Aims of Case Study

Case study aims explain the events those need to follow in sequence;

1) How the residual strength of building is to be calculated?
2) What and where is the shortfall/s in respect to objectives of retrofitting?
3) Type of necessary retrofit i.e. Local and/ or global,
4) Selection of retrofit methodologies,
5) Checking the results of methodologies selected, in respect of matching
   a. with the objectives, resources availability, and applicability, and
   b. preparation of comparative statement of results,
6) Proposing the best methodology with reasoning,
7) Working the detailing, and drafting,
8) Acceptance to the proposal in principle from the owners,
9) Preparation of estimate,
10) Approval to the estimate in respect of expenditure,
11) Execution of project,
12) Testing, if necessary,

CASE STUDY I

Case History

The building under the case study reference is located in Mumbai, falling in seismic zone III, the MSL between 8-15 m, is not reclaimed land, the strata is sound and consolidated soil mass. The property belongs to M/s Pidilite, the building was originally constructed in the year 1967. Over the period addition and alteration have been carried out. The changes in the usage and structural
load on the structure were made during the course of time as per the then requirements of the company.

M/s Jamnadas & Bhide designed the Marketing department’s building ground floor + First floor. The building second floor constructed later on in the year 1975 and was designed by M/s Mehtalia & Associates with terrace slab.

Later on third floor is added above it, thus converting the roof slab into Floor slab of Third Floor, by removing the brick bat coba & tiling above it which was constructed in the year 1994 and was designed by M/s Mehta & Associates. The building is G+3 standing as on the day.

Further horizontal extension of G+3 floors towards swimming pool was carried out in the year 2007 which was subsequently designed by M/s Mehta & Associates. Front Entrance Foyer was reconstructed in the year 2007 designed by M/s Mehta & Associates.

The maintenance engineer observed the cracks in ground floor columns and beams, and felt necessity of investigation about the formation of cracks and accordingly, the ND Testing carried out through professional specialized agency in the field. The tests carried out and the agency submitted their report. The results pointed out that the concrete is weak and corrosion weakened the strength of reinforcement reducing the factor of safety.

The G+3 upper storied building has 10 years left of the designed life (assuming 50 years of designed life span), in the past life though, the changes in the layout made and construction of additional floors were carried out, was maintained properly. The owner then therefore consulted with the qualified and experienced structural consulting engineer about whether the building be demolished and reconstructed or retrofitting will enhance the life of structure and if so, by how many years?

There were no other problems like foundation settlement, ageing of structure, and effects of pollution, geotechnical deficiency, fire or accidental damages, seismic damages.

Hence, the structural engineer’s task of choosing the methodology of retrofitting / rehabilitation reduced only to select the method, on the merits of

1) Achievement of strength,
<table>
<thead>
<tr>
<th>2)</th>
<th>The gain of additional life span,</th>
</tr>
</thead>
<tbody>
<tr>
<td>3)</td>
<td>Expected quality of work,</td>
</tr>
<tr>
<td>4)</td>
<td>Time requirement for execution of work,</td>
</tr>
<tr>
<td>5)</td>
<td>Undisturbed or minimum disturbance to functionality and</td>
</tr>
<tr>
<td>6)</td>
<td>Expenditure to be incurred.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Figure 69:– Cracks appear on the tiling. Location no.1</th>
</tr>
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<tbody>
<tr>
<td>Figure 70:– Cracks appear on the tiling. Location no. 2</td>
</tr>
</tbody>
</table>

**Cracks developed on tiled portion due to weakness of the column**

**Figure 71 Vertical Cracks all around the Column above Granite**
The non-destructive testing of the structure was carried out by Advanced Diagnostic Laboratory. Some of the relevant points of the report are as under:

a) The Ultrasonic Pulse Velocity and Schmidt Rebound Hammer Test Report indicate that the columns of ground floor badly damaged.

b) The testing of concrete reveals that grade of concrete is doubtful.

c) The columns of ground floor show large distress.

d) The grading of concrete is poor as confirm by the Rebound Hammer test.

e) The chloride test report it is clearly shown that the values are higher than the limiting value, it confirm that corrosion has taken place in the reinforcement.
PROPOSAL

The building being G+3 structure and is extended vertically three different times, the designed life of foundation remains as 60 years, but it is also observed that the buildings can last, if maintained properly and periodically, for 50% more life. The theoretical remaining life of building 14 years and another 30 grace years put together makes 47 years, it is therefore worthwhile to rehabilitation, retrofit, and maintain the structure and en-cash these 47 years. Considering the reports of tests carried out, the building requires the rehabilitation and retrofit.

In order to retrofit the building the first step required was to model the structure, and to carry out the analysis subjecting it to the requisite given loading and structural parameters as existed. Modeling was done with STAAD and STRUDS software, ready program, analysis was carried out to assess the residual strength of the building and initial report to that effect was prepared.

The Initial report was, then submitted and client called for a meeting, including site visit of the ground floor. During the meeting, it conveyed to the client about the weakness in other members of the structure, found while estimating the residual strength.

Client asked to submit the revised proposal, for floor wise strengthening measures.

It was necessary at this stage to prepare model of the structure and analyze.

Accordingly site was visited to collect more information such as detailed structural drawings, to record detailed report of cracked sections in proper order, of every column and beam member, to check whether the existing measurements on site tally with the drawings or otherwise and prepare fresh record as per site conditions.
BASIC ANALYSIS METHODOLOGY AND ASSUMPTIONS FOR MODELING

a) Structural analysis of the building frame Has been performed by creating model, in STAAD and STRUDS software. Geometry of the model is developed based on the available RCC drawing forwarded by the client.

