TECH-CHRONICLE
AN INTERNATIONAL E-JOURNAL ON
EMERGING TRENDS IN SCIENCE, TECHNOLOGY AND MANAGEMENT

STRUCTURAL ASSESSMENT OF AN OLD BUILDING

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Abstract: - **In India there are many old structures and some of them are of great importance. The strength of these old structures reduces as time passage because of its usage, poor quality of construction materials use in its construction, environmental conditions. Also several factors such as plastic deformation, interaction with the environment, initial design, construction flaws and natural disasters develop various stresses in the structure which may result in development of cracks, corrosion in reinforcement, leakage and seepage. The final soundness of a building can vary due to various reasons and thus, only proper precautions at the initial stage and good maintenance in the later life span of the structure can result in a technically sound building. So in order to maintain the soundness of building Structural assessment are done base on the distress which have occur in construction.**

Key words: Environmental conditions, initial design, leakage.

I. INTRODUCTION

The Structural assessment of old buildings is a process of evaluating the present state of the frame present in the structure. There are various factors which can make the frame weak after construction is over out of which some of them are as follows:

1. Modifications.
2. Usage of building.
3. Poor maintenance.
4. Aging of building.
5. Weathering and Environmental effects on building.

For this various techniques are used in Evaluation of present frame status of the building. The most common and initial technique is visual and hammer tapping. Most buildings this suffices. More detailed techniques are used in some cases; they are the non destructive tests (NDT) [1]. Here the samples of materials from frame are collected and tested for certain parameters. Based on the results the Evolution of the frame is made.

Structural assessment of old buildings as it is as an regular health checkup of an building. It's basically for ensuring that the building and its components are safe and under no risks. Because as a building gets older & older it shows signs of wear and tear due to ageing, use, its exposure to the weathering/environment and structurally unplanned modifications and many more .Which will affect the health of the building significantly. In the initial service life of any structure, there are no problems that are faced by the owner but as soon as one monsoon season passes after another the series of trouble never cease [2].

During any structural assessment of an old building there are some objectives of it which are as follows:

1. To indentify the causes of distress and their sources.
2. To assess the following things:
    a) The extent of distress occurred due to Corrosion, fire, earthquake or any other Reason.
    b) The residual strength of the structure.
    c) It's Rehabitability[4].
3. To prioritize the distress element according to Seriousness for repairs
4. To select and plan the effective remedy
5. To save LIFE & PROPERTY.
6. To know the health of your building and to project the expected future life
7. Highlight the critical areas that need to be attended with immediate effect.
8. To proactively assist the residents and the society to Understand the seriousness of the Problems and the urgency required to attend the same.
9. To comply with Municipal or any other statutory Requirements.
10. To evaluate soundness of existing structures.

The structural assessment of an old building is always carried out in some stages and few steps which involve the whole statists of structure and all the required information required form the evaluation of that building[3]. So the steps are;

1. Inspection.
2. Gathering basic information about the structure.

3. Photographical records.

***Inspection*:** In inspection conditional survey of the building is done .There are four stages of Condition Survey which are Described below:

1. Preliminary Inspection.
2. Planning.
3. Visual Inspection.
4. Field and Laboratory testing.

A. Preliminary Inspection:

The primary objective of the preliminary inspection is to assess and collect following necessary information for a thoughtful planning before a conditional survey is practically undertaken [8].

B. Basic Information Gathering:

A programmed has to be evolved to obtain as much information as possible about the distressed structure at reasonable cost and in a reasonable time. Accordingly, the information required from the owner/client has to be listed out. Even though, many construction details and other related information may not be available with the owners/clients, yet as much as information and details as possible be gathered during the Preliminary Site Visit.

C. Photographic Record:

It is always necessary to carry a camera with flash during such Preliminary inspection and take the necessary photographs of distress structural members. So that they can be used as an recorded information about the structure in its assessment.

