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STRUCTURAL AUDIT, REPAIR AND REHABILITATION OF BUILDINGS

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ABSTRACT: Civil Engineering Industry is one of the oldest industries which provide a basic infrastructure to all the human beings. Structures can be any kind it can be Historical, Heritage Structure, Residential building, Commercial building or an Industrial building. Every structure has its own service life, and within this servicelife it should stand firmly on its position. Ex- ATajMahal in Agra in India which is one of the oldest structure and a Wonders of the World, and still stand on its position very efficiently. But this not a condition about the today's Structures. A collapsed mechanism has increased and today's Structures are getting collapsed before there service life is completed. Therefore, it is advisable to monitor it periodically by taking a professional opinion. Structural Audit is a preliminary technical survey of a building to assess its general health as a civil engineering structure. It is usually initiated as the first step for repair. In this Project a Root Cause of a faulty mechanism of structure and a preventive measures to overcome a failure of this structures. The construction material mainly reinforced concrete is being used extensively for various types of construction projects. However, the deterioration of Reinforced Concrete structures is recognized as a major problem worldwide. Apart from requiring regular maintenance, many structures require extensive Repair, Rehabilitation &Retrofitting. Over a period of time, as these structures become older, we find in them certain degradation or deterioration with resultant distress manifested in the form of cracking, splitting, delaminating, corrosion etc. Such deteriorated structures can be rehabilitated and retrofitted by using various types of admixtures & modern repair materials. The paper brings out the present state of concrete structures & the major areas where improvement is needed during its service life stage for sustainable development & also the method of carrying out Repair, Rehabilitation &Retrofitting. This has been brought in details in the paper along with Case studies, where the Author of the paper was directly involved in planning and execution of the jobs.

KEY WORDS: Structural audit, Structural Engineering, Rehabilitation, Sustainable Development, Polymers.

I. INTRODUCTION

The need of structural audit is for maintenance and repairs of existing structures whose life has exceeded the age of 30 years to avoid any mishaps and save valuable human life. The concrete is widely used as construction material being inexpensive, easy for construction, applications and because of it high strength-cost ratio. More than ever, the construction industry is concerned with improving the social, economic and environmental parameters of sustainability. In India, from 1980 onwards the infrastructure industry witnessed stepping up of public investment and growth in infrastructure industry which results in construction of new multi-storey concrete apartments which are now in the age of thirty plus years. There are many buildings during this period and earlier have reduced strength in due course of time because of structural deficiency, material deterioration, unexpected over loadings or physical damage. If, further use of such deteriorated structure is continued it may endanger the lives of occupants and surrounding habitation. There is demand of appropriate actions and measures for all such building structures to improve its performance and restore the desired functions of structures which may leads to increase its functional life. The periodical structural auditing and diagnosis for health of existing buildings is thus utmost important for finding the present serviceability and structural viability of structures. The structural audit must be carried out following auditing norms, methods of non-destructive testing and code provisions. The structural auditing will help to implement maintenance and repair work timely which leads to prolonged life of the building and safety of the occupants. In India there are many old buildings which have reduced strength in due course of time

II. OBJECTIVES

In this project the fundamental principles of NDT methods are considered in some detail with a view to establishing a definite role for them in the Structural Evaluation Program. Part of this role is the setting of agreed standards & guidelines both for the execution of each surveying method in the field and the interpretation of the physical data obtained as an integral part of the investigation program.

1. To recognize the types of structural defects
2. To identify any signs of material deterioration
3. To carry out methodology and analysis of this study.

4.The give recommendations on structural audit, repair and rehabilitation method.
5. Lead a department of maintenance and custodial personnel, whose major responsibility is to provide the associated officials and staff with safe, attractive, comfortable atmosphere

III. NEED OF STRUCTURAL AUDIT OF BUILDING

According to the model bye-law no. 77 for co-operative housing societies, it is mandatory that if the age of a building is 15 to 30 years, a structural audit must be carried out once in five years and for buildings older than 30 years it should be carried out once in three years. One may, however, go for it even earlier if one suspects the condition of the building to be bad. Perhaps monsoon/ post monsoon is the best time to commission a structural audit since the seepage is more evident at that time. The certificate, issued by a structural engineer registered with BMC, will have to be submitted within a year after a building completes 30 years. For any corrective repairs suggested by the commissioner, the owner or occupants will be asked to submit the structural stability certificates again after a specific period suggested by him. If found unsafe, he has been given the authority to issue a notice to the owner to submit a structural stability certificate within 30 days from the date of notice.