Refer figure 1 and 2 for STRUDS and STAAD model of the building.

b) The concrete grade is considered as M20 for the complete structure. However it is to be noted that the non destructive testing report of the ground floor columns suggest that the pulse velocity test and rebound hammer test result reveal poor quality of concrete i.e. grade even less than M20. But in the software used for analysis minimum concrete grade taken is M20 and hence considered. It implies that the compressive strength as obtained from analysis will be higher than actual present in the column at site.

c) Reinforcement grade for main flexure reinforcement and shear stirrups is considered to be Fe 415.

d) Nominal cover to reinforcing steel is considered as 40mm for column and 25mm for beams.

e) All columns considered as fixed at base.

f) Main basic loads applied on the structure are dead loads, imposed loads, wind and seismic loads

g) It is assumed that concrete and reinforcing steel have not deteriorated and do not have corrosion or loss of strength.
RECOMMENDATIONS

The results obtained after analysis were studied in detail in collaboration with the NDT report as given by the client.

The following recommendations deduced for making the structure safe:-

Columns of Ground Floor

As the NDT report suggest the concrete strength and the quality cannot be ascertain and both the rebound hammer test and pulse velocity test indicates poor quality of concrete. Therefore, it is recommended that, the columns at the ground floor, be strengthened by Column Jacketing with 75mm microconcrete and steel.

The methodology for the same is as per design drawing detail number SHM-PID-1-R-01 attached.

Columns of First, Second and Third Floor

The selective NDT of the columns are suggested to be done. However on the analysis of the results and the steel incorporated in the columns as given in the structural drawing provided by the client there is deficiency observed in the steel required. Therefore, it was assessed that the following number of columns required, to be strengthened by fiber wrap as per design drawing detail number SHM-PID-R-02.

(a) First floor- 21 columns
(b) Second Floor- 35 columns
(c) Third Floor- 36 columns

Beams of Ground and First floor
The Peripheral beams at the ground floor and first floor level need strengthening with laminates and the methodology for the same as given herewith.

Figure 72:-

**Rusted Rebars of the Column**

The rusting is the indicator of presence of moisture or chemical reaction. The rusting reduces the cross sectional area of the rebars and thereby the strength is reduced. This justifies the need of retrofitting of the structure.

**TECHNICAL SPECIFICATIONS**

1. **REPAIRING OF R.C. STRUCTURAL MEMBERS**

   a. All distressed R.C. members shall be exposed of existing plaster and loose and disintegrated concrete for the investigation of corrosion activity in Rebars by chisel and light weight hammer (prefer vibro-hammer). Proper scaffolding and shoring shall be provided.
2. Rust passivation coat shall be applied and rebars shall be cleaned with rotary wire brush and rust remover.

3. Wherever the rebar reduced by more than 20% of original, extra main rebar shall be provided by tying a suitable dia. bar to existing rebar with a lap of 12 to 40 times the dia. of such bar depending on location and type of structural member. In case development length of 12 to 40 times is not available, a hole will be drilled in the hard & healthy concrete and new rebar shall be anchored therein using Epoxy mortar.

G.I. weld wire mesh of 100 mm. x 100 mm. (10 gauges) shall be clamped on all sides of RC members. The mesh shall be clamped onto concrete surface by means of concrete nails and binding wire.

4. A bonding coat of Polymer Latex (SBR) over the exposed steel/mesh/concrete shall be applied in 1:1 ratio of cement to Polymer Latex prior to application of new polymer based mortar/modified mortar / micro-concrete / modified concrete / ordinary concrete as directed in step (i).

OR (as specified)

An Epoxy bonding coat shall be applied between the old and new concrete subjected to high stresses, prior to repairs to be done with Polymer Modified Mortar after the coat becomes sticky (leaving finger prints when touched).
5. Repair of Damaged Portions: Repair with Micro-silica and Fiber blended repair mortar of following specifications.

Polymer Modified Mortar, (PMM)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Material Description</th>
<th>QTY</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cement (OPC).</td>
<td>500</td>
<td>Kg.</td>
</tr>
<tr>
<td>2</td>
<td>Quartz Sand well graded 2.36 mm. downgraded</td>
<td>1500</td>
<td>kg.</td>
</tr>
<tr>
<td>3</td>
<td>Polymer Latex @ 20% dose</td>
<td>100</td>
<td>kg</td>
</tr>
<tr>
<td>4</td>
<td>Water</td>
<td>150 to 170</td>
<td>liters</td>
</tr>
</tbody>
</table>

Table 1: Material Description

Curing, with spraying water, for 3 days, & drying for next 5 days.

The thickness, of applicant material Coating:

In one application, 10 to 15 mm. thicknesses shall be built. Subsequent layer shall be built with one bond coat of Polymer modified cement slurry.

Application Method:

i. Hand packing shall be used and surface finish shall be obtained with trowel. Surface shall be roughened by binding wire.

ii. In one application 10 to 15 mm. thicknesses shall be built. Subsequent layer shall be built with one bond coat of Polymer modified cement slurry.

iii. Hand packing shall be used and

iv. Finished surface shall be obtained with trowel. Surface shall be roughened by binding wire.
2. REPAIR OF HONEYCOMBED AREAS AND STITCHING OF CRACKS

When RC members have honey combing inside after removal of loose concrete material it is advised to inject low viscosity epoxy injection resin in the honey combed area. Also same technique could be adopted in case of cracks (2 to 3 mm. wide) in these elements. Drilling holes in concrete and fixing one way injection packers using with ready to use polymer based quick stopper plug (sealer).

“A hole shall be drilled into the honey combed area and along the cracks. Compressed air shall be used to clean the hole, cracks and honey combed portion to remove dust and dirt. One way injection packers shall be fixed into the holes. Spacing of holes shall be 300mm to 600 depending upon the deficiency / crack pattern. Surface of crack shall be sealed with epoxy sealant to ensure that injection material does not leak from cracks. Also the honey combed areas shall be sealed in the similar manner. Injection packers shall be secured in fixed position with help of epoxy sealant. This preparation shall be left for 24 hours for drying and hardening.”