II. PHYSICAL ASSESSMENT CONDUCTED AT AN OLD RESIDENTIAL BUILDING

Fig 1: Cracks seen on pardi.

Fig 2: Cracks seen on chajja.

Fig 3: Uplift of tiles due to corrosion

Fig 4: Corrosion seen in slab.

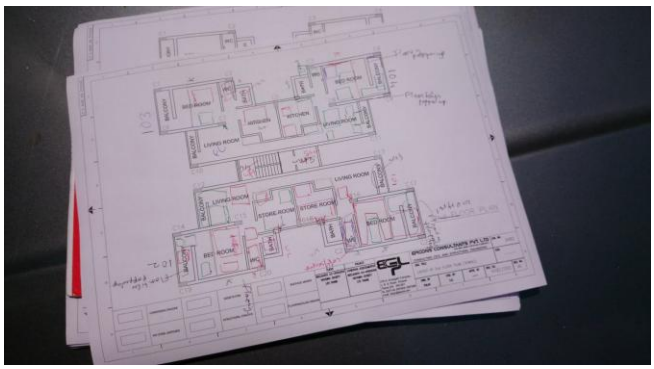

Fig 5 : First floor plan of the building.

Fig 6: Cracks on balcony Parapet walls.

III. ASSESSMENT REPORT OF BUILDING

1. PREAMBLE

'Jivdani Apartment' is a residential society located at LBS Marg, Thane, Mumbai. The structure was constructed approx. in the year 1982. In view to know the present structural condition of the structure & the concrete, the society appointed M/s EPICONS CONSULTANTS PVT. LTD. to carry out the Structural Assessment of the society building. In order to check the in-situ strength & quality of the RCC elements, the Non Destructive testing was planned. Accordingly, the field work was carried. Condition survey was carried out during this period between 17th December 2016 to 25th December 2016 & Non Destructive testing was scheduled between 7 January 2017 to 11th January 2017.

2. STRUCTURE

The structure is stilt G+8 storied RCC framed structure. The 8th floor slab is of two levels named as upper level & lower level.

Two lifts & one staircase block is provided as a utility for the structure. The flats are spacious 2 BHK with 1 no. of toilet block.

There are concrete fins provided as elevation treatment to the structure & also chajjas are provided at periphery. The stilt columns were jacketed approx. 10 years ago.

3. VISUAL INSPECTION METHODOLOGY

Visual inspection of the building was carried out up to humanly possible heights to identify possible structural and non-structural distresses like structural cracks, separation cracks, corrosion cracks, reinforcement corrosion as well as leakages/ seepages etc [9].

4. NON DESTRUCTIVE TEST METHODOLOGY

The following Non Destructive tests were carried out on structural elements as per decided testing scheme. The stilt column are jacketed the same were chipped off for ND testing so to get the old concrete surface, the surface was sound & met the requirements of the testing. After chipping of this it was observed that steel was not present for jacketing.

1. Core test to assess the compressive strength of the concrete.
2. Rebound Hammer test to assess the in situ compressive strength of cover concrete [7].
3. USPV test to assess the integrity of concrete [6].
4. Carbonation test to assess the depth of carbonated concrete.
5. Half cell potentiometer test to assess the probability of active corrosion.
6. Resistivity test to assess the risk of corrosion present corrosion.
7. Cover Meter test to estimate the cover provided.
8. Chemical Test- To carry out following laboratory tests on the concrete samples extracted in the form of cores and/or powder:-
    a) Chloride Content: To know the chloride content of concrete sample.
    b) pH test: To know the alkalinity of concrete sample.

5. VISUAL OBSERVATIONS

Internal Observations

Ground Floor

The Slab near C2 & C9 has corrosion cracks.
The slab near C20 & C21 has corrosion cracks.
The beam between C2 & C3 has corrosion cracks.
The beam between C2 & C9 has corrosion cracks.
The beam near C19 has corrosion cracks.
The beam through C18 & C19 has corrosion cracks.
The column C9 has corrosion cracks.
The beam near C15 has corrosion cracks.

