# Retrofitting of an Existing Industrial Building (Avari Towers, Karachi)

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***Abstract*: Retrofitting is expanding its grasp like a wild fire in the world, as many of the historical, public and important private structures become weak with the passage of time. One of the best alternatives to sustain these structures is retrofitting. Retrofitting makes inadequate existing building safe from potential future earthquakes or other environmental forces. The process involves adding new characteristics to older buildings, heritage structures, bridges, etc. Retrofitting decreases the level of Vulnerability of disruption to an existing structure during seismic activity. It is aimed at improving a system in order to satisfy the seismic design criteria of the new codes. Retrofitting in this regard is beyond traditional repairs or rehabilitation. It is the alteration of existing structures in order to make them more resistance to seismic activity, seismic movement, Land and soil failure due to earthquakes or other natural hazards such as tornadoes, cyclones, and winds High speed thunderstorms, snowfall, hailstorms, etc. In due course of time, structures lose their power, some public, social structures hold a historical significance in the public's eye, such structures are important. Retrofitting helps improve power, resistivity and strength. It increases the structure's total lifespan**

***Keywords:* Earthquake, Earthquake Proof, ETABs, Retrofitting, Seismic Waves.**

## I. INTRODUCTION

### *A. Retrofitting.*

Retrofitting is actually addition of new technologies to old structures. The old structures may be vulnerable or weak. It can be used to increase the efficiency or make it economical; it may also decrease emissions. However, from Civil engineering point of view The Retrofitting term may be referred to Seismic Retrofitting Changing current structures in order to make them more prone to seismic activity, ground movement or soil failure due to earthquakes. To meet the requirements of new emerging materials/technologies for advanced infrastructure the civil engineering industry has begun to work its way through this. With frameworks growing weaker and weaker. The old buildings have begun to show a significant need for additional maintenance. Retrofitting with Structures such as buildings which require repair, maintenance and reinforcement of the structure, are not just the need for design and management in urban areas but is also a concern for structural engineers in property management disciplines Retrofitting has become an essential and important method for reducing hazards.

### *B. Why is Retrofitting required?*

In order to improve the survival functionality, retrofit is performed in systems. The requests contain numerous types of applications Bridges, homes, and industrial systems, urban transport structures, earth retention structures, and marine structures there are some explanations that could lead to retrofitting:

- [i]. Buildings that are designed only for gravity loads.
- [ii]. Earthquake Resistant Design (EQRD) construction activities for buildings and other design systems lead to transition and change in concepts.
- [iii]. Lack of timely updates of standards and codes of conduct.
- [iv]. Lack of updates to the country's seismic zone map.
- [v]. In cases of alterations in high seismic activity zone buildings, i.e., an improvement in the loading class, an increase in the loading class, increase in the number of stories.
- [vi]. In cases of earthquake (EQ) degradation resistance to earthquake forces decreases e.g., decrease in strength of
- [vii]. Construction material due to construction deterioration, damage caused by fire, and foundation settlement.
- [viii]. The construction standard actually completed could be lower than what was initially expected.
- [ix]. Lack of comprehension by the designer.
- [x]. Improper preparation on floors and bulk production.

*C. Advantages of Retrofitting:*

*i. Low operating cost*

This is the big advantage achieved by retrofitting the existing building and making it energy efficient.

*ii. Better corporate image*

It is another advantage by retrofitting as many biggies will contact you for the leasing purpose.

*iii. Increasing productivity*

Productivity of the building occupants will be increased greatly as they will get a lively environment with improved air quality.

*iv. New asset*

It creates a new asset at a fraction of the cost.

*D. Principles and Objectives of Retrofitting Design*

The concepts of building retrofitting design are:

i. Members' reinforcement versus systemic framework reinforcement. It is important to reinforce members that do not meet safety requirements; however, there is always an underlying error that it is ignored to reinforce the entire structure. For structural integrity, strengthening the link between members is very influential. Local strengthening versus global strengthening. Local strengthening of an individual member can be carried out only if the strengthening does not affect the structural performance of the whole system.
ii. Local reinforcement vs global reinforcement. Only if the strengthening does not impact the structural efficiency of the whole system local reinforcement of an individual member be carried out.
iii. Temporary reinforcement versus permanent reinforcement. The temporary strengthening criteria and requirements may be lower than those for permanent strengthening.
iv. To use new seismic technologies.