Inject Corrosion Inhibitor of approximate quantity of 100ml in each nozzle so that material penetrates inside the concrete surface and arrests corrosion of rusting steel. Injection of epoxy resin shall be completed in two stages using Very Low Viscosity Injection Resin and Low Viscosity Resin with 24 hrs operation interval. Very Low Viscosity Injection Resin shall be injected to fill very fine cracks and micro-cracks and, also to strengthen the injected portion. Low Viscosity Resin shall be injected to finally fill the micro-cracks and honeycombs. Both operations shall be used in combination. Injection pressure shall be 2 kg/cm for Very Low Viscosity Resin and 2.5 to 3.0 kg/cm for Low Viscosity Resin. Machine operated compressor shall be used with small air flow. In case no material could be injected from one Injection packers due to path blocked, maintain the pressure for 10 min. and continue the operation from next Injection packers. Having completed the injection process the Injection packers shall be flush cut after 24 hours.”

3) FIBRE WRAPPING SYSTEM

a) Mortar Treatment: Application of average 10 to 20 mm thick Polymer Modified Mortar over the uneven RCC element surface by using Polymer Modified Cement bonding coat.
b) Curing of subsurface: Mortar should be cured properly, maintaining moisture level in substrata less than 4 to 6%.

c) Surface Preparation: The surface to be repaired is ground to smooth out the irregularities and sharp corners. Rounding of column / beam edges shall be done by grinding.

d) Application of Primer: In order to improve adhesion and prevent the surface from drawing resin from the wrap, a low viscosity epoxy primer is applied with a roller until the substrate is locally saturated.

e) Application of Putty: adhesive, high viscosity putty is applied when necessary to the surface to fill in pin holes, offsets or voids.

f) Application of Saturant: Apply Saturant coat to primed surface and FRP sheet using a medium nap roller. (Mechanized wetting of fiber sheet: Cut the fabric to required size. Mix the saturant and fill the same in tub area of the wet lay up saturation machine. Place the fiber on metallic rods and pass through the rollers of machine and saturant tub ensuring complete wetting (65% fiber volume fraction) of fibers. Remove the fiber on rod and place the new fiber sheet.)

g) Application of Composite Wraps: Fabric will be carefully laid onto the surface and smoothed out to remove air bubbles and ensure that the fibers are straight and there are no wrinkles.

h) Sand Sprinkling: Sand should be sprinkled on the final coat of wrap.

4) METHODOLOGY FOR PRE-STRESSING LAMINATE SYSTEM

A) Surface preparation: basic treatment must be made to the surface prior to strengthening with pre-stressing laminate system. Surface is very well grinded to make the surface clean & free from undulations to mark easily & for strong bonding between the existing concrete & laminate.

B) Marking on surface: after grinding the surface is well prepared for marking as per the drawings. Now you can start preparing the design on the surface keeping in mind that the alignment of machine must be maintained accurately. Misalignment while marking may cause damage to the laminate.
C) Fixing of anchor plates: after preparation of surface further step is to fix the end anchor plates as per the markings by drilling the holes up to the sufficient depth & inserting the hilty bolts to tighten-up the anchor plates on both sides with proper alignment. Anchor plates helps to avoid pealing of laminates from ends on excess loads.

D) Fixing of clamping device: just behind the anchor plate the another step is to align the clamping devices on both sides with supporting l – clamps in which the laminate is placed and tightly hold with the help of high tension bolts as shown in the picture.

E) Aligning of cylinder body: the last step is to fix the piston body maintaining the alignment of other two bodies, in which the hydraulic cylinder is locked and pressure is applied to stretch the laminate as per the design load in tons.

F) Placing laminate: after the overall fitting and the alignment of the pre-stress machine now its time to take the measurement & cut the laminate according to the cut length and fix it on the beam surface.

G) Cylinder fixing: now as all steps are completed in a sequence it’s a time to fit the hydraulic cylinder inside the cylinder body with proper clamping of locks and hose pipes to avoid any kind of damages & leakages.

H) Applying pressure: fixture is ready to take the sufficient load applied to stretch the laminate. The picture shows that load applied on the system, to increase the flexural

    strength of the beam.

I) Pre-stressed Column: finally after applying pressure the machine is dismantled and the end anchors plates is fixed

1) **APPROVED BRANDS OF CONSTRUCTION / REPAIR CHEMICALS AND OTHER MATERIALS**

The materials used must be approved by the Consultant in writing. The following Materials approved for use.
Any material brand name not specified above, shall be used, after having written approval from the consultant. Equivalent material shall be permitted after approval of consultant in writing.

