Int. J. Struct. & Civil Engg. Res. 2014

International Journal of Structural and Civil Engineering Research

ISSN 2319 – 6009 www.ijscer.com
Vol. 3, No. 3, August 2014

Research Paper

STRUCTURAL SAFETY AND REHABILITATION OF A COLLEGE BUILDING: A CASE STUDY

K V Ramana Reddy[1]*

Corresponding author:K V Ramana Reddy** ✉ reddykalluru@gmail.com*

This paper deals with the structural safety and rehabilitation of a 25 year old building of Engineering College at Hyderabad, India. Rehabilitation of structures have become very essential on account of many factors. Deterioration of a structure may occur due to a host of factors such as poor workmanship, improper maintenance, atmospheric effects, abuses, accidents, natural calamities, etc. Certain causes like environmental effects, natural calamities etc, can't be controlled. Damage assessment and structural safety of an old building was studied through non- destructive and destructive tests. In-situ strength of an existing college building was assessed from the design curve developed by the authors without taking cores except for cross verification of results from the same building. The feasibility of extension of floor of an existing building with rehabilitation measures was also studied.

Keywords: Structural safety, Rehabilitation, Damage assessment, Non-Destructive tests, Destructive test, Design curves

INTRODUCTION

The existing building named 'J C Bose Block' in the premises of Vasavi College of Engineering, Hyderabad, India is a conventional R C Framed structure consisting of ground + 2 upper floors only. It was reported that the building was constructed about 25 years back. Of late, the concerned authorities wanted to construct one more additional floor over the existing building. In response to this a detailed investigation was carried out by me along with the team of Civil-Aid Technoclinic Pvt. Ltd., Hyderabad, India, in September, 2005 and these results were used for assessing the in-situ strength of existing building. Damage assessment was carried out through Non-Destructive Evaluation (NDE) techniques like ultrasonic pulse velocity, rebound hammer and combined method. In-situ strength of a building was estimated from the design curve and mathematical equations developed by the authors were given in Figure 1 and Table 1, respectively. Theoretical analysis was also carried out through STAAD software for life assessment of a building. For verification purpose 55 mm cores were also

[1] Department of Civil Engineering, Mahatma Gandhi Institute of Technology, Hyderabad, India.

Figure 1: Equal Strengthing Lines Based on Linear Regression Analysis of Data Obtained from Combined Method of Rebound Hammer and Utrasonic Pulse Velocity

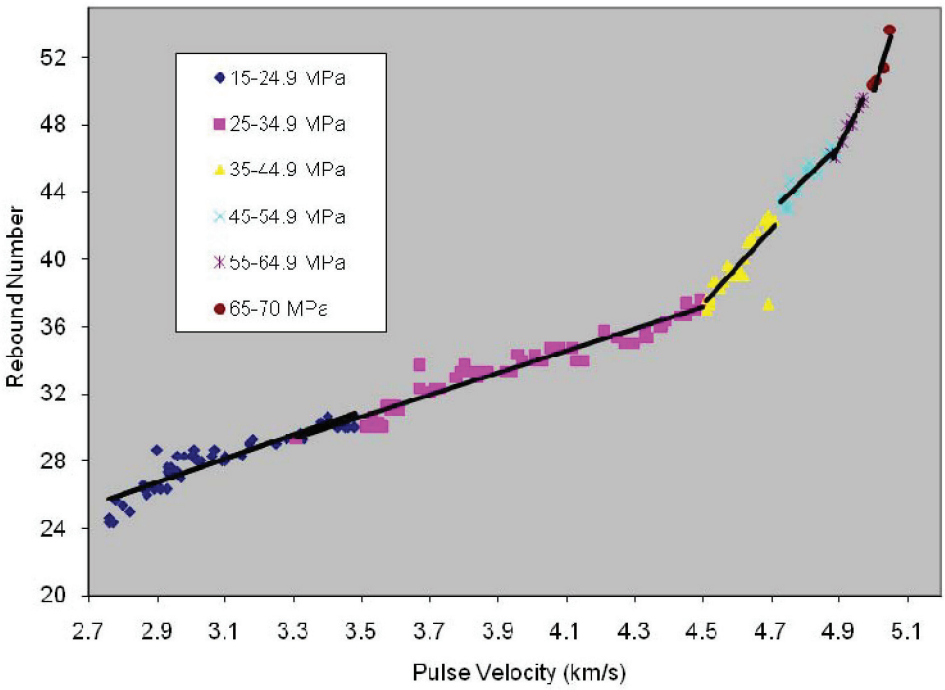

Table 1: Mathematical Equations for Compressive Strength From NDE Techniques

S.No	NDE Technique	Equation	Regression co-efficient
1	Ultrasonic Pulse Velocity	$f_c = 11.711\ v - 16.468$	$R^2=0.9771$
2.	Rebound Hammer	$f_c = 1.455\ n - 19.803$	$R^2=0.9695$
3.	Combined Method	$f_c = 1.24\ n + 0.058\ v^4 - 24.1$	$R^2=0.629$
	Where	f_c = Compressive strength of concrete in MPa v = Ultrasonic pulse velocity in km/s n = Rebound number	

extracted from the columns of a building and conclusions were made for structural safety. Feasibility study was made for extension of a floor of existing building by conducting load test on the existing structure. By checking the adequacy of footings, rehabilitation measures were suggested for extension of a floor.