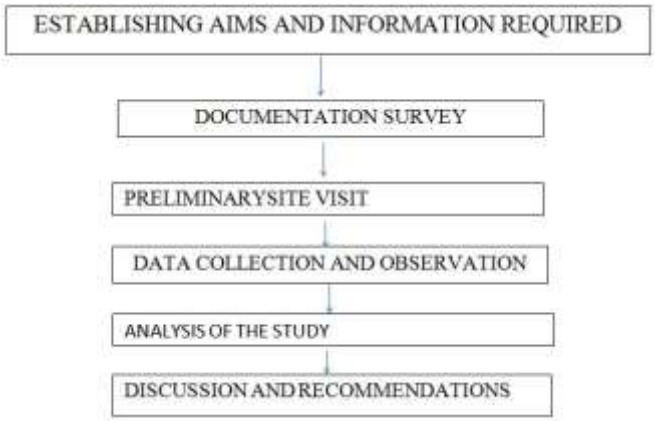
IV. DEVELOPMENT MODEL

A Norm According to the model bye-law no. 77 for co-operative housing societies, it is mandatory that if the age of a building is 15 to 30 years, a structural audit must be carried out once in five years and for buildings older than 30 years it should be carried out once in three years. One may, however, go for it even earlier if one suspects the condition of the building to be bad. Perhaps monsoon/ post monsoon is the best time to commission a structural audit since the seepage is more evident at that time. The certificate, issued by a structural engineer registered with BMC, will have to be submitted within a year after a building completes 30 years. For any corrective repairs suggested by the commissioner, the owner or occupants will be asked to submit the structural stability certificates again after a specific period suggested by him. If found unsafe, he has been given the authority to issue a notice to the owner to submit a structural stability certificate within 30 days from the date of notice. It will be binding on owners to carry out corrective repairs to the satisfaction of the commissioner. The certificate, issued by a structural engineer registered with BMC, will have to be submitted within a year after a building completes 30 years. For any corrective repairs suggested by the commissioner, the owner or occupants will be asked to submit the structural stability certificates again after a specific period suggested by him. If found unsafe, he has been given the authority to issue a notice to the owner to submit a structural stability certificate within 30 days from the date of notice. It will be binding on owners to carry out corrective repairs to the satisfaction of the commissioner.

V. SCOPE OF THE STUDY

The scope of the study is limited to state of Jammu and Kashmir where an area of district KUPWARA is chosen for analysis and observation of my thesis. The description of the selected building is given by:-
No of storeys – 4 storied
Type of apartment – 12 flats
Year of construction-Aug 1987
Age- 27 years

VI. METHODOLOGY



VII. REBOUND HAMMER TEST

The method of using the hammer is explained. With the hammer pushed hard against the concrete, the body is allowed to move away from the concrete until the latch connects the hammer mass to the plunger. The plunger is then held perpendicular to the concrete surface and the body pushed towards the concrete. The hammer can be used in the horizontal, vertically overhead or vertically downward positions as well as at any intermediate angle, provided the hammer to the surface under test. The position of the mass relative to the vertical, however, affects the rebound number due to the action of gravity on the mass in the hammer. This movement extends the spring holding the mass to the body. When the maximum extension of the spring is reached, the latch releases and the mass is pulled towards the surface by the spring. The mass hits the shoulder of the plunger rod and rebounds because the rod is pushed hard against the concrete. During rebound the slide indicator travels with the hammer mass and stops at themaximum distance the mass reaches

after rebounding. A button on the side of the body is pushed to lock the plunger into the retracted position and the rebound number is read from a scale on the body.maximum distance the mass reaches after rebounding. A button on the side of the body is pushed to lock the plunger into the retracted position and the rebound number is read from a scale on the body.

Average Rebound No.	Quality of Concrete
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
<20	Poor concrete
0	Delaminated

Table 1. Quality of concrete for different values of rebound no.

VIII. ULTRASONIC PULSE VELOCITY TEST

UPV methods can be considered as one of most promising methods for evaluation the concrete structures once it makes possible an examination of material homogeneity. The total control of the structure is also possible by using the variations of properties with the time. The tests can also be used to explore the relation between the concrete qualities with the compressive strength. The main idea is to explore the fact that ultrasonic velocity waves are a function of the material density, which is correlated with the compressive strength. The relation is not always trustworthy once there are a lot of variables that affect the concrete strength such as the water/cement ratio, the size and type of aggregate, the molding procedure, the specimen size and the cement type. A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time T of the pulse to be measured. Longitudinal pulse velocity (in km/s or m/s) is given by:

$V = L/T$

Where, V is the longitudinal pulse velocity, L is the path length,T is the time taken by the pulse to traverse that length.