*E. Objectivess*

i. Increasing the strength and stiffness of the building.
ii. Increasing the ductility in the lateral load versus deformation behavior and enhancing the energy dissipation capacity.
iii. Giving unity to the structure.
iv. Eliminating features that are sources of weakness or that produce concentration of stresses in some members.
v. Avoiding the possibility of brittle mode of failures.
vi. Elimination of the possibility of collapse.
vii. The retrofit scheme should be cost effective.
viii. The main goal of retrofit is to provide public safety.

*F. Objectives to be achieved:*

i. Design and analysis of a building.
ii. Increment of story to check the capacity.
iii. Failure point.
iv. Re-strengthening of the building by suitable retrofit technique.

### *G. Methodology*

Methodology for the project comprises of following steps:

i. Analysis and design of initial building
ii. Check drift and torsion of building
iii. Increment of story from five to nine floors
iv. Analysis and design after increment
v. Check drift and torsion
vi. Check steel in columns
vii. Use localized retrofitting
viii. Jacketing of structural member (column) to increase strength
ix. Final analysis and design of structure after retrofitting
x. Check drift and torsion should be under allowable limits

## II. BASIC CLASSIFICATIONS OF REFTROFITTING

### *i. Before a damaging earthquake:*

The required strengthening to be determined by using a survey and analysis.

### *ii. Just after a damaging earthquake:*

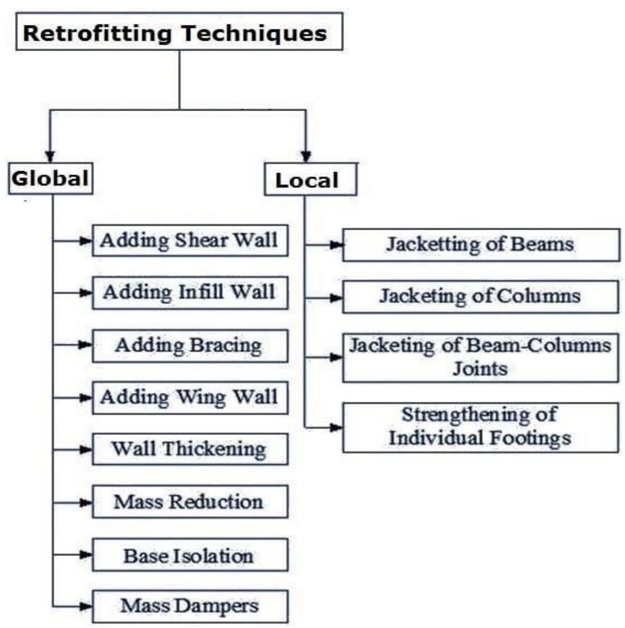
Temporary supports & emergency upkeep are to be accomplished. Those actions are needed in order that the homes can be re-function and now not collapsed because of aftershocks.

### *iii. After a damaging earthquake when things start settling down:*

Distinction to be made in the type of action required:

a) Repair*:* The main purpose is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly.
b) Restoration*:* The main purpose is to carry out structural repairs to load bearing components to restore its original strength.
c) Strengthening. The main purpose is to make buildings stronger than before.

### *A. Classification of Retrofitting Techniques*



## III. METHODOLOGY

### A. *General:*

Because of the variety of structural building requirements, it is difficult to develop standard retrofitting laws. Based on the structural deficiencies, every building has different approaches. In order to prepare and layout the retrofitting methods, engineers are therefore required. The engineers should observe the building codes within the design of the retrofitting method. The outcomes generated through retrofitting strategies need to meet the minimal requirements on constructing codes, together with deformation, energy detailing, and so forth. Structure repair and rehabilitating is a manner wherein an existing shape is enhanced to boom the opportunity that the shape will live on for a long period of time. Before any restore work is put in hand, the purpose of harm have to be identified as surely as viable. This precept may additionally seem self-obvious however it's miles sudden how often it is omitted, with the end result that further maintenance need to be carried out within a brief time. The subsequent step need to be to take into account the objective of the restore, to be able to normally be to repair or enhance one or extra of the following:

- Durability
- Structural Strength
- Function
- Appearance

### *B. Retrofitting Strategy:*

*i.* Specify the condition of efficiency for the structural member to be retrofitted.

