican Concrete Institute (ACI). Fiber reinforced polymers (FRP) systems have emerged as an alternative to traditional materials and techniques for the strengthening of existing concrete structures to resist higher design loads, correct deterioration-related damage, design or construction error, or increase ductility. Structural elements strengthened with …

CE Bakis, A Ganjehlou, DI Kachlakev… -Reported by ACI …, 2002 - academia.eduFiber-reinforced polymer (FRP) systems for strengthening concrete structures have emerged as an alternative to traditional strengthening techniques, such as steel plate bonding, section enlargement, and external post-tensioning. FRP strengthening systems use FRP composite materials as supplemental externally bonded reinforcement. FRP systems offer advantages over traditional strengthening techniques: they are lightweight, relatively easy to install, and are noncorrosive. Due to the characteristics of FRP materials, the behavior of FRP strengthened members, and various issues regarding the use of externally bonded reinforcement, specific guidance on the use of these systems is needed. This document offers general information on the history and use of FRP strengthening systems; a description of the unique material properties of FRP; and committee recommendations on the engineering, construction, and inspection of FRP systems used to strengthen concrete structures. The proposed guidelines are based on the knowledge gained from worldwide experimental research, analytical work, and field applications of FRP systems used to strengthen concrete structures.

Guide for the design and construction of externally bonded FRP systems for strengthening existing structures to investigate the efficiency of using two new types of fibers, polyethylene naphtha late (PEN) and polyethylene terephthalate (PET) fiber, for seismic strengthening of RC piers. These fibers have the properties of low stiffness and high …
Guide for the design and construction of externally bonded FRP systems for strengthening existing structures of strengthening the existing structure to Improve seismic performance. The walls were cast-in-site. The shear and Wing walls were connected to the foundation

Conference, Copenhagen (2009) agreed on a climate deal forced after the first commitment period of the 1997 Kyoto Protocol [3]. A desirable transformation towards green buildings and green building rating systems took roots in early nineties. But green performance based assessment of old existing buildings to recognize the functional interruptions and human interventions towards maintaining the deteriorating environment, is still a lesser adopted concept, more so in developing countries. With approximately 17.5% of the entire world's population, an urban population of 372 million (larger than the entire US population) and 59% of area exposed to seismic hazards, India faces monumental challenges related to urbanization. India currently has LEED-India (Leadership in Energy and Environmental Design) derived from US-LEED and indigenous GRIHA (Green Rating for Integrated Habitat Assessment) developed by TERI (The Energy Resource Institute) and adopted by Indian Ministry of New and Renewable Energy. MNRE has directed to have mandatory three stars GRIHA rating for all new constructions. There were no formal assessment criteria for existing buildings in India till 2017. In the recently published standard 'GRIHA for existing buildings, 2017' [4], the criteria included do not consider durability, resilience and structural safety parameters. Building Research Establishment Environmental Assessment Method (BREEAM) [30] from UK is a well established rating system, with maximum rated footprint, considers durability and resilience to hazards of existing buildings which is yet missing in Indian rating systems. The adverse environmental practices followed by the building occupants like waste water discharge, use of low rated appliances, solid waste disposal etc. need to be checked and curbed by a single agency assessing the building. This led to a number of research questions, first being, are the current rating tools measuring the building performance holistically and would it be possible to track and monitor the structural and green quotient over time. Is sufficient information on building statistics available in the public domain to evaluate it or will the owners of the buildings get incentives to go in for holistic assessment if not made mandatory?

In light of the above issues, it turns into a test for MCs to choose a reasonable technique for evaluation of hazard vulnerability and appropriate environmental initiatives in a given local circumstance and need. There is an absence of temporal and spatial database on different hazards, ecological and infrastructural parameters alongside statistic points of interest in public area/community that discourages action/research in this field. The onerous task of assessing the huge existing building stock with little or no information available in the public domain and uncertainty about their structural/environmental performance can only be achieved by a fast and coarse appraisal of buildings considering the dismal housing data from Census of India, 2011.An expert opinion method can thus be adopted assuming that numbers of each building type is known to obtain a rough approximation of the risks without the more costly process of specific loss studies [5]. A walk in survey by experts collectively both for structural adequacy and green parameters will prove to be a fast and inexpensive method of holistic assessment of buildings after an interval of two to three years as mandated. The expert opinion based holistic assessment problem will involve many quantitative and qualitative criteria and thus Multi Criteria Decision Making (MCDM) methods will be ideal to employ. The experts/decision makers will have to consider many criteria simultaneously with differing weights to evaluate the alternatives. Also, due to lack of availability of design or operational data of old existing buildings, there will be uncertainty of information in the decision process. This uncertainty together with ambiguities of human feelings and recognition makes exact evaluation or numerical prediction of criteria difficult. The decision makers cannot always explain their judgments in distinct and discreet scales but would make subjective assessments expressed in linguistic terms. Fuzzy linguistic models [6] help in translating verbal expressions to numerical ones. While dealing quantitatively with imprecision in the expression of the importance of each criterion, MCDM method like TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) [7] based on fuzzy logic is proposed in this paper to assess the buildings. The proposed model covers the assessment criteria by considering Indian evaluation forms suggested in the codes for RVS [8], GRIHA for existing buildings parameters and other possible building distress features. More detailed and precise analyses can subsequently be performed if the first coarse screening has pointed out that the structural safety level or its green score is lower than a minimum threshold.