IX. DATA ANALYSIS AND RESULTS

The main cause for distress to RCC elements are

- Inadequate thickness of cover concrete •
- Highly permeable and porous concrete •
- Carbonation of concrete
- Most distressed portions were chajjas along with lintel/beam, which is directly exposed to marine atmosphere and frequented by alternate wetting and drying.

Seepage observed in roof slab was due to leakage from pipe line.

Sample No.	Compressive strength (MPa)	Rebound No.	
		Horizontal ( )	Vertical ( )
1	15.88	25.34	21.63
2	15.33	25.00	20.23
3	10.57	25.10	24.15
4	15.19	24.60	20.15
5	6.15	16.50	13.67
6	8.30	18.50	16.90
7	13.94	22.30	18.56
8	9.37	19.50	17.10
9	9.52	20.30	17.20
10	14.14	22.60	19.00

Table 2. Average rebound number & compressive strength of sample

Sample No.	Observed rebound number (RN)										Avg. RN	Remarks
	1	2	3	4	5	6	7	8	9	10		
1	23	25	27	19	24	26	27	26	23	27	24.70	Fair
2	27	22	26	24	24	23	27	23	27	27	25.00	Fair
3	25	24	26	24	28	24	26	26	22	26	25.10	Fair
4	24	27	22	25	22	24	26	27	26	23	24.60	Fair
5	14	15	15	14	16	20	19	15	20	17	16.50	Poor concrete
6	20	18	16	21	20	16	20	17	18	19	18.50	Poor concrete
7	22	23	22	22	25	26	22	18	23	20	22.30	Fair
8	16	15	22	19	23	22	15	21	22	20	19.50	Poor concrete
9	18	20	19	22	23	20	20	24	19	18	20.30	Fair
10	22	21	22	18	25	26	24	20	28	20	22.60	Fair

Table3. Rebound number for horizontal (→) hammer position

Sample No.	Observed rebound number										Avg. RN	Remarks
	1	2	3	4	5	6	7	8	9	10		
1	17	28	14	19	24	24	25	21	21	22	21.50	Fair
2	21	20	18	22	28	23	16	17	21	24	21.00	Fair
3	16	27	26	22	26	28	22	27	16	19	22.90	Fair
4	19	14	22	18	32	23	17	23	21	21	21.90	Fair
5	15	15	10	14	12	19	10	11	17	22	14.50	Poor concrete
6	18	17	18	16	15	18	15	14	18	20	16.90	Poor concrete
7	21	17	20	18	26	16	21	15	17	22	19.30	Poor concrete
8	18	19	15	18	17	18	16	18	16	16	17.10	Poor concrete
9	21	15	18	15	13	18	17	18	18	19	17.20	Poor concrete
10	20	20	19	17	15	23	16	20	21	19	19.00	Poor concrete

Table 4: Rebound no. for vertical (↓) hammer position

X. RECOMMENDATIONS

1. Looking into all aspects of the building maintenance and as per our detailed survey, we suggest that the building needs to be thoroughly repaired and painted in a planned manner.
2. For any RCC framed structure the RCC components are like the bones in a body and hold the entire load of the body and any damage to the same has to be rectified immediately and cannot be left unattended for long period of time.
3. To bring the RCC components to their near original strength the same have to be repaired by polymer modified mortar method.
4. The RCC members originally deteriorated due to ingress of water and to prevent it happeningagain all sources of leakages must be stopped completely.
5. Plaster acts like a skin to the bones in a RCC structure, but the skin also needs to have a raincoat and the same is provided by a good quality resin based coating.
6. To stop the ingress of water the following steps have to be taken.

a) Structural Repairs (Wherever Necessary).
b) External Plaster(Patch)
c) Crack Filling/Joint Filling.
d) External Drain down take Plumbing (Wherever Necessary).
e) Terrace waterproofing by using non destructive method.
f) Dead wall / Internal Terrace parapet wall plaster repairs.

XI. REPAIR, REHABILITATION TECHNIQUES

11.1 POLYMER

High strength, resilient materials which have high resistance to attack from chlorides &sulphates are normally used for repair materials. The polymer modified concrete (PMC)/polymer modified mortar, which are commonly used as repair material has following properties:-

- High compressive strength at early age.
- Increased flexural & tensile strength.
- Water tightness
- Adhesion
- Resilience, durability &impermeability etc.