*ii.* Set an overall schedule from the inspection stage to the selection of the retrofitting process, the retrofitting structure design, and the execution of retrofitting work.

*iii.* Upon completion of the plan, examine the structural part to be retrofitted..

*iv.* Assess the efficiency of the structural part on the basis of the results of the inspection work

*v.* Check if performance criteria are met by the structural part.

*vi.* Proceed with the design of the retrofitting structure if the structure does not meet performance criteria and if continued use of the structure by retrofitting is required.

*vii.* Select an appropriate form of retrofitting.

*viii.* Specify the materials, structural requirements and method of construction to be used.

*ix.* If it is decided that the retrofitting structure with the chosen retrofitting and construction methods is capable of meeting performance requirements, enforce the retrofitting work.

### *C. Data Collection*

The most critical aspect of every project is data collection. Data collection is a concept that is used to describe a data processing and collection process. For instance, as part of a process enhancement or similar project. The aim of the collection of data is to obtain information to keep on record in order to make decisions on important issues and to pass on information to others. In order to provide information on a particular topic, data is primarily collected. Our project is totally focused on modeling, the designs we received from the consultants of the project are then carried out for the modeling on ETABs.

### *D. Description of Site*

The project is a revised proposed plan of factory on plot no.LA-8/21, block no.22, SCH.no. 16, F.B area, Karachi, M/S Casual Clothing Co. It covers an area of 8050 sqft. The type of construction is the RCC frame structure. Initially it consists of 5 story, which was revised with the increment in story to about 9 story structure. The building occurs in the seismic zone 2B and the soil profile type is Sc that is very dense soil and soft rock. The contractor and the consultant of the project is supervised by the ArifKasam& Associates.

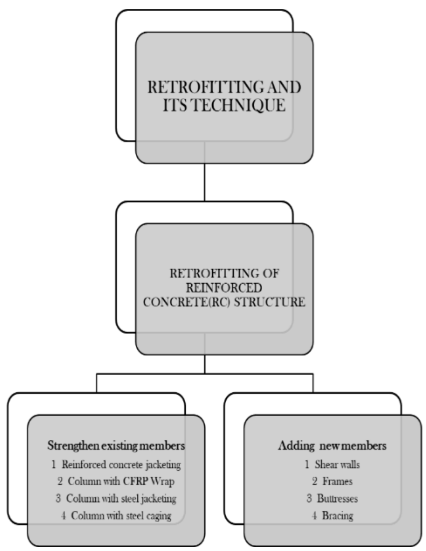
### E. *Building Details*

- Columns

| **Floor \ Mark** | **C1** | **C1A** | **C2** | **C3** | **C4** | **C5** | **C6** |
|---|---|---|---|---|---|---|---|
| Roof<br>To<br>4th Floor | 18”x18<br>” | 18”x30<br>” | 10”x30<br>” | 12”x30<br>” | 12”x24<br>” | 12”x24<br>” | 15”x30<br>” |
| 4th Floor<br>To<br>2nd Floor | 21”x21<br>” | 18”x33<br>” | 10”x33<br>” | 12”x33<br>” | 15”x30<br>” | 15”x30<br>” | 15”x33<br>” |
| 2nd Floor<br>To<br>Foundation | 24”x24<br>” | 18”x36<br>” | 10”x36<br>” | 12”x36<br>” | 18”x30<br>” | 15”x33<br>” | 15”x36<br>” |

- Beams
  8”x24”