PHYSICAL OBSERVATIONS

The following are the physical observations made during the study.

i) No settlement of the foundation was observed in any part of the building.

ii) No structural cracks were observed in the members.

iii) The reinforcement used in these RC members was observed to be of Fe 415 grade.

iv) Plinth beams were not provided.

v) The depth of foundation was found to be about 2.1 m at the exposed locations.

vi) The expansion joint was observed to be clogged by bitumen.

NON-DESTRUCTIVE TESTS

Ultrasonic Pulse Velocity Test: To assess the quality/ strength of in-situ concrete in R C beams and columns, Ultrasonic Pulse Velocity Test was carried out using PUNDIT equipment from M/s CNS Electronics, UK. Direct method of test was adopted for the testing. The layout of columns and beams is shown in the Figure 2. and the test results (average values) are tabulated in Table 2.

Rebound Hammer Test: This test was conducted on the accessible regions of RC slabs (i.e., underneath of the slab) to assess the strength of concrete on them by using Schmidt Rebound Hammer from M/s Proceq, Switzerland. The test results (average values) are tabulated in Table 2.

Profometer Studies: To map the disposition of reinforcement bars in the selected typical RC members such as columns and beams, profometer studies were carried out using Profometer-4 from Proceq, Switzerland. This test was also conducted to identify the place in RC members, at which there was no reinforcement so that cores can be extracted for evaluating the actual strength of in-situ concrete structures.

Core Tests: To assess the reliable strength of in-situ concrete in the RC members, core test was resorted to. Cores were extracted from the randomly selected columns of a building using diamond core cutter. The diameter of the core barrels used was 55 mm. The extraction of concrete cores was carried out according to scope of work mentioned above. Total 5 numbers of concrete cores were extracted. The extracted cores were trimmed, capped with epoxy cured for a minimum period and tested for compressive strength on a digital compression testing machine of 3000 kN capacity. The results of tests carried out on extracted cores are tabulated in Table 2.

Load Test: After construction of additional floor, the existing roof slab and beams will be subjected to additional loads as floor slab/ beam. In view of this, to assess the behavior of the existing beam and part of slab under proposed loading, load test was conducted on a typical beam-slab panel. The location of the panel selected for the testing is shown in Figure 2. Load testing on the building is shown in Figures 3 and 4.

The loading considered for the test are as follows:

Design live load = 3 kN/sq.m

Floor finish + ceiling plaster = 0.5 kN/ sq.m

Unknown partitions = 1 kN/sq.m

Total load applied = 1.25x L.L + Dead load= 5.25 kN/sq.m

The loading material consists of sand bags. The locations of deflectometers arranged underneath the beam and slab during test to