Methods of strengthening of existing building structure

GPR ScanningTheCompany provides Ground Penetrating Radar and Ferro scan equipment for old concrete buildings and structures. This equipment scans the RCC element of the old concrete surface and determines the location and sizes of rebar's to a depth of up to 300 mm. The output of the scans is readily available on site which is collected after analyzing the top view, section view or 3-D form. This scan details analysis helps during structural modification needed for an existing structure and it also helps to decide the exact location for core and cuts required requirements of the structure.

Epoxy injection The Company utilizes the epoxy injection technique to repair cracks in buildings and structures. Cracks are traced and opened in v groove manner, cleaned and sealed with epoxy putty and grouting nozzles non return type are fixed at specified intervals which later are injected with epoxy grout under pressure till rejection

FRP Composite System – PT and Non-PTFRP Systems are used to enhance the structural capacity of members in shear, flexure, compression, to aid in blast mitigation, upgrades for seismic loads and to control the propagation of existing cracks. The company designs retrofit systems and provide application solutions with Glass, Glass Aramid composite and High strength carbon fabric systems woven in uni-direction, bi-direction and diagonal pattern with density ranging up to 1200 GSM with wet layup system.

Fiber-mesh Reinforced cementations mortar (FRCM*)*Fiber-mesh Reinforced cementations mortar (FRCM) system involves a specially treated fiber mesh sandwiched in between a special grade high strength inorganic repair mortar. The company has trained applicators to apply FRCM layups in layers of about 6 to 8 mm thickness each over damaged structural elements. The High strength, lightweight and non-corrosive FRCM system result in long-lasting repairs. This is a durable alternative to the GI mesh-based grunting system which is used to degrade easily due to corrosion.

Micro reinforced Jacketingprovides sections enlargement or reinstatement involving thickness ranging from 40 to 100 mm thick is generally done with high strength self-leveling and compacting micro concrete mixes. Reinforcement is provided in the form ofa regular rebar cage, hard wire stainless steel mesh or metallic fibers dispersed in the micro concrete mix. Shear keys are provided as usual for effective transfer of load.

Special metal alloy strengtheningdesigns and installs special high-strength metal alloy near-surface reinforcements Plates of the strength of up to 600 Mpa and in lengths of up to 12 meters and varying widths are installed as per site requirements.

THE NEED OF STRUCTURAL STRENGTHENING

Load increases due to: – higher live loads, – increased wheel loads, – installations of heavy machinery – vibrations.
• Damage to structural parts due to: – aging of construction materials – fire damage, – corrosion of steel reinforcement – impact of vehicles. The need of structural strengthening
• Improvements in suitability for use due to: – limitation of deflections, – reduction of stress in reinforcement – reduction of crack widths.
• Modification of structural system due to: – elimination of walls/columns – openings cut through slabs.
• Errors in planning or construction due to: – insufficient design dimensions – insufficient reinforcing steel Load increases due to: – higher live loads, – increased wheel loads, – installations of heavy machinery – vibrations.

• Damage to structural parts due to: – aging of construction materials – fire damage, – corrosion of steel reinforcement – impact of vehicles. The need of structural strengthening

• Improvements in suitability for use due to: – limitation of deflections, – reduction of stress in reinforcement – reduction of crack widths.

Strengthening Can Be Achieved By:

• Replacing poor quality or defective material by better quality material
• Attaching additional load-bearing material
• Redistribution of the loading actions through imposed deformation of the structural system

Evaluation Process

-Existing buildings not designed in accordance with the principles, philosophies and requirements of current seismic codes.
Preliminary evaluation-This involves broad assessment of its physical condition, structural integrity and strength of structure, including simple calculations.
Detailed evaluation-A detailed evaluation is required unless results of preliminary evaluation are acceptable. Which include further assessment?