First Floor

The beam through C18 & C19 has corrosion cracks.
Flat No. 11 – The kitchen slab has seepage marks towards East side.
Flat No. 12 – The kitchen slab area near C6 has corrosion cracks.
The column C12 at junction has corrosion cracks.
The beam between C8 & C14 has corrosion cracks.
The beam between C13 & C14 has corrosion cracks at centre.

Second Floor

Flat No. 21 – East side chajja bottom has corrosion cracks.
The slab bottom in the hall has corrosion cracks.
The toilet slab portion is showing seepage marks.
The West side chajja bottom has corrosion cracks.
The slab bottom at passage/ lift lobby has corrosion cracks.

Third Floor

Flat No. 31 – The Kitchen beam at East side has corrosion cracks & seepage marks.
The solid sitting arrangement in the hall is extended which is increasing the load.
The beam through the columns C18 & C19 has corrosion crack .
The beam in hall at West side has corrosion cracks.
Flat No. 32 – The flooring slab in hall has cracks at some places.
Also the passage near to kitchen is observed with floor slab cracks.
The beam between C8 & C14 has corrosion cracks.
The beam between C13 & C14 has seepage marks.
The beam portion near to C17 has corrosion cracks.
The West side beam has corrosion cracks.
The West side chajja at has corrosion cracks at sides & bottoms.

Fourth Floor

Flat 41
The beam has through C18 & C19 has corrosion cracks.
The toilet block slab has seepage marks.
The East side chajja has corrosion cracks at edges.
The West side chajja has corrosion cracks & seepage marks.

Fifth Floor

Flat No. 51 - The flooring slab in hall has cracks.

The solid sitting arrangement in the hall is extended which is increasing the load.
The entrance passage also has floor cracks.
The beam through columns C18 & C19 has seepage marks.
The WC slab has seepage marks.
The beam between C2 & C3 has corrosion cracks.
The beam between C9 & C10 has corrosion cracks.
The beam at Kitchen at East side has corrosion cracks.
Flat no. 52 – The slab at passage has corrosion cracks.
The chajja corner at North West & portion at South side has corrosion cracks.
The passage / lift lobby has seepage marks towards East side.

Sixth Floor
Flat No. 61 – The beam between C2 & C3 has corrosion cracks.
Flat No. 62 – The beam between C8 & C14 has corrosion cracks.
The beam between C13 & C14 has corrosion cracks at center.
The column C14 has corrosion cracks.
The chajja has corrosion cracks at West side corner towards South side.

Seventh Floor
Flat No. 72 – The beam through C20 & C21 has corrosion cracks.
The beam between C8 & C14 has corrosion cracks.
The beam between C17 & C21 has seepage marks.
The beam between C13 & C14 has seepage marks.
The passage / lift lobby has seepage marks & corrosion cracks towards East side.

Eight Floor
Flat No. 81 – The beam through C19 has corrosion cracks at West side.
The beam through C18 & C19 has seepage marks.
The Bathroom & toilet slab has seepage marks
Flat No. 82 – The beam C13 & C14 has corrosion cracks.
The beam through C20 has corrosion cracks (West side).
The passage / lift lobby has seepage marks & corrosion cracks towards East side.

External Observations
Front Side Elevation – West Side
The column at first, fourth & fifth floor has corrosion cracks.
The chajja at second, third & fourth level has corrosion cracks.
Back Side Elevation – East Side
The first floor fins at both ends have corrosion cracks.
Left Side Elevation – North Side
The first floor fins at both ends have corrosion cracks.
Right Side Elevation – South side
The columns at fourth, fifth & seventh floor has corrosion cracks.
The chajja at first, second, third, fifth, eight floor has corrosion cracks.
The fins in center at first floor have corrosion cracks.
The fins at first floor have corrosion cracks.