<table>
<thead>
<tr>
<th>SN</th>
<th>MATERIALS</th>
<th>APPROVED BRAND / MAKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rust Remover</td>
<td>Dr. Fixit Rust Remover, Feovert : Krishna Conchem or equivalent</td>
</tr>
<tr>
<td>2</td>
<td>SBR Latex Polymer</td>
<td>Dr. Fixit Pidicrete URP, Monobond – SBR Krishna Conchem / Rheomix 141 of BASF or equivalent</td>
</tr>
<tr>
<td>3</td>
<td>Anti-corrosive Protective Coat on Rebars</td>
<td>Dr. Fixit Epoxy Zinc Primer or IP NET RB Krishna</td>
</tr>
<tr>
<td>4</td>
<td>Epoxy Bonding Agent</td>
<td>Krishna Conchem, Dr. Fixit Bonding Agent (Two Part Epoxy based) / Conressive 1414 of BASF or equivalent</td>
</tr>
<tr>
<td>5</td>
<td>Migratory Corrosion Inhibitor</td>
<td>Ferrogard – 903 of Sika, EPCO-KP-100 : Krishna</td>
</tr>
<tr>
<td>6</td>
<td>Sand for Plaster</td>
<td>Conchem River sand or equivalent</td>
</tr>
<tr>
<td>7</td>
<td>Sand for Polymer Mortar</td>
<td>Quartz sand / Washed river sand or blend of two at specified proportion or equivalent</td>
</tr>
<tr>
<td>8</td>
<td>low viscosity high molecular weight thermoset polymer</td>
<td>Monopol : Krishna Conchem or equivalent</td>
</tr>
<tr>
<td>9</td>
<td>Polypropylene Fibre</td>
<td>Rheofibre Of BASF or equivalent</td>
</tr>
<tr>
<td>10</td>
<td>Cement 43 grade</td>
<td>OPC / Fly ash blended (Ambuja)</td>
</tr>
<tr>
<td>11</td>
<td>Acrylic Paint</td>
<td>(100%) Apex, ICI or as approved</td>
</tr>
<tr>
<td>12</td>
<td>Protective Coating System</td>
<td>(Primer Masterkure 181 + Master Seal 200 H) of BASF or equivalent</td>
</tr>
<tr>
<td>13</td>
<td>Carbon wrap</td>
<td>R&amp;M C-Sheet (400 gsm) or equivalent</td>
</tr>
<tr>
<td>14</td>
<td>Primer</td>
<td>R&amp;M Resin Primer or equivalent</td>
</tr>
<tr>
<td>15</td>
<td>Saturant coat</td>
<td>R&amp;M Resin Epoxy or equivalent</td>
</tr>
<tr>
<td>16</td>
<td>Carbon Shear Anchors</td>
<td>(Single) R&amp;M ECFA/1 or equivalent</td>
</tr>
<tr>
<td>17</td>
<td>Carbon Pre-stressed Laminates</td>
<td>R&amp;M CFK Laminates or equivalent</td>
</tr>
<tr>
<td>18</td>
<td>Mechanical Pre-stressing Anchor System</td>
<td>R&amp;M Pre-stressing Anchor System or equivalent</td>
</tr>
</tbody>
</table>

Table No. 5 Materials and their approved make
CASE STUDY-II

The aim:

The aim of this case study was to Observe and Discuss the scenario and status of the Rehabilitation after 13 yrs of post Bhuj earthquake disaster of 26\textsuperscript{th}, Jan. 2001, with construction community, occupants from the rehabilitated buildings, and public at large, from seismic zones, III – V in Gujarat.

In the process, I visited Ahmadabad, Bhuj, Adipur, Gandhidham cities. Interviewed the Architects, Structural Engineers, Contractors, Builders / Developers / Owners; occupants of reconstructed, retrofitted buildings, NGO’s, and public at large. The findings are

The change took place, after striking of earthquake, in Approach / Lookout of members, of construction industry community. The changes in the mind set of


   In city of Ahmadabad falling in seismic, zone III
   In engineered Buildings
   There is noticeable change in attitude of majority of builders / developers about following the structural engineer's instructions and detailing of reinforcement. They do not play any more roles in concrete mix proportion.
   Clerk of works (Site Engineer) appointed,
   Better construction practices adopted, in Non-engineered buildings and low cost buildings or chawals. In single stoery, chawal type buildings roof provided is in tin or fiber sheets. In some places plinth, lintel, and roof level bands seen provided.

   In city of Bhuj, Gandhidham, Adipur, falling in seismic, zone V
   In engineered Buildings.
   RCC construction done carefully; other activities are not done as per specifications in majority of cases.
   Clerk of works (Site Engineer) not appointed,

   In Non-engineered buildings and low cost buildings or chawals
More care exercised as compared to pre earthquake scenario especially in execution of RCC construction,
In rural areas hut/ dwellings walls constructed in light weight material, and roofing is in thatched or tin / fiber sheets,
Locally developed proven method of construction adopted, dwelling of about 200 Sq.ft. in circular shape, seen most preferred one.

2. Architects

In city of Ahmadabad falling in seismic, zone III
They are in better position to follow the Building Rules, Regulations and Bye laws more intensely as they are experiencing less pressure from builder /developers / Owners as of pre-earthquake era,
No change marked in regards with; elevation treatment, providing offsets in vertical and horizontal direction, provision of floating column, provision of stilt parking,

In city of Bhuj, Gandhidham, Adipur, falling in seismic, zone V
They are in better position to follow the Building Rules, Regulations and Bye laws laid down by the local authority more intensely as they are experiencing less pressure from builder /developers / Owners as of pre-earthquake era.

3. Structural Engineers

In city of Ahmadabad falling in seismic zone III and in city of Bhuj, Gandhidham, Adipur, falling in seismic, zone V
They are experiencing more freedom from pressure for opting for undue saving in steel provision.
Post earthquake generation of engineers is update in knowledge of seismic resistant designing.
The need for seismic resistivity is, now cared for as against pre-earthquake scenario.

4. Clerk of Works (Site Engineer)
In city of Ahmedabad falling in seismic, zone III
Post earthquake new generation Engineers posses more in-depth knowledge of construction of seismic resistant building, they have a better scope to serve the society, there services utilized only for RCC works and have no presence during construction of non-structural works of building.

In city of Bhuj, Gandhidham, Adipur, falling in seismic, zone V
They have a little scope in these small towns as these are being developed horizontally, and in a refined traditional pattern.

5. The authorities

In city of Ahmedabad falling in seismic, zone III
Post earthquake era saw constitution of Ahmadabad Urban Development Authority (AUDA), for Urban Planning and Implementation. The changes made are

i. No fancy like terrace top swimming pools, gardens allowed.

ii. On site checking at various levels of constructions exercised at
   a. Foundation,
   b. Plinth,
   c. Every slab level,
   d. Pre-issuance of building completion certificate.