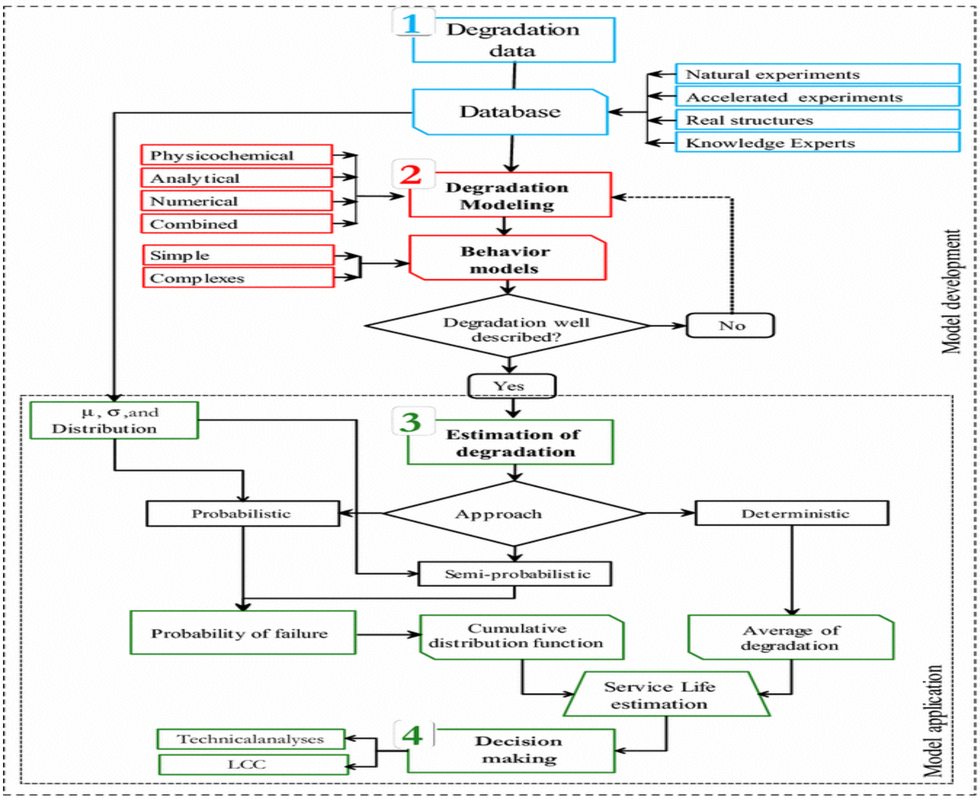

fig.no 1.Process for strengthening of new building and existing building

The problems of repair, restoration and seismic strengthening of buildings:

Before the occurrence of the probable earthquake, determine the strength by a survey and analysis of the structures.
Just after a damaging earthquake, temporary supports and emergency repairs are to be carried so that precariously standing buildings may not collapse.
When things start settling down at this stage i,e repairs, restoration & strengthening, since the cost, time and skill required in the three may be quite different

Repair, Restoration & Strengthening

Repair:

It brings back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. It do not pretend to improve the structural strength of the building.

Restoration:

It is the restitution of the strength the building had before the damage occurred. It may be done when there is evidence that the structural damage can be happen again and that the original strength provides an adequate level of safety.

Strengthening: It is an improvement over the original strength when the evaluation of the building indicates that the strength available before the damage was insufficient and restoration will not be adequate in future.

Techniques to restore original strength and Repair materials
Shot Crete: Combinations of sand and cement used for crack filling.
Epoxy resins Excellent binding agents is of low viscosity and can be injected in small cracks
Epoxy mortar Combination of epoxy resins with sand aggregate to form epoxy mortar with higher compressive & tensile strength. It has a lower modulus of elasticity than Portland cement concrete.
Gypsum cement mortar It has lowest strength at failure among above three materials.