### F. *Retrofitting Method to Be Adopted*




### G. *Jacketing:*

Jacketing is one of the most widely used methods for strengthening columns of reinforced concrete (RC). This approach improves the initial column's axial power, bending capacity, and stiffness. It is well recognized that this procedure's success depends on the composite element's monolithic behavior. The common practice is to increase the surface roughness of the interface and to apply a bonding agent, usually an epoxy resin. Steel connectors are sometimes applied as well. Specialized workmanship, time and costs are involved in these steps. With regard to the added concrete mixture and due to the reduced jacket thickness, the alternative is typically a grout with self-compacting concrete (SCC) characteristics and high strength concrete (HSC).Jacketing's main objective is to improve the seismic efficiency of the moment when framed structures are immune. For almost every case, the columns have been jacketed as well as beams of the existing structure. Compared to the jacketing of reinforced concrete columns, it is difficult to jacket reinforced concrete beams with slabs to yield good containment as the slab causes obstacles in the jacket. The increase in stiffness obtained by jacketing columns and some of the ribs in structures with waffle slab has improved structural efficiency.

In certain situations, by jacketing their beams, base grids are reinforced and stiffened. It is possible to achieve an improvement in strength, stiffness and ductility or a combination of them. By confinement of compression concrete, jacketing helps to maximize the lateral strength and ductility. It should be noted that it might not be efficient enough to retrofit a few members with jacketing or any other enclosing strategies to enhance the structure's overall actions. If the remaining members are not ductile.

Reinforced concrete jacketing can be used as a device of repair or reinforcement. The current members ' weakened regions should be patched before the jacketing.

### *H. Requirements to be fulfilled for reinforced concrete jacketing*

| | |
|---|---|
| Properties of jackets | • Fit the current framework with the concrete.<br>• Compressive strength of 5 N/mm2 or at least equal to that of the current structure, greater than that of the existing structures. |
| Minimum Width of Jacket | • 10 cm for cast-in-place concrete and 4 cm for shot-crete.<br>• Four-sided jackets should be used if possible.<br>• The composite column should be assured of its monolithic behavior.<br>• To avoid any potential increase in bending capability, a narrow gap should be provided. |
| Minimum area of transverse reinforcement | • Built and spaced as per experience of earthquake architecture.<br>• The minimum diameter of the bar used for the links is not less than 10 mm or 1/3 of the largest longitudinal bar diameter..<br>• The links should have hooks of 135 degrees with a 10 bar diameter Anchorage |
| Minimum area of longitudinal reinforcement | • 3Afy, where A is the contact region in cm2 and fy is in kg/cm2.<br>• Spacing does not exceed six times the width of the new elements (in the case of the jacket) up to the 60 cm threshold.<br>• The percentage of steel in the jacket should be reduced from 0.015 to 0.04 compared to the area of the jacket.<br>• For a four-sided jacket, at least 12 mm bar should be used at all corners. |
| Shear stress in the interface | • Provide ample mechanism of shear transfer to ensure monolithic behavior.<br>• It is important to avoid relative movement between the two concrete interfaces (between the jacket and the current element.<br>• Chipping the original member's concrete cover and roughening its surface may strengthen the bond between the old and the new concrete.<br>• The ties should be used for four-sided jackets to confine and for shear reinforcement to the composite element. |
| Connectors | • Connectors in both the concrete should be anchored so that it can at least grow.<br>• 80 percent of their pressure to yield<br>• Uniformly spread across the interface, limiting concentration in particular locations<br>• Usage of reinforced bars (rebar) anchored with grout epoxy resins is safer. |