11.2 Epoxy Mortar/Grouting

Epoxy mortars are used for repair of spalled concrete in underside of slab floor/roof slab &chajjas having damage less than 75mm. Epoxy grouting is used normally for filling of cracks. Epoxy grouting systems have high mechanical strength. They obtain strength only in a few hours and are resilient in nature. Epoxy systems are immune to sulphate& chloride attack and are impermeable. They have got high compressive & tensile strength also. Since epoxy grouting system can be injected into even hair line cracks, effective repairs can be carried out with them.

11.3 Polymer Coating

For enhancing the life of structure, coatings like IPN (Interpenetrating Network) or other equivalent polymer should be applied on all the concrete surface of the structure. The coating prevents any future ingress of air & harmful chlorides, sulphates etc. into the structure. It thus protects the entire structure from corrosion &spalling. However, these coats are to be applied periodically, normally with interval of 5 years or so, depending on type of product being used.

11.4 Guniting/Shotcreting Methodology:

Shotcrete is defined as pneumatically applied concrete or mortar placed directly on surface The cement and sand are batched and mixed in the usual way and conveyed through a hose pipe with the help of compressed air. A separate pipe line brings water under pressure and the water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired. In good quality work, a density around 2100kg/m3 is achieved. For effective guniting, the nozzle should be kept at 60cm to 150cm from the work normal to the surface. Before guniting is applied, the old concrete surface is prepared properly, all the cracks treated and the new reinforcement fixed in position. Cracks wider than about 0.5 mm should be cut out and filled with hand-applied mortar or with gunite.

11.5 Routing and Sealing Methodology

Routing and sealing is a common method of repairing dormant cracks. The procedure should not be used on active cracks. A minimum surface width for a crack to be routed and sealed is one-quarter inch. When you are dealing with pattern cracks or narrow cracks, the routing will enlarge the cracks to make them suitable for sealants. Sealants are used to prevent water infiltration. This involves enlarging the crack along its exposed face and sealing it with crack fillers. Care should be taken to ensure that the entire crack is routed and sealed. Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant (Fig.(e)). This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole).

XII. CONCLUSION

From the consideration of all the above points we conclude that the defects of structural members are due to combined effects of carbonation, corrosion & effect of continuous drying and wetting. The result of visual survey prompt us to conclude the distress is wide spread and is an ongoing process and so needs to be stopped at this stage so as to avoid complete collapse of the structure. There for Rehabilitation of the RCC members and will constitute the following steps:-

1. Propping the structure wherever necessary
2. Removing loose/disintegrated concrete
3. Cleaning the affected steel
4. Adding steel wherever necessary
5. Applying Passivator coat to the steel
6. Applying Bond Coat and doing Polymer
7. Concrete treatment depending on the requirements
8. Finishing with new plaster

The condition of the building appears to be quite bad and major structural distress is observed in some of the columns and beams of the external walls. Micro Concrete Repairs to R.C.C. Column, Beam, etc.: In terms of to restoration of extensive damages in R.C.C. micro concrete: micro concrete is a very high strength mix design concrete, its factory made product. its dry powder in grey color more like cement constitutes cement as a one component & other's graded fine aggregate, additive in powder form & free flowing agent, because of this micro concrete can placed in less thickness & mix. Material can travel in narrow gape & having self-leveling properties, so that it provides very smooth & uniform finish. Strength equivalent to 35 m concrete can be achieved in only three day setting / placing time.

The defects of structural members are due to combined effects of carbonation, corrosion &effect of continuous drying and wetting. The result of visual survey prompt us to conclude the distress is wide spread and is an on going process and so needs to be stopped at this stage so as to avoid complete collapse of the structure. There for Rehabilitation of the RCC members and will constitute the following steps Propping the structure wherever necessary.

XIII. FUTURE SCOPE

The concept of Repair, rehabilitation and strengthening of buildings is less popular technique in the construction industry and then it is necessary to spread awareness of the same. Result of this study will show the importance as well as the need and effectiveness of this study.

- The study can be used by other building safety departments as a guide for their researches.
- The study can be used for further repair and rehabilitations techniques.
- The study will provide a first-hand information to other safety departments.
- A similar study may also be conducted in other areas also..
- A similar study may be conducted for the other factors which are necessary to be discussed for repair and strengthening of building.
- Such research can be very useful for the marketers in designing the repair strategies
- Finding of the present research may be very useful in designing the repair and rehabilitation strategies, in other hilly areas likeBanihal.

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