Reasons of Additional of New Structural Elements

In every case, the new structure, composed of the old structure and the additional Members, has to be analyzed and designed as such. The lateral force is taken over jointly by the old and the new structure depending on their relative rigidity and Location within the structure. Retrofitting and strengthening of Existing Building Foundation 113 Repair of reinforced concrete elements is often required to replace lost strength. Strengthening of reinforced concrete structure elements is one method to increase the earthquake resistance of damaged buildings. Thus, the strength of the structures can be moderately or significantly increased and ductility can be improved. Depending on the desired level of the damage, the type of the elements and their connections, members can be repaired and / or strengthened by removal and replacement of damaged parts or by jacketing. Establishing sound bond between the old and the new concrete is of great importance. It can be provided by chipping away the concrete cover of the original member and roughening its face, by preparing the surfaces with glues (for instance, with epoxy prior to concreting), by additional welding of bent reinforcement bars or by formation of reinforced concrete or steel dowels. In the present study of an existing sweet factory called El Rushed, several problems were found as follows:-
i. Deterioration of some concrete elements such as columns and foundations due to old age of building. The damage condition of the foundation was due to washing floors with chemicals to remove sticky sweets and no adequate disposal system was found (waste water collection).

ii. Inadequate design of the building to resist earthquake conditions. Strengthening of existing foundation was done by considering the old foundation it as a plain concrete. New raft foundation has been designed and placed on the old one connected with anchors. In addition, some columns of the existing building were strengthened. To resist lateral loads some shear and wing walls have been placed. The added shear and wing walls were monolithic to the existing columns and were along

1. Foundations

Repair and strengthening of foundations is a difficult and expensive construction procedure. It should be performed in the following cases:
i. Deterioration of concrete elements due to old age of building.
ii. Excessive settlement of the foundations due to poor soil conditions.
iii. Damage in the foundation structure caused by seismic overloading.
iv. Increasing of the dead load as a result of the strengthening operations.
v. Increasing the seismic loading due to changes in code provisions or the strengthening operations.

vi. Necessity of additional foundation structure for added floors. Repair and strengthening of foundation structure can be performed strengthening the existing foundation structure, adding new foundation structure, or modifying the soil for improved foundation support. Strengthening of existing footing necessitates increasing the dimensions of the footing to increase the bearing area of footing. Fig (1) shows jacketing details for columns and footing connected together. Special attention should be paid to incorporating the existing footings into the newly introduced foundation structure in a manner that the parts will function together properly.

2. SHEAR WALLS

Shear and/or wing walls provide the most significant part of the earthquake resistance of the building because of their high stiffness and lateral strength. However, a severely damaged or poorly designed building must be repaired or strengthened by added shear and/or wing walls in order that the structure's strength for seismic force can be significantly improved. In such cases, the new shear and/or wing walls should have sufficient strength and stiffness to provide the entire lateral force resistance. However, the new structural elements in an existing building will change the dynamic behavior of the whole space structure considerably during an earthquake

Retrofitting and strengthening of Existing Building Foundation 119

Some examples of favorable distribution of added structural shear wall elements are shown in Fig (4-a, and 4-b). In case of pure skeleton structure with insufficient lateral resistance, shear and/or wing walls should be added in architecturally convenient places. The distance between the shear and/or wing walls must be less in the case of flexible floor structures and may be greater for stiff monolithic reinforced concrete slabs. However, it is desirable that the shear and/or wing walls be oriented in transverse direction of the building. In addition, it is necessary to locate the additional shear and/or wing walls with sufficient strength while reducing unfavorable torsion effects. However, monolithic reinforced concrete shear walls can be situated either along the periphery of the building or inside of it. Adding walls along periphery is often easier as it does not upset the interior function of the interior layout as in Fig (5-a). Monolithic shear walls placed inside of the building as in Fig (5-b) should be connected with the floor structure by vertical longitudinal reinforcement passing through opened holes in the existing slab as in Fig (5-c). However, in all cases added shear and/or wing walls should be connected to the existing foundation as well as to the skeleton of the building as shown in Figs (6 and 7).

4. Retrofitting of an Old Foundations in the Existing Sweet Factory

Figs (8-a, 8-b and 8-c) presents the general arrangement of columns for the existing sweet factory in Cairo area as well as the added shear and wing walls. The analyses of the structural elements of that existing building showed that it is seismically inadequate in addition of deterioration of some concrete elements due to old age. While preparing the columns for strengthening, it was found that the foundation of the building was completely damaged and deteriorated as shown in Figs (9-a, 9-b & 10). The said condition of the foundation was due to washing floors with chemicals to remove sticky sweets.