## IV. ETABS

### *A. Overview, Uses and Features of ETABS:*

The progressive and modern new ETABS is the last included software program package for the structural analysis and layout of buildings. Incorporating forty years of non-stop research and development, this latest ETABS presents unrivaled 3D item-based modeling and visualization technology, brilliantly rapid linear and nonlinear analytical potential, sophisticated and targeted layout capabilities for a wide range of materials, and informative image displays, reports and schematic diagrams that enable customers to decipher quick and without difficulty and understand evaluation and layout consequences. ETABS contains each a part of the engineering design procedure from the beginning of challenge introduction through the production of schematic drawings. Model development has never been less complicated-intuitive drawing commands permit brief floor and elevation framing to be created. You may remodel CAD drawings directly into ETABS fashions or use them as templates to overlay ETABS items. The kingdom-of - the-artwork sixty four-bit SAP Fire solver permits for fast analysis of extremely massive and complex models and embraces non-linear modeling techniques which includes creation sequencing and time consequences (creeping and shrinking). The layout of metallic and urban frames (with computerized optimization), composite beams, composite columns, metallic joists and shear partitions for concrete and masonry, in addition to the strength check for steel connections and base plates are covered. Models may be rendered correctly and all consequences may be shown directly at the version. Comprehensive and interactive documents are available for all research and design manufacturing, and for concrete and metal systems it is possible to generate schematic production diagrams of constructing plans, schedules, descriptions and pass-sections. ETABS offers an unheard of array of structural engineering methods constructing homes, both working on one-story business structures and the best residential excessive-rises. Immensely succesful, yet easy-to-use has been the hallmark of ETABS on the grounds that its introduction decades ago, and this modern-day release continues that tradition by means of presenting engineers with the technologically-superior, but intuitive, software they require to be their maximum productive.