The Architect, the Structural Engineer, and the Clerk of works are required to submit undertaking on stamp paper of proper execution of work by them, only than the building completion certificate issued.

In city of Bhuj, Gandhidham, Adipur, falling in seismic zone V
The earlier authority was chaired by elected public representative member, a non technical person. Number of multistory buildings approved by the than authority committee prior to earthquake, it is learned that, dissent was expressed by the only technical member for many of these buildings was over ruled on basis of majority of
votes, have fallen prey of earthquake disaster. A lesson learnt and new Bhuj Area Development Authority (BHADA) constituted post earthquake, and chaired by a Town planner Engineer.

The new committee laid many new rules, for relocation of disaster affected persons, and few prominent of them are

- Building height is restricted between 9 Mts-12 Mts, inclusive of OH Tank.
- Plastic O.H. Tanks to be provided in place of RCC O.H. Tanks.
- Plots for residence allotted restricted to about 200 Sq. Mts.; with permission to construct a building up to 60% of the area of the plot.
- On site checking at various levels of constructions and many other rules are same as for AUDA (as mentioned above).

Many Structural Engineers from both the seismic zones expressed need of cross checking of the design submitted by them, at present a hard and a soft copy of design is submitted to authority and no cross checking is done. The status of this issue is same all over India, which needs to be dressed.

A very valued and remarkable information came to fore during discussion with a senior civil engineer from Adipur. After 1956 earthquake in Kachchh region, a colony of more than 100 buildings were developed by a local visionary in consultation with Earthquake Expert Engineers from France, and more than 90% of them withstood safely the 2001quake tremors and exist today as well.

For relief of disaster-affected people, many NGOs participated and worked all over Ahmadabad and Kachchh in Gujarat.

Prior to earthquake some NGO’s worked in the field of education in rural area, their presence, knowhow of the area and their acquaintance and association with the villagers made them flung into activity of rescue and relief operation., initially temporary shelters raised In relief operation in association with, governmental and other NGO’s. Responsibility shouldered by few of them of helping, supervising and monitoring the Owner driven Reconstruction (ODR) Collaborative scheme. The summery of their work recorded in the CD (attached in appendix)
A NGO founded in the year 2003, by the association of like-minded persons of breakaway group from various NGO’s. They have set a very 'Ideal Aim' of working field for them. Their area of operation includes rescue, construct relief shelters, operate ODR Collaborative scheme with locally available earthquake resistant proven traditional construction knowledge, material, and respective skilled labour, and the last but very important aspect of teaching, spreading and sharing this knowhow with the laborer.

They have shouldered many rescue, relocation, and resettlement programs in India and in Asia. In the process, they have constructed 30000 interim shelters and 12000 permanent reconstructions put together till date. In Bhuj, in all 70%, buildings retrofitted and rest reconstructed.

(Two booklets published by the NGO HFL attached in the Annexure)

Owner driven Reconstruction (ODR) Collaborative scheme
After math of disaster may it be because of natural or manmade calamity, rising of temporary shelters followed by permanent reconstruction of building is inevitable. This is an innovative scheme and appreciated all over the world for the direct and active participation of Owner of the building in rebuilding process.

Comments

In city of Ahmadabad falling in seismic, zone III
It was learnt, from the interviewees, as they refused to give the personal details, but opined that prior to striking of earthquake, majority of tower buildings that were passed for G+X floors were constructed with G+X+ (2, 3, and 4) additional unauthorized floors many of they were prey of quake. It is doubtful whether the provision for additional was done in advance or otherwise. Further, the G+5-6 storied buildings that collapsed were majorly for; Soft storey effect accompanied by insufficient detailing, some other buildings had irregular shapes in plan and or elevation and poor quality of construction. Collapses for pounding effect were absent but some buildings were sufferers for falling of OH Tank, part of falling floor or debris of adjacent collapsing building.

At Ahmadabad
Interview with residents of Mansi building

They initially refused to discuss anything about scenario, post 13 yrs of the incident of earthquake of 26th, Jan. 2001. They did not want to remember those very sad and painful moments, but with my request and explaining the purpose of interview, they agreed to discuss but on the condition that, their identity should not be disclosed, as the matter still subjugated. Therefore, the sum and substance of discussion written in script form, and could not be presented in question and answer format.

The details of the building

A G+10-stored tower, with two wings, stilt parking provision, and occupied.

One wing collapsed, killing many of the occupants, as the day was a republic day national holiday, the number of residents at home was more than on normal working day.

An owner of the commercial shop from the neighboring building, explained me, with heavy heart and tears in his eyes, the scenario, who witnessed the miserable unforgettable incidence. With movement of the ground and hearing of loud cracking and banging noise of he came on the road, only to observe and witness the collapsing the neighboring building, "The Mansi Apartment". By then, it was clear in the minds that were on the road, the striking of earthquake, which caused the collapse of the building. They rushed to safer distance near to the collapsing building, in order to rescue and help the trapped ones. He observed the top floor was tilting and slowly coming down. By then, the bungalow owner and his family had came out in the open space, were a gasped with what they were witnessing. The top floor of the collapsing building came slowly to rested on the side and roof of the bungalow and in some moments a person, survivor, resident from the top floor, struggled and came out from the main entrance of the bungalow. He was shocked as all others, and observed and tried to sensitize situation only to visualize that in all probabilities his family members trapped under the derbies of the fallen building, he had built.

By the time, the fire brigade rescue came in to operation, the first after shook struck at about 11-45 am., collapsing loosely hanging parts/ portions of the building.
It was fact that the collapsed building had a swimming pool and guardian on the top floor, where the builder was occupant. The plans for this building were passed for G+7 stored building but the constructed building had G+10 stores, at the time of incident.