Fig.8 column jacketing

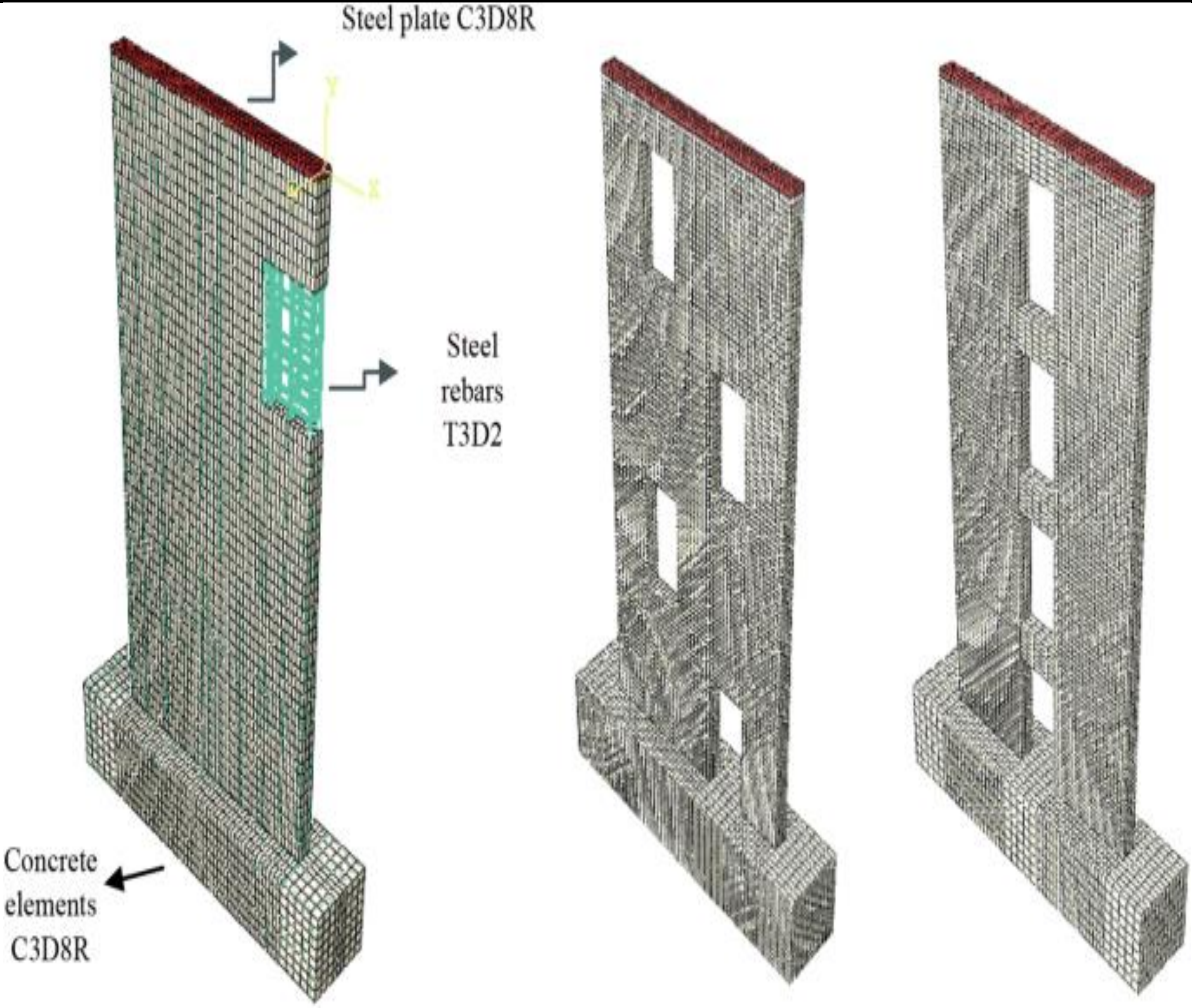

Fig.9 shear wall with wire mesh with shot creting

Fig.11 Epoxy Application

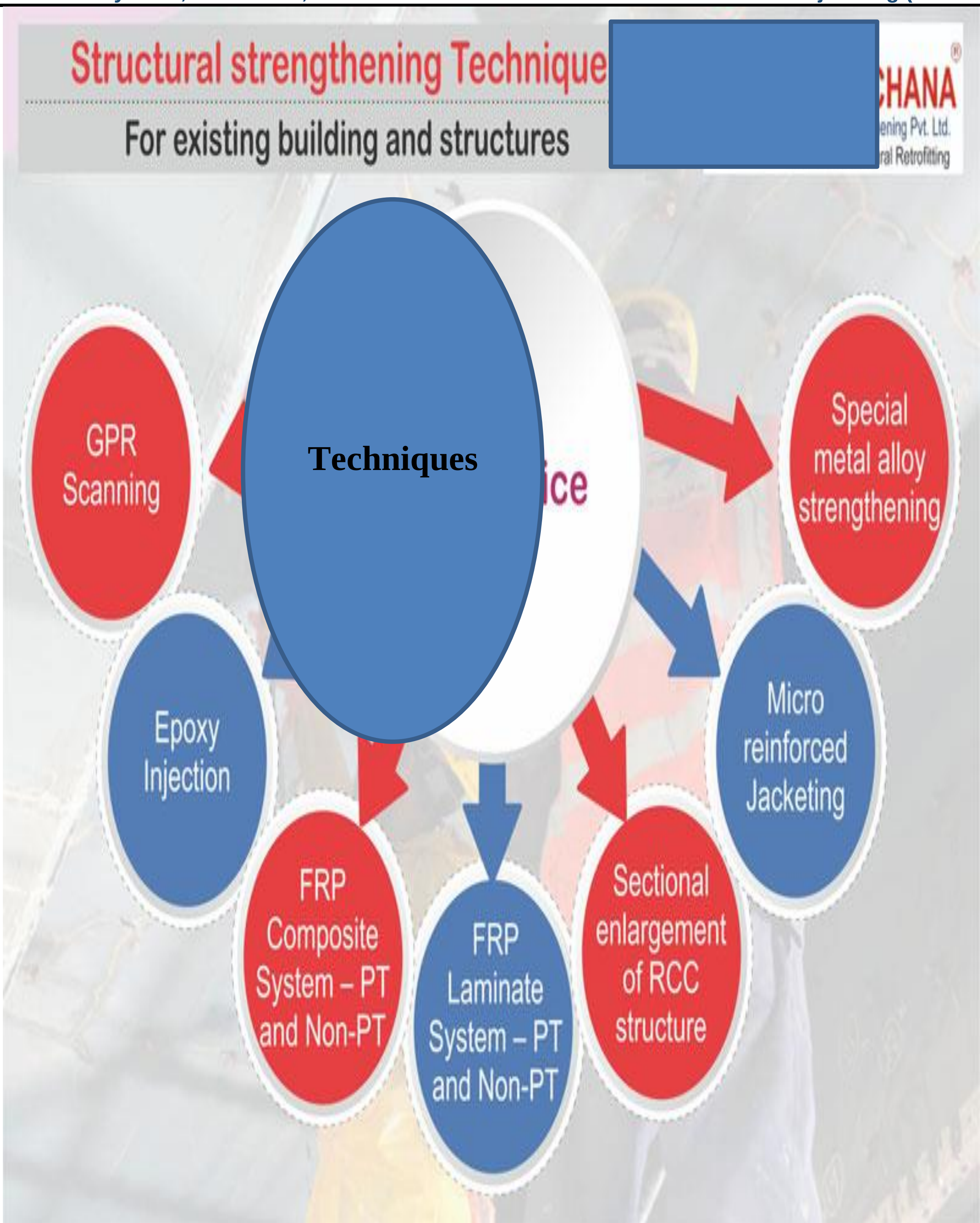

Fig.2 Techniques of strengthening

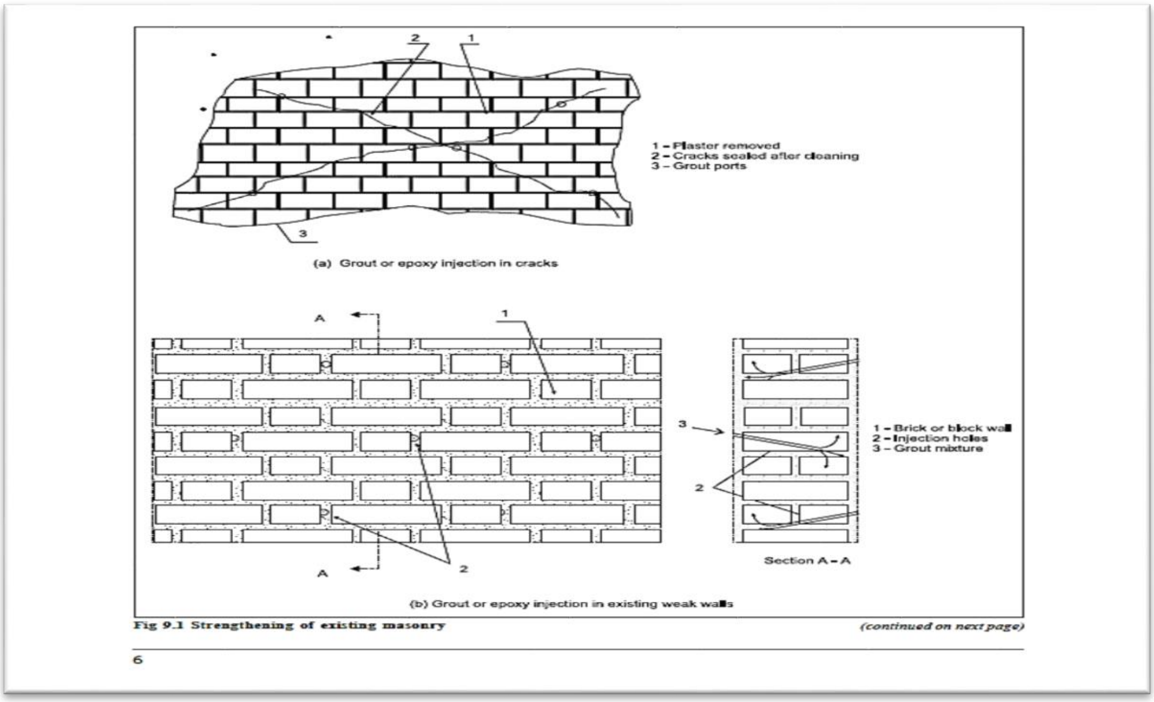

Fig3.Strengthening of existing masonary

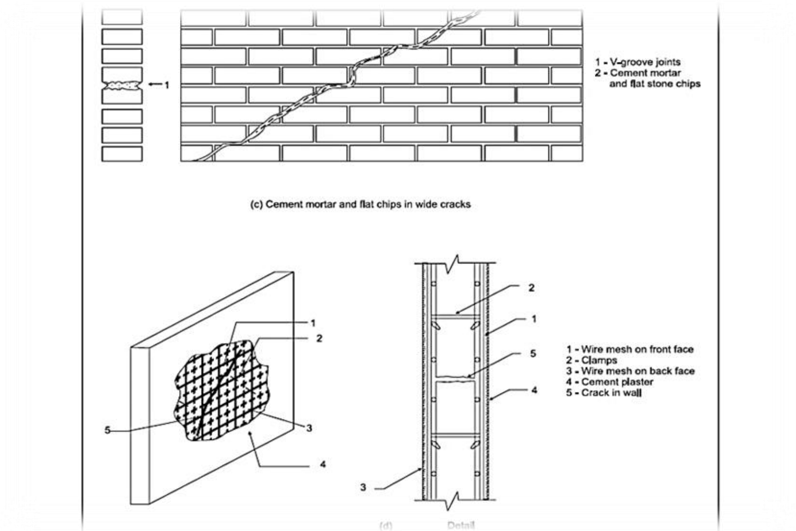

Fig.4 repair on damaged wall surface by shot Crete and wire mesh

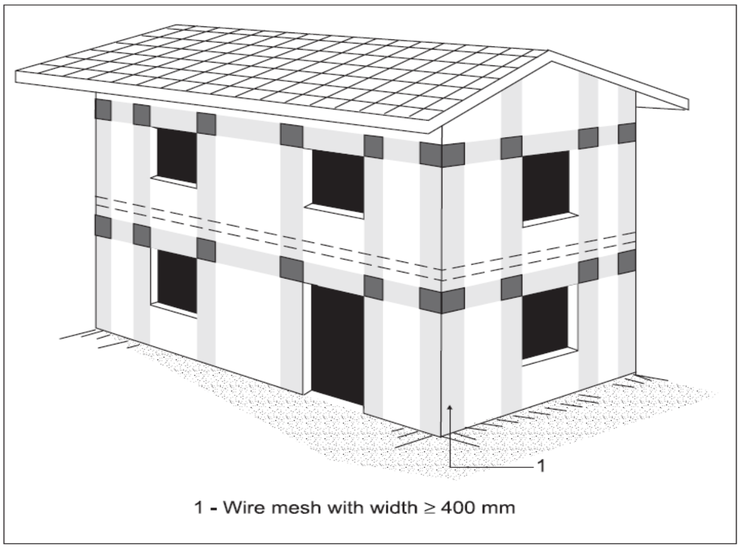

Fig.5 strengthening of roof slab with wire meshes and short Crete

Fig.6 retrofitting of columns building

Fig.no 7 elevating height of building

Advantages of strengthening of building

1. **Marketability** of a building is improved
Buyers are attracted the security a seismic retrofit provides to tenants. The number of potential **lenders** increases when the Probable Maximum Loss (PML) is low. More lenders can mean more buyers!
2. The **risk of injury and legal litigation** is reduced
3. **Earthquake coverage** can be reduced
A lower coverage cap can reduce premiums. (At this time, some insurance companies do not recognize the PML of a building).
4. **Lenders** who request a PML of less than 20% are usually satisfied when a thorough and professional seismic retrofit has been completed.
5. **Insurance companies** in the future may not write coverage for earthquakes due to past losses and other events. Rates have increased 3 to 6 times the rate charged since 2005!
6. **Tenants** who consider the operation of the building critical to the survivability of their businesses feel more secure and will remain in occupancy contracts for longer periods.