Figure 2: Layout and Location of Load Test

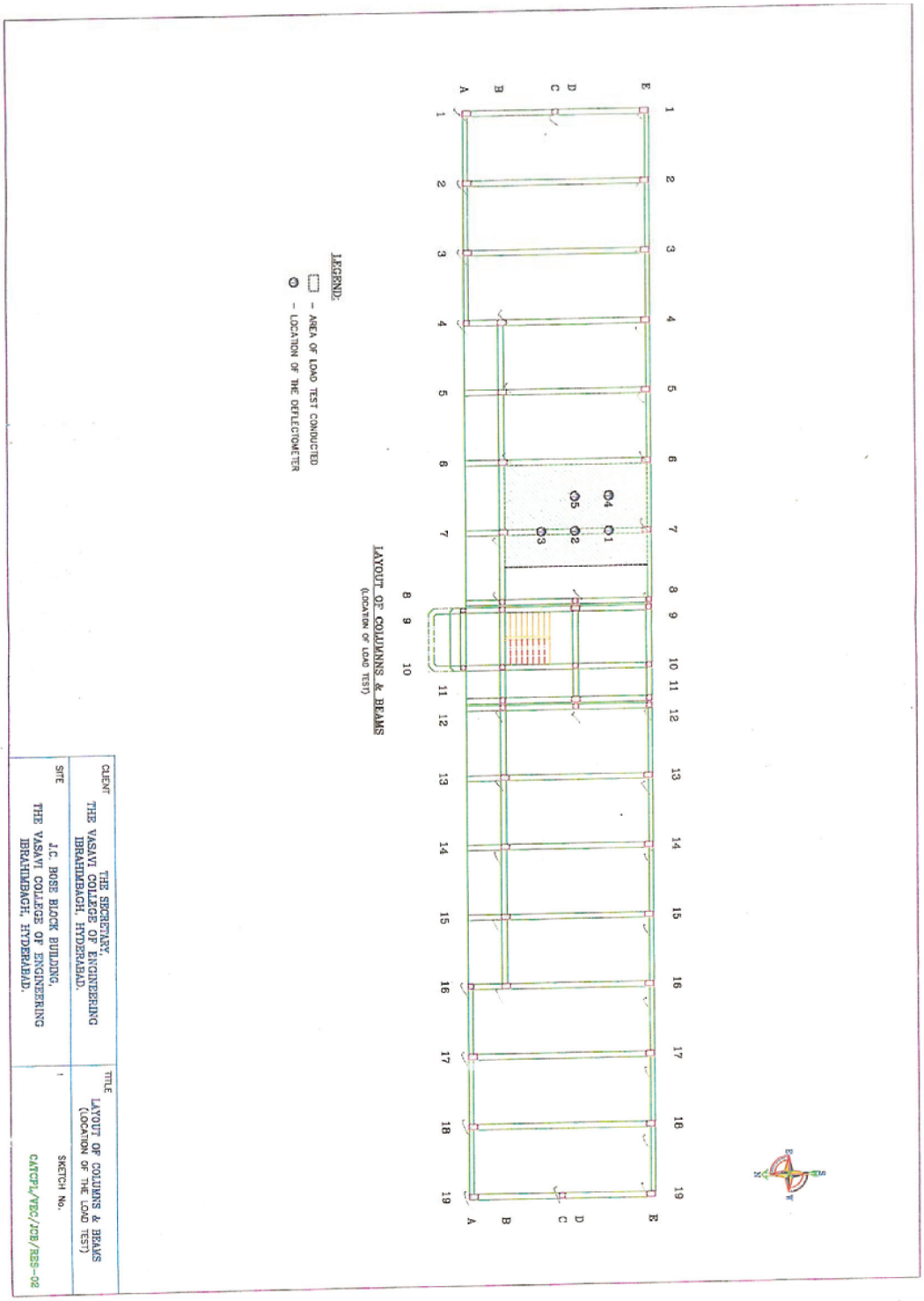

Table 2: Results of Non-destructive and Destructive Tests Conducted on the Existing Building Named 'J.C. Bose Block' Located in the Premises of Vasavi College of Engineering, Hyderabad, India

Floor level	Member identification	Average Values of NDT and Partially Destructive Test Results		
		Ultrasonic pulse velocity (km/s)	Rebound number	Compressive strength from concrete cores (MPa)
Ground floor	Columns	3.7	29	24.4
	Beams	3.5	28	25.8
First floor	Columns	3.6	31	23.9
	Beams	3.8	31	24.2
Second floor	Columns	3.6	29	25.6
	Beams	3.6	28	25.66

measure the deflections are shown in Figures 3 and 4. The load was applied in four equal increments. After completion of each increment of load, deflectometer readings were taken. The structural member was kept under fully loaded condition for 24 h. Thorough observations were carried out to check the development of new cracks if any and to ascertain whether the deflections were well under limits.

Figure 3: Load Test on a J.C. Bose Block, Hyderabad, India

Figure 4: Position of Dial Gauges Underneath Of R C Slab While Conducting Load Test

THEORETICAL ANALYSIS

Based on the dimensions of various RC Members at site and proposed layout of additional floors, a 3-D analysis was carried out using STAAD Pro. Live load on floor was considered as 3 kN/sq.m with allowable reduction as per IS: 875(Part-II). The actual strength of concrete, which was obtained from non-destructive testing on the existing members, was considered in the analysis. Wall loads were considered as per actual in the existing floors and light weight partitions and light weight floor finish loads were considered in the proposed floor.

The RC columns were checked for their adequacy for the loads from the additional floor apart from the existing. The reinforcement obtained as per the design, was checked with the details were from profometer studies.