The open end of the episode; whether the building was designed architecturally and or Structurally for G+10 from conception of the project or the idea of adding the three unauthorized floors was conceived at latter stage, nobody knows accept builder, and perhaps the Architect, and the structural Engineer.

The lose end, raises following questions and they are:

1) Was the building architecturally and or structurally designed with the provisions for G+10 stores or otherwise? And
2) Whether occupation certificate (O.C.) issued was for G+7 or for all G+10 stores?
3) If O.C. was issued for G+7 building, then, was objection raised for additional three unauthorized constructed floors by the O.C. issuing authority?
4) If not, why not?
5) If so, was and is the matter subjugated?

Few members gathered after about a year (In the early part of year 2001.), and discussed about the rebuilding of the structure under the scheme declared by the government of Gujarat State. More members joined them and the general body meeting of the society passed the resolution empowering committee of few members to move on the task of rebuilding. The first of all the things was to gather the requisite documents of both society and the proof of the collapse of the building and its evaluation by the CEPT Institute, a government appointed organization for assessing and evaluating the damages of the buildings suffered during the quake strike.

The second issue was that of unauthorized occupant members. The high court by than had issued orders to accommodate all the sufferer occupiers, irrespective of their occupancy authorized or otherwise.

The third of the issue was whether the survived wing, to be demolished and entire building to be reconstructed or otherwise. The members residing in the survived wing, as it would cost them a big amount, raised this issue. The issue entered in the court of law, the fast track court ordered, to
demolish the survived part and reconstruct the building accommodating all the members, based on the CEPT's recommendations.

The forth issue came up was whether to appoint a builder or construct the building by appointing contractor? Subsidies offered by the GOG on cement and steel were for owners constructing the building, thus a contractor was appointed to avail the subsidies.

The reconstruction coasted every member about Rs. 6-7 lakh, beyond the subsidies and help for rebuild the building by GOG of Rs. 1,75,000/-. The banks offered loans to the sufferers at the fixed rate of 8% p.a. with 15 yrs repayment term and IT Dept. of GOI waved the tax on entire repayment amount.

Finally the building was completed and reoccupied by the members in 2008 i.e. it took 7 & 1/2 yrs for rehabilitation.

**In city of Bhuj, Gandhidham, Adipur, falling in seismic zone V**

The new rule restricting height of building though enforced, decision about quake stricken survived existing building in view of height restriction is pending for socio, political and economic reasons.

A government owned Hospital building constructed for G+2 stories with rubber bearing base isolation system in Bhuj. Retrofitting of about 70% of damaged buildings was done, about 15 % of buildings were reconstructed, and rest still is in collapsed form.

A hostel building collapsed for the reason of improper connectivity between the existing building and the extended portion, some privet owned bungalows, which were extended after 15-20 yrs had fallen for the same reason in Gandhidham, Adipur.

Regarding non-engineered buildings and especially dwellings in rural areas villages or some clusters are relocated. The local artisans and masons are trained by a NGO run school, for them, in modified format of traditional construction pattern, with locally available low cost material like bamboo walls with modified mud plaster, thatched roof, and dried mud bricks etc. gained popularity, for its low cost and fast construction.
At Bhuj, Adipur, Anjar

There are many multistory buildings exist that have withstood the earthquake in these towns, but the traditionally, but poorly constructed stone masonry bungalows, building, old houses become the pray, and death toll increased as many office goers, schoolchildren were at home.

A heart breaking incidence in this respect was narrated by a Bhuj resident and owner of the lodge and he explained it to me with tears in his eyes. A member from family of 18 persons, having family business of catering, went to market at 8 am, all others were at home when the tremor struck, and the building, the family was staying, collapsed, killing all 17 persons at home.

In old town area, the houses were built very close to each other, having narrow lanes in between them. Majority of these houses were old traditionally built in stone masonry and had heavy structure for roof, the focus of quake being very shallow and close to the town. The walls could not stand the force of the quake and crumbled, the roof portion being heavy latter part of killing of the inmates followed it.

About fifteen unfinished structural frames with brickwork partly completed were seen, on enquiry it was learnt that, these buildings were under construction at the time of striking of earthquake. After the incidence, the work was stopped by the BHADA, and decision about the fate of these buildings is pending as the disputed matter is subjugated. Few of these buildings are facing major roads, if any untoward incidence to happen these incomplete buildings may crumble and endearing the life of passer byes, and adjoining buildings.

A civil engineer by profession from Adipur town confessed, though knowing that the town falls in high-risk zone and the technical effects of odd configuration of structure in plan and elevation. Extended few additional rooms on ground floor disturbing the configuration in plan and part first floor added, further disturbing configuration in elevation, after 15 years of construction of existing house, about a year prior to quake without considering, the resistivity requisite of earthquake. He had to witness the collapsing house,

The rally of Independence Day celebration of about 200 students was taken out in town of Anjar, on hearing roaring noise students were instructed by the teacher to lie down on the ground, thinking that it was aerial attack of war. It was un-apprehended earthquake and the
falling derbies from collapsing buildings from both sides of the road took the toll of the students from the rally as they were lying in the middle of the road. Either the resistive structures and or wider roads would have saved lives of innocent students. A resident who lost his son, participating in that rally, narrated the incident.

**Observations, suggestions, and Comments**

Nature normally do not attack without warning, a fair alarming for 26 th, Jan. 2001 quake was in a way of the severe tremors experienced in the Bhavnagar district falling in seismic zone IV, in the month of October 2000.