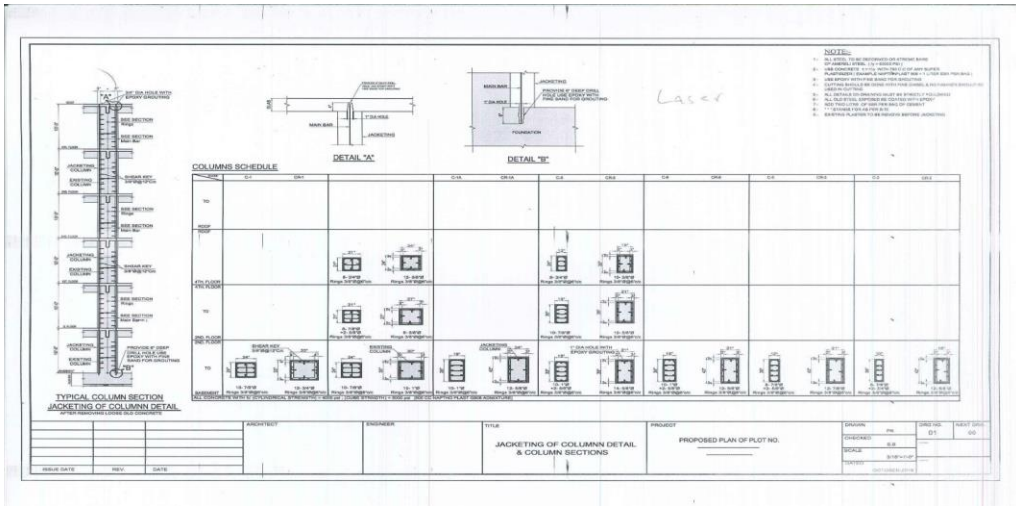
## V. RESULTS

Comparison of drift and torsion results of the building

| STORY | LOAD | INITIAL DRIFT | DRIFT (AFTE R STOR Y INCRE M ENT) | INITI AL TORSI ON | TORSIO N (AFTER STORY INCREM ENT) | DRIFT (AFTER RETROFIT TING) | TORSION (AFTER RETROFIT TING) |
|---|---|---|---|---|---|---|---|
| ROO F | EQX | | 1/254[illegible] | | 1.111 | 1/3306 | 1.104 |
| 8 | EQX | | 1/134[illegible] | | 1.113 | 1/1390 | 1.106 |
| 7 | EQX | | 1/460 | | 1.115 | 1/475 | 1.106 |
| 6 | EQX | | 1/283 | | 1.114 | 1/291 | 1.103 |
| 5RO OF | EQX | 1/722 | 1/216 | 1.1 | 1.110 | 1/252 | 1.096 |
| 4 | EQX | 1/500 | 1/210 | 1.097 | 1.102 | 1/248 | 1.087 |
| 3 | EQX | 1/386 | 1/193 | 1.094 | 1.098 | 1/236 | 1.087 |
| 2 | EQX | 1/357 | 1/198 | 1.101 | 1.104 | 1/255 | 1.099 |
| 1ME Z | EQX | 1/335 | 1/193 | 1.133 | 1.138 | 1/280 | 1.125 |
| GF | EQX | 1/515 | 1/303 | 1.038 | 1.040 | 1/504 | 1.036 |
| ROO F | EQY | | 1/571[illegible] | | 1.082 | 1/6611 | 1.100 |
| 8 | EQY | | 1/199[illegible] | | 1.083 | 1/2092 | 1.100 |
| 7 | EQY | | 1/622 | | 1.082 | 1/648 | 1.100 |
| 6 | EQY | | 1/375 | | 1.082 | 1/382 | 1.103 |
| 5RO OF | EQY | 1/932 | 1/287 | 1.079 | 1.082 | 1/330 | 1.105 |
| 4 | EQY | 1/657 | 1/280 | 1.078 | 1.081 | 1/314 | 1.110 |
| 3 | EQY | 1/514 | 1/263 | 1.079 | 1.082 | 1/302 | 1.117 |
| 2 | EQY | 1/522 | 1/295 | 1.082 | 1.084 | 1/346 | 1.128 |
| 1ME Z | EQY | 1/504 | 1/302 | 1.085 | 1.086 | 1/390 | 1.130 |
| GF | EQY | 1/850 | 1/522 | 1.039 | 1.038 | 1/726 | 1.079 |
| ROO F | EQXP EY | | 1/274[illegible] | | 1.239 | 1/3126 | 1.238 |
| 8 | EQXP EY | | 1/121[illegible] | | 1.243 | 1/1244 | 1.240 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | EQXP EY | | 1/404 | | 1.245 | 1/416 | 1.241 |
| 6 | EQXP EY | | 1/248 | | 1.244 | 1/255 | 1.239 |
| 5RO OF | EQXP EY | 1/631 | 1/188 | 1.232 | 1.240 | 1/219 | 1.232 |
| 4 | EQXP EY | 1/437 | 1/183 | 1.228 | 1.231 | 1/216 | 1.222 |
| 3 | EQXP EY | 1/336 | 1/169 | 1.224 | 1.226 | 1/205 | 1.221 |
| 2 | EQXP EY | 1/326 | 1/180 | 1.229 | 1.230 | 1/229 | 1.231 |
| 1ME Z | EQXP EY | 1/297 | 1/172 | 1.259 | 1.262 | 1/247 | 1.257 |
| GF | EQXP EY | 1/456 | 1/270 | 1.075 | 1.078 | 1/445 | 1.077 |
| ROO F | EQXN EY | | 1/2379 | | 1.011 | 1/3082 | 1.022 |
| 8 | EQXN EY | | 1/1357 | | 1.009 | 1/1544 | 1.022 |
| 7 | EQXN EY | | 1/528 | | 1.008 | 1/546 | 1.022 |
| 6 | EQXN EY | | 1/326 | | 1.009 | 1/337 | 1.025 |
| 5RO OF | EQXN EY | 1/834 | 1/249 | 1.024 | 1.013 | 1/292 | 1.032 |
| 4 | EQXN EY | 1/554 | 1/237 | 1.027 | 1.020 | 1/262 | 1.040 |
| 3 | EQXN EY | 1/399 | 1/203 | 1.029 | 1.023 | 1/238 | 1.040 |
| 2 | EQXN EY | 1/363 | 1/202 | 1.020 | 1.014 | 1/264 | 1.026 |
| 1ME Z | EQXN EY | 1/357 | 1/206 | 1.012 | 1.020 | 1/303 | 1.002 |
| GF | EQXN EY | 1/583 | 1/343 | 1.010 | 1.012 | 1/575 | 1.007 |
| ROO F | EQYP EX | | 1/6053 | | 1.017 | 1/7016 | 1.035 |
| 8 | EQYP EX | | 1/2131 | | 1.017 | 1/2232 | 1.035 |
| 7 | EQYP EX | | 1/665 | | 1.016 | 1/693 | 1.034 |
| 6 | EQYP EX | | 1/402 | | 1.016 | 1/409 | 1.037 |
| 5RO OF | EQYP EX | 1/997 | 1/307 | 1.012 | 1.015 | 1/354 | 1.039 |
| 4 | EQYP EX | 1/703 | 1/300 | 1.010 | 1.013 | 1/337 | 1.044 |
| 3 | EQYP EX | 1/552 | 1/282 | 1.011 | 1.012 | 1/325 | 1.049 |
| 2 | EQYP EX | 1/561 | 1/318 | 1.012 | 1.013 | 1/372 | 1.059 |
| 1ME Z | EQYP EX | 1/536 | 1/321 | 1.014 | 1.014 | 1/417 | 1.061 |
| GF | EQYP EX | 1/917 | 1/564 | 1.008 | 1.007 | 1/783 | 1.050 |
| ROO F | EQYN EX | | 1/5414 | | 1.147 | 1/6251 | 1.164 |
| 8 | EQYN EX | | 1/1883 | | 1.147 | 1/1968 | 1.164 |
| 7 | EQYN EX | | 1/584 | | 1.147 | 1/609 | 1.164 |
| 6 | EQYN EX | | 1/352 | | 1.147 | 1/359 | 1.167 |
| 5RO OF | EQYN EX | 1/876 | 1/269 | 1.145 | 1.147 | 1/309 | 1.170 |
| 4 | EQYN EX | 1/616 | 1/263 | 1.145 | 1.148 | 1/295 | 1.176 |
| 3 | EQYN EX | 1/481 | 1/246 | 1.147 | 1.150 | 1/283 | 1.183 |
| 2 | EQYN EX | 1/487 | 1/276 | 1.151 | 1.154 | 1/323 | 1.194 |
| 1ME Z | EQYN EX | 1/471 | 1/281 | 1.155 | 1.157 | 1/364 | 1.198 |
| GF | EQYN EX | 1/793 | 1/486 | 1.067 | 1.066 | 1/676 | 1.106 |

