A CASE STUDY ON HERITAGE STRUCTURE - REPAIR AND REHABILATION TECHNIQUES

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Abstract: Strengthening techniques place a significant role in the repair of old monumental structures. Looking at the background of the historical structure (temple), it was constructed 90 decades ago as per the record, these structures generally prone to weathering over a long time. To preserve these constructions we go far different kinds of retrofitting techniques. Here in this paper physical investigation is carried out and non-destructive testing methods are employed to find the strength of the structure and strengthening techniques are used to enhance the strength and durability of the structure to preserve the historical monuments.

IndexTerms - Durability, Historical structure, NDT methods, strengthening techniques, Repair and rehabilitation.

I INTRODUCTION