Terrace Observations
The terrace is having conventional waterproofing of Brick Bat coba covered with china mosaic finish up to vata.
The flooring is having cracks on its surface.
The parapet is covered with kadappa coping at top portion.
The cable dish antenaes are fitted at some places.

6. NON DESTRUCTIVE TEST ANALYSIS & INTERPRETAION

Core Test Result

Total 4 nos. of cores were extracted from columns of stilt level, for extracting the core thin jacketing layer of micro-concrete was removed.
The core test results are tabulated & attached as Annexure A with this report;
The average value of estimated in-situ Equivalent cube strength results for columns is 12.0 N/mm^2, which can be marginally accepted as M_{15} concrete, which is the expected design grade considering the construction period. The actual acceptable value for M_{15} concrete is 12.75 N/mm^2 as per the acceptance criteria provided in IS 456:2000.

7. REBOUND HAMMER, ULTRASONIC PULSE VELOCITY & CARBONATION TEST RESULT

To obtain correlation between rebound hammer & in-situ strength, core test results at ground floor were used. However it is noted that rebound hammer test at ground floor could not be taken on formed surface, as a layer of micro-concrete jacketing was removed, Due to this, it is expected to get higher

RH value as thin cement paste surface layer is not available & more aggregate surfaces are available.

Rebound hammer readings at ground floor were reduced by correction factor of ratio between the average rebound hammer of all the other level columns to average rebound hammer at ground floor columns.

While doing this, it is assumed that expected grade of concrete at all floor columns is same i.e. M15.

1. Average in-situ compressive strength value on the average value of Estimated equivalent cube strength results for columns & beams of floor is 10.2 N/mm^2 & 7.7 N/mm^2 respectively; as per IS 13311 (Part 2), accuracy of predication of concrete strength by rebound hammer test is + 25 percent.
2. The in-situ strength results indicate still lesser strength than core test results. Thus, in general, based on rebound hammer test results, the overall concrete cannot be accepted as M_{15} concrete.
3. The coefficient of variation is very high in both the groups of concrete i.e. of 21% & 23% which clearly indicates the non-uniformity in the concrete.
4. The average of direct Ultra Sonic Pulse Velocity on columns & beams is **3.0 & 3.0 Km/sec** respectively. The average indirect Ultra Sonic Pulse Velocity on columns & beams is 3.1 & 2.4 respectively, Also, coefficient of variation excluding extreme results, is in the range of 21 to 23% in column & 13 to 18% in beams, which can be considered as moderate for lower grade of concrete.

5. Thus, integrity wise concrete quality for columns can be called as 'Medium' Quality of concrete as per the guidelines given in IS 13311 (Part 1) – 1992.
6. The average depth of carbonation of columns & beams is observed as 13 mm, with maximum value of 20 mm which can be considered as 'moderate' considering age of building.

8. HALF CELL POTENTIOMETER TEST RESULT

These tests could be conducted only on ground floor columns due to limitation for opening up of reinforcement. The result of half cell potentiometer test indicates that 10% probability of active corrosion for 3 nos. of test locations & one of the columns indicates 50% probability of active corrosion, which can be considered as low to moderate. This is on expected lines due to good quality of protection available in the form of micro-concrete.

9. RESISTIVITY TEST RESULT

The average resistivity value is 216.4 KΩcm & the values ranges between 102 KΩcm to 534 KΩcm.

The test results indicate negligible risk of corrosion at all the locations from the point of view of moisture ingress in the concrete. This can be attributed to dry concrete owing to good external protection.

10. COVER METER TEST RESULT

The cover meter test results suggest that average cover provided to reinforcement in columns about 41 mm & minimum cover obtained is 33 mm at 8thfloor level. Thus the cover provided to columns can be considered as acceptable for codal compliances on an average.

11. CHEMICAL TEST RESULT

Three number of ground floor cores were used for this, with three number of sample per core with 15 mm, 30mm & 45mm from the surface of concrete, after removing the micro-concrete portion.