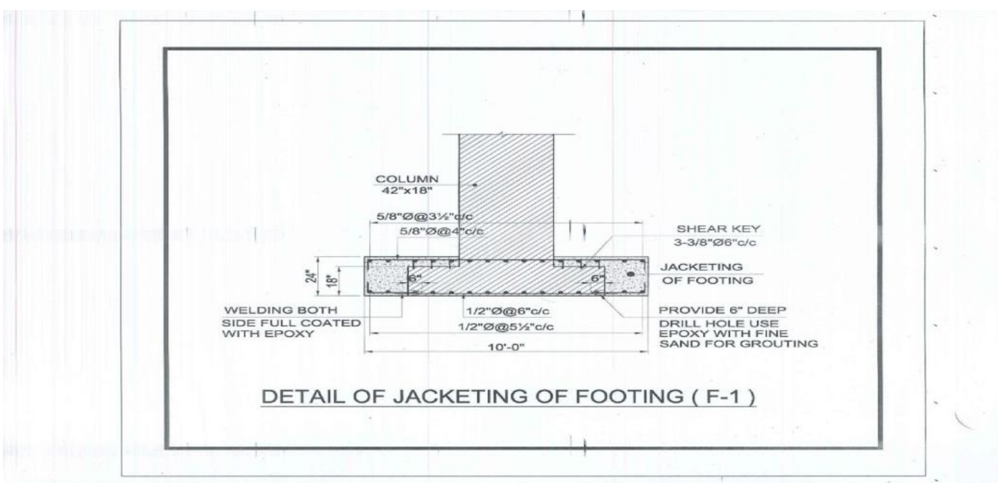
NOTE:
Drift should be > 1/192
Torsion ratio should be < 1.200




Final drawings of columns and footing after retrofitting are shown below:

## VI. CONCLUSION

On the basis of above work and calculations the project concludes:




### A. *Story drift:*

The story drift of the building at certain locations with respect to load cases was exceeding allowable limits (>1/192) which was controlled by retrofitting structural members (columns and footings).

### B. *Torsion*:

Torsion of the building was in limit.

### C. Reinforcement:

Additional steel required after jacketing of columns and footings was provided in jacketing area to bear the additional load of stories added.

## VII. RECOMMENDATIONS

- Additional steel required for seismic is outside the scope of this project.
- It can be easily provided for excess moments by using carbon door strips and shear by carbon wraps.

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