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2. The **risk of injury and legal litigation** is reduced

Owners can lose substantial amounts of money if it can be proven they were aware a building needed structural work, but had no plan in place to correct the problem. No amount of insurance coverage will probably cover successful litigation against negligence. A thorough seismic retrofit provides peace of mind and asset protection.

A lower coverage cap can reduce premiums. (At this time, some insurance companies do not recognize the PML of a building).

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6. **Tenants** who consider the operation of the building critical to the survivability of their businesses feel more secure and will remain in occupancy contracts for longer periods.

• Retrofitted buildings are more adaptable and suitable to existing activities or future activities if required, more comfort;

• Retrofitted buildings are more energy efficient, lower carbon emissions from the building operations;

Following are also some merits of strengthening by retrofitting

1. Greater sustainable use of embodied-carbon investment (capital carbon).This method is utilized to prevent displacement from the structure's concrete
2. To boost protection levels of the structure.
3. To resist load safely, the Retrofitting of the structure plays an important role in existing or future actions.
4. The Retrofitted structures do energy-efficient and lower carbon emissions.
5. It creates the structure stronger and controls
6. It protects the structure from earthquakes and provides safety to the residents.
7. Insurance firms help to expand their insurance.
8. Improving the capability of structure as well as its components.

The challenges of retrofitting (disadvantages)

• Expensive and inconvenient;

• Internal spaces may reduce upon installation of internal wall-insulation;

• Might cause negative impact to heritage and archaeological assets caused by usage of unproven methods, technologies or instruments;

• Further research is needed especially on insulation mechanism on walls and the effect on retrofit on buildings fabrics;

• More education, training and activities on maintaining and preserving the buildings need to be taught to address issues and to create awareness;

• The risk of retrofitting needs to be highlighted, not just focusing on the benefits of retrofitting and discussion between retrofit and refurbishment.

Other benefits of retrofit existing buildings includes; cost saving in long run by reducing the usage of energy and water by incorporating new technology, services or equipment; increasing the comfort level in a building by redesign the facade and interior to improve end users productivity and satisfaction through improving interior thermal comfort; lowering the greenhouse emission and optimizing the water usage in building; future-proof buildings which means the building will be use and last for many years when it is equipped with current technology based; and preserving cultural and heritage significance of an existing buildings by enhancing the building exterior and interiors to meet current standards and design based on the needs of end users.

Analysis of Retrofitting

It's critical to have a systematic technique to assess the state of the cement and support before implementing any maintenance strategy.

This will necessitate a highly specific assessment and understanding of the behavior of the fundamental structures that are being repaired. **Materials and methods for retrofitting** are chosen based on these analyses.

This ensures that everyone is safe. After considering the administration life of designs that are built up based on financial and technological developments, the decision to retrofit or replace a structure or its components can be made.

CONCLUSION

Seismic retrofitting and strengthening of building has now become a crucial issue. Recent occurrences of earthquakes in different parts of the world have clearly demonstrated the urgency of repairing seismic deficient structures. Several numbers of experimental and analytical programs focused on innovative seismic retrofitting techniques have been included in current state of an art review. Design guidelines and recommendations should be made more readily available to ensure more rapid and effective applications of various strengthening methods. Design manuals and codes of practice should be updated to take these issues into consideration. However, before applying any seismic retrofit method to a damaged or deficient structure, a proper and accurate assessment of the seismic performance and current state of the structure is essential.Seismic retrofitting has now become a crucial issue. Recent occurrences of earthquakes in different parts of the world have clearly demonstrated the urgency of repairing seismic deficient structures. Several numbers of experimental and analytical programs focused on innovative

Adding new raft foundation and considering the old foundation as plain concrete. The addition of new shear and wing walls is undoubtedly the best method of strengthening the existing structure to improve seismic performance. The walls were cast-in-site. Monolithic reinforced concrete shear and wing walls were situated along the periphery of the building. The shear and wing walls were connected to the foundations.

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