The analysis of chemical contents in concrete core sample is as below:

(i) Chlorides -

The result of the chloride test indicates that chlorides content for sample tested is more than permissible limit for all the 3 nos. of samples tested.

[5]As per IS: 456:2000, Clause 8.2.5.2, Table 7, limit of chloride content of concrete is: Maximum total acid soluble chloride content expressed as kg/m3 of concrete is 0.6 for reinforced concrete or plain concrete containing embedded metal.

Therefore for reinforced concrete with 2400 kg/m3 density, maximum total acid soluble chloride content works out to (0.6/2400) x 100 = 0.025 %.

The chloride content obtained is in range of 0.053 % to 0.22 % which is higher than permissible limits i.e. 0.025%, which is on expected line considering the exposure to highly saline atmosphere over many years. Further it is interestingly noted that maximum chloride content is at 15/30 mm depth & not in 0 – 15 mm depth. This may be due to considerably less rate of chloride penetration after micro concrete jacketing & inward migration of available chlorides during the period.

(ii) PH Value – Freshly prepared concrete is highly alkaline in nature having pH value of 12 to 13. The alkalinity of concrete gets affected on ageing due to various factors like inherent concrete quality, effect of surrounding environmental conditions etc.

The pH value for concrete sample tested is in range 11.2 to 11.8 which shows that there is minor reduction in concrete alkalinity, which can be still considered to be in acceptable range.

12. CONCLUSION & REMEDIAL MEASURES

The following are the conclusions drawn from the above detailed observations & analysis of Non-Destructive testing.

1. Based on results of non-destructive tests namely - concrete core test and rebound hammer test, it could be inferred that subject concrete can be marginally accepted as M_{15} concrete at majority of the locations, which can be acceptable as design grade considering practices during construction period. However, it is to be noted that the revised code IS 456:2000 do not consider it as a structural design grade.
2. Integrity wise concrete tested could be classified as of medium quality based on ultrasonic pulse velocity test results as per the classification provided in IS 13311 (Part1).
3. In spite of the low grade & medium level integrity & the highly saline atmosphere the corrosion distresses observed can be only considered as 'moderate' in most of the elements. Also, the durability related test results like carbonation, half-cell potentiometer test & resistivity test also confirm the low to moderate risk. This is mainly due to good level of protective measures & maintenance over all the years.
4. As a result the building can be still considered as in 'Satisfactory' structural condition as these are no severe distresses noticed which can critically affect overall structural stability of the building in near future.
5. However, it needs to be noted that the risk of corrosion damage will increase over the time due to further ingress of chlorides which are already present in abundance in concrete as well as carbonation level reaching reinforcement. The only measure to mitigate the risk is to effectively protect concrete from moisture ingress in any form as moisture is the necessary ingredient for corrosion process. This can be achieved by adopting following remedial measures at the earliest:
   I. All the structural elements identified with corrosion related distresses shall be attended by carrying out patchwork repairs in the form of following step by step procedure:-
      a) Removing loose concrete with well-defined edges.
      b) Thoroughly cleaning the reinforcement & augmenting the same if required.
      c) Applying passivator coat to reinforcement.

d) Applying bond coat to concrete surface.
e) Application of single pack polymer modified mortar (PMM) from reputed manufacturer.
f) Some of the key areas where such patchwork repairs are to be carried out include stilt level beams at few internal columns & beams inside the flat, beams in car parking areas etc.

II. It is noted that the 50 mm micro concrete jacketing carried out previously has performed well, significantly reducing the corrosion potential in spite of poor concrete inside. Ideally, it would be worth repeating the same for all the floor columns as full proof solution. However the same is highly impractical; considering the nuisance it will create to the occupants. Hence, can't be recommended & we have to restrict ourselves to patchwork repairs.