Disaster preparedness, mitigation planning, readiness, and spreading word of awareness in the citizens, with the alarm raised in October 2000, would have lowered the death toll. The evaluation survey of the buildings would have reduced number of collapsed buildings, retrofitting to building done by few (even if say 5%) alert owners of buildings, those many buildings, occupants there in, would have been safe.

The past earthquake of 1956 at Anjar thou was of higher intensity did not prove as devastative as the 2001. It affected only the sub-district, as compared 2001 affected about 22 districts and 4 major cities in state of Gujarat. The statistical inference explains the fact that the multistory towers and with 5-6 storied buildings in these cities were the pray, for the reason of use of poor quality material, incompetent design and or method of application and workmanship. In cities, it was major of manmade devastation then by quake.

In past hundred years, tremors, more than 200, of the scale measuring more than 6.0 of Richter scale have struck. The seismic records reveal the fact that the Northeastern states of India hit by quakes of intensity around 5.0 thrice a year, and of intensity of about 6.0 four times in every three years. This repeated event has taught the citizens from the region to be alert and prepared, round the clock, and they cop up and equip, themselves to face the situation. They have devised the earthquake proof buildings with the locally available material, by applying the basics of; keeping the roof as light as possible, constructing buildings of regular shapes viz. square, rectangular, walls properly connected to vertical supports.
It is said, that public memory is short lived. In case of Kachchha region the 26th, Jan. 2001 disaster struck after 44 years, it is more than two generations before, so it appeals me that the citizens from the region had also forgotten the fact that they leave in high intensity seismic zone, and therefore were caught completely unaware, unprepared, and so were government functionaries.

It rightly pointed out in an article in The Times of India, "There is an in-built tendency for these ‘Acts of God’ to inflict their worst effects on the poorest people. None of the modern industrial establishments of Gujarat damaged. ‘God must be an industrialist’.

The survival of industries with minor or no damages, to me, is not astonishing, and the reason I am putting forth is different perhaps from many others. It is psychology and philosophy based reason.

An industrialist is investing hug amount; may be partially loan but he has to repay the same in a fixed period, therefore he emphasizes and never compromise on security and safety of the entire project, no matter if the project has to bear extra cost for the same. All industrialists run the industry and never think ofshouldering off their responsibility.

On the other hand, many but not all, builders/developers of building projects have a different look out. The investment made is to come back by sailing the flats, as well as they are always on the lookout of reducing costing, by hook or crook, and on sailing the flats they shoulder off the their many of promises, commitments, and responsibilities silently. In such scenario where and how will the additional cost of security and safety, in respect of earthquake, for would be purchasers, would fit in his psychology and philosophy.

This is what exactly happened, in my opinion, in cases of many of the collapsed buildings in Ahmadabad city.

Northwestern part of state of Gujarat is located in the zone where tectonic plate known as Indo-Australian is sliding under the neighboring plate named as Eurasian north worldly. This makes the region vulnerable to frequent earthquakes. It is therefore essential that the citizens leaving in this region alerted frequently and trend to be ready to face the emergent situation under Disaster
mitigation program of state and central government organizations as well as with the help of NGOs.

**Conclusion**

The citizens have accepted and adapted to the present scenario and the intensity and the pinch of the disaster has diminished, and so is the awareness about the Safety for life and the Home. The momentum that had gathered in post quake years is losing its footprints and foothold. It is therefore essential for government organizations and NGOs to campaign and promote the awareness about the **Safety of Life and the Home of the citizens.**

All the study up to now in this paper is based on technical and general aspects in respect and regards with material, skilled labour, local traditional practices, and economic viability of all types of residential structures. The objective of the paper is to give "at a glance" information in simple words for a common non-technical person, urban or rural citizen, in order to help him in decision making about the safety of his/her family, in the present or proposed construction or purchase of "SWEET HOME."

Now a comparison of methods of retrofitting in respect of life cycle evaluation will through light on the real worthiness and for best choice.

More of rural population and their residences and few major cities with densely populated areas fall in seismic zones IV & V. The landmass covered in these zones is about 29% and further 30% under zone III of entire country. This means about 59% of landmass of India is subjected to moderate to very high risk of earthquake strike and thereby of the safety of citizens and there habitats is under luring danger.

The scene needs to be changed by imbibing awareness, preparedness, and mitigating strategies in citizens, through governmental organizations, NGOs, media, and all other communication modes.
The types of buildings that will have to react with seismic forces vary from a dwelling in rural areas, to a multi-storied building in urban areas. The modes of rehabilitation therefore would have to be different for structures in rural and urban areas according to material, skilled labour, availability, socio, legal, policy, and last but not the least important aspect of economical viability of the owner. Beyond all these aspects, a centralized policy in respect of safety of every person and his/her residence need to be adapted.

New approaches and techniques are emerging in both traditional as well as in developed Innovative methodologies of retrofitting; they are helping society to move towards the goal.

The new trends are:

1) **In low cost buildings,**
   a. Reducing mass of construction i.e. Thatched roofing, and bamboo walls with mud plaster.
   b. Dried mud bricks with Refined and treated quality of locally available mud.
   c. Setting, proper layout forming clusters, of houses.
   d. Educating owners, craft-mans, and masons.

2) **In medium low cost buildings,**
   a. Wrapping of Adobe masonry with plastic mesh,
   b. Provision of bands at plinth, sill, lintel and roof levels,
   c. Provision, of vertical reinforcement, at corners of wall, and intermediate junctions made.

3) **In medium high cost buildings,**
   a. Wrapping masonry, with provision of ferrocement panels, for better resistivity.
   b. Jacketing members, imparting strength with FRP Laminates.
   c. Providing steel bracing.

4) **In high cost, high raise buildings,**
a. Construction of Base isolator system, in building.
b. Providing, Rubber or rubber-steel bearings.
c. Post-tensioning.
d. Placing Tuned mass or supplementary dampers
e. Provision of Slosh Tank
f. Constructing, Infill shear walls.
g. Providing additional exterior concrete columns.