INFERENCES

The following are the inferences drawn based on the physical observations, probing tests carried out and theoretical analysis.

i) From the results of Ultrasonic Pulse Velocity (UPV) test it was found to be the in-situ strength of concrete in the tested columns and beams was estimated to in the range of 20- 23 N/sq.mm.

ii) From the results of Rebound Hammer (RH) test, it was found to be the in-situ strength of concrete in the tested columns and beams was estimated to in the range of 20-24 N/sq.mm.

iii) From the combined method of UPV and RH test, it was found to be the in-situ strength of concrete in the tested columns and beams was estimated to in the range of 20-24 N/sq.mm.

iv) From the load test it was found to be the existing beam-slab system is capable of transferring loads when used as a floor slab for a live load of 3 kN/sq.m.

v) From the theoretical analysis and design check it is inferred that the identified columns of the structure are theoretically inadequate for the loads from the existing structure as it stands. But the sectional dimensions of the existing footing are adequate to transfer the loads from the existing and proposed one additional floor (light weight type such as steel columns with trussed roofing).

In view of this and to provide one additional floor it is recommended to strengthen the columns up to the level mentioned in Alternate 1 or to provide additional columns at the recommended locations and strengthen these columns up to the ground floor ceiling level as Alternate II.

REHABILITATION MEASURES

The following are the rehabilitation measures for the inferences drawn.

Alternative I: Providing additional column from foundation level at identified locations

a) New footing shall be cast at a depth of existing footings

b) The proposed reinforcement shall be brought up through the holes in slab and beams.

c) Column should be cast up to the bottom level of Jack located at 2 m from the footing level with M25 grade.

d) The proposed Jack shall be fixed and tightened.

e) Micro concreting of top portion of column shall be carried out.

f) The new concrete column shall be cured for sufficient period (min. of 14 days)

Alternate II: Increasing the sectional dimensions of identified columns by M-30 grade concrete encasement

a) The masonry on both sides of the identified columns shall be removed to the required distance.

b) The plaster over the surface of columns shall be removed by gentle chipping and cleaned with water jet to remove all dust particles.

c) 12 mm diameter holes 75 mm deep shall be drilled at specified spacing and cleaned with water jet to remove dust, etc.

d) 8 mm diameter shear connections shall be fixed in the drilled holes using anchor resign grout.

e) The surface of RC Members to be encased shall be thoroughly cleaned using wire brush and cleaned with water jet.

f) Proposed reinforcement shall be provided and fixed in position and tack welded/ tied to shear connectors.

g) A coat of epoxy bonding shall be provided over the surface prior to concreting.

h) M-30 grade concrete encasement to the required thickness shall be provided using tight shuttering as per specifications and cured for 14 days.

CONCLUSION

1. The in-situ strength of concrete obtained from the destructive testing is about 10% more than that predicted based on the design curves and mathematical equations presented in this paper.
2. Based on the NDT tests and load tests, the existing building is safe and capable to take an additional floor if proposed rehabilitation measures are carried out.

ACKNOWLEDGMENT

Vasavi College of Engineering and Civil-Aid Technoclinic Private Limited, Hyderabad, are greatly acknowledged for extending the facilities and co- operation for conducting the experiments.

REFERENCES

1. Chandrakant B Shah (2002), "NDT of earthquake-affected structures in Gujarat: Case study", *The Indian Concrete Journal.*
2. Francois Buyle-Bodin (2003), "Contribution of coupling non-destructive methods for diagnosis of concrete structures", *International symposium (NDTCE-2003)*, Japan.
3. Giovanni Pascale (2000), "Evaluation of Actual Compressive Strength of High Strength Concrete by NDT", Rama, Italy.
4. Konstantin Kovier and Isaak Schamban (1999), "Mathematical Methods of Experimental Design in Nondestructive Testing", *International Symposium on NDT Contribution to the Infrastructure Safety Systems,* Brazil.
5. Malhotra V M (2001), *Testing of in-situ concrete: Non-Destructive Methods.*
6. Ramana Reddy K V *et al.* (2007), " Assessment of Strength of Concrete By Non-Destructive Testing Techniques", I*nternational conference on Fast track construction of Bridges (IIBE),* 23-25 Feb, 2007, Hyderabad, India.
7. Ramana Reddy K V *et al.*(2007), " Non-Destructive Evaluation Techniques for Assessment of Strength of Concrete", National conference on Theoretical and Experimental Advances in Civil Engineering (TEACE-2007), 8-9 Feb. 2007, Chennai, India.
8. Ramana Reddy K V *et al.* (2008), " Design Curves and Mathematical Equations for Assessment of In-situ Strength of Concrete Structures By NDE Techniques", *International conference on Advances in Concrete and Construction (ICACC_2008)*, 7-9, Feb. 2008, Hyderabad, India.
9. Samarin A (1984), "Determination of in-situ concrete strength; rapidly and confidently by nonpdestructive testing", *ACI,* Detroit.
10. Sivagnanam B (2002) , "Damage assessment and rehabilitation of concrete structures: Three case studies", *The Indian Concrete Journal.*