a) Some of the flats show minor as well as major well defined cracks in the floor slab at top of the flooring. These cracks occur in slab concrete due to deflection in the slab associated with corrosion of slab reinforcement. These cracks shall be exposed & grouted with approved low viscosity epoxy grout with 300mm c/c nipples, in addition to the patchwork PMM repairs, wherever corrosion distresses are observed, which will be at edges of such slabs at top level.
b) In the flat nos. 31 & 51, in the hall, the solid seating arrangement is extended from the original, this arrangement is increasing load of the structure & the same may result into cracks in the adjoining slab.
c) The RCC window sills in some of the flats are exhibiting corrosion cracks, it is advisable in all the flats RCC window sills to be demolished & the same to be replaced with stone over the brick work of 230 mm thick window sill.
d) In some flats seepage marks are observed on slab soffit of the toilet blocks, it is a source of leakages in structural members; the sources of leakages shall be checked using following method:
    i. First, all the tile joints shall be sea.
    ii. Door frame bottom portions shall be checked & replaced, if necessary.
    iii. W/c Pans shall be checked for cracks.
    iv. Drainage pipe joints shall be be checked by breaking the floor tiles.
    v. Concealed plumbing joints shall be redone after checking.
e) The area between 7th floor level &8th floor level & between the duplex at 8th floor level there is a RCC box, there are leakages through this element, it is recommended cover it with layer of waterproofing using the APP membrane coat in two layers.
f) The Duplex flat at 8th floor level have balconies, these balconies are covered by the Owners making part of the adjoining room. This modification increases the leakages through these joints which are not designed. Hence such modifications shall be avoided from long term durability point of view.
g) The RCC fins provided at the corners of the building as an elevation treatment. These fins are observed with corrosion cracks at most of the areas, As it is not cost effective to repair the thin fins, it is recommended to cut these fins with concrete cutter and replaced by lightweight ACP treatment if required, in order not to disturb the elevation.
h) External chajjas have severe corrosion cracks, patchwork repairs of these thin members is not advisable as it is neither effective nor cost effective. Hence, it is strongly recommended to demolish the existing chajjas & re-construct the same using better quality concrete.
i) Top floor flats i.e. the flats below terraces level do not show leakages or seepages, indicating that terrace waterproofing is still effective. However as a preventive measure it is advised to provide additional layer of flexible membrane waterproofing of any reputed manufacturer, over the top of existing treatment.
j) The plumbing is also a main source of leakage from external face of the structure, the plumbing & sanitation lines are quiet old & have lived their life. Hence it is recommended to replace all the plumbing & sanitation pipes with new PVC pipes. During this schedule the connector piece to be checked along with the sleeve & new PVC piece to be fixed.
k) The terrace parapet is covered with kadappa coping which generally have joints. This can cause water seepage through parapet in the flat below. Hence, it is recommended to remove the kadappa & the parapet to be covered with concrete coping with projection outside.
l) The dish antennas are fixed to parapet at few places the same to be removed & a proper provision to be made for their placing these dish antennas so as not to disturb the parapet plaster.
m) The external plaster is deboned at some places, these deboned plaster & cracks in plaster façade, these cracks in plaster is also a major source of leakage, hence while the repairs work execution it is recommended to firstly tap the entire façade with light weight hammer & mark the deboned & hollow areas. The only deboned & hollow sound giving plaster to be removed & patch plaster to be done. Please note that the bond coat to be applied between the old & new plaster.

IV. LIMITATIONS

a) The report is based upon the visual observations carried out upto humanly possible heights.

b) The report is based upon the results of In-situ tests, which are fundamentally limited to the relevant test locations alone and the results are based only to estimate the pertinent characteristics of the subject concrete for forming guidelines for further decisions.

c) The flats are completely decorated with false cladding/ceiling which pose a serious limitation in identifying the structural distresses unless it is opened up. The best possible efforts were made to access all the structural elements internal & external.

V. IMPORTANT NOTES

a) All the observations / remarks are applicable as on the date of survey.

b) Our scope is limited to the submission of this report & we do not undertake any responsibility for any involvement in any type of litigation / legal matters arising out of these remarks of this structural assessment.

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