From four types of retrofitting trends, indicate that, “in low cost building” capital and maintenance cost are low, and are most eco-friendly, the hierarchy trend follow successively.

**CASE STUDY- III**

Case history:

Name of property owner: - M/s SBI Employees’ Housing Society, "Daya, Kshama, Shanti"

General Information:-

1. Plot Area. 2895.5
2. Prop. Built Area 4261.17m2
3. TDR @ 40% available on paying premium 998.88 m2 + 4261.17m2=5262m2= 56620 Sq.ft.)
4. Possession year 1966

The SBI Bank employees formed a society with intention of constructing a residential building for them. The housing society of 48 members constructed three G+3 storied building in the year of 1966 located in the city Thane, Maharrastra. All members have occupied the building since last 48 years.

The society buildings are maintained properly, and have no major problem except that of rainwater leakage during Manson. The alternative solution to the problem were either redo the
terrace waterproofing or provide a roofing, as per rules and regulations of Thane Municipal Corporation, over all the three terraces.

The issue was discussed in the general body meeting held 7 yrs. earlier. Few members proposed that, in place of spending money on solution of leakage problem, instead all the buildings be demolished, and reconstructed. The buildings are 40 years old are nearing the end of designed life of 50 years. They further added that the buildings would need extensive recurring expense of repairs after the span of designed life is over. A member opined that the issue is threefold having individual advantages and disadvantages,

1) To repair and maintain the buildings,

2) Reconstruct the buildings, by constituting a special task construction Committee. That will act as per the advice from the experts in the respective fields, of law, architecture, structural designing, and project management.

3) To call for offers from reputed developers and select the best offer by lending the rights of redevelopment and sale of additional area, as per TMC Bylaws, developments rules and regulations.

It was therefore, unanimously decided to seek expert's advice.

The problem;

If a building, though nearing end of its designed serviceable life span, if is in good condition and can be estimated to last at least 20 more years of life with retrofitting measures implemented, the choice was of selection of better alternative from the following:

1) To retrofit and enhance the life, by say 20 years, of the existing building, or

2) To demolish the building and reconstruct, by appointing construction contractor, or

3) Evaluate the offers by the builders/ Developers, for lending them the rights of redevelopment of the property and sale of additional area to prospective purchasers.

The expert submitted the report. The details are as follows:
To choose the option, it was essential to evaluate and consider the following points:

Information to opt choice of retrofitting

A. Estimation of Residual strength of building.

B. Retrofitting requirements at local and global level.

C. Selection of retrofitting method and cost estimate.

D. Estimation of extended life.

2) Information about demolishing and reconstructing the building.

A. Salvage value of the structure.

B. Reconstruction cost.

C. Rent cost for alternative accommodation during reconstruction period.

D. Cost for Transportation, Lift and shifting of household material back and forth of members.

E. Additional assessment charges for new building.

F. Income through sale of additional constructed area (flats)

3) Information about Offers by the builders/developers, in respect of right of redevelopment

The best offer forwarded is as stated below:

A. Rent compensation of Rs 15000/- to each member

B. Additional area of about 80 Sq.ft and existing area 530 Sq.ft.(Total 630Sq.ft) free of cost to all the members

C. Registration fees+ legal charges+ Cost of shipment to and fro of household bags, of all the members will be borne by the builder/developer.
D. Corpus fund to each member Rs 50,000/- The general body discussed all the options, suggested by the expert. The summary of discussion is as follows:

Point no. 1

1) To repair and maintain the buildings,

Issue of continuing the so far good maintenance and discarded the redevelopment proposal. The family was enlarged during the past years, of every member, therefore need of additional space was priority, of every member. Hence the point no. 1 was discarded.

Point no. 2

2) Reconstruct the buildings by appointing a special task construction Committee, under the advice from the experts in the respective fields of law, architecture, structural designing, and project management.

All the members are now senior citizens of more than 65 years of age. All expressed inability to work on the construction committee, majorly on personal fitness and health ground.

Hence the point no. 2 was discarded.

Point no. 3

3) To call for offers from reputed developers and select the best offer by lending the rights of redevelopment and sale of additional area, as per TMC Bylaws, developments rules and regulations.

This resolution passed unanimously.

My Observations, Comments, and Conclusions

Point no. 1

1) To repair and maintain the buildings,

The existing building of G + 3 storied, the structure is in sound condition, having uniform layout, as informed by the members the total cost of repairs and maintenance till date is less than 40% of life cycle cost. The carbon emission rate has reduced as the age of the building
is >40 yrs., which is environment friendly. Therefore the buildings should not be redeveloped on technical grounds.

Point no. 2

2) Reconstruct the buildings by appointing a special task construction Committee, under the advice from the experts in the respective fields of law, architecture, structural designing, and project management.

This was most profitable method in point of view of members. The general trend of keeping profit marking @ 33% of the expenditure (Estimated Rs 27, 00, 00,000/-), i.e. Rs 9, 00, 00,000/- would have converted into corpus fund for existing members as against offered as Rs 24, 00,000/-.

a. The new construction adds up environmental problems.
b. The will be increase population concentration of the area.
c. Burden on Infrastructural and disposal systems rose, necessitating them to enlarge their capacity.
d. Carbon emission increases with the new construction.
e. All members now senior citizens, aged more than 65 years, they couldnot be blamed for declining the most profitable option.

Point no. 3

To call for offers from reputed developers and select the best offer by lending the rights of redevelopment and sale of additional area, as per TMC Bylaws, developments rules and regulations.

There was scope for further negotiations with the developers.

Under the circumstances the 3rd option proves best suit for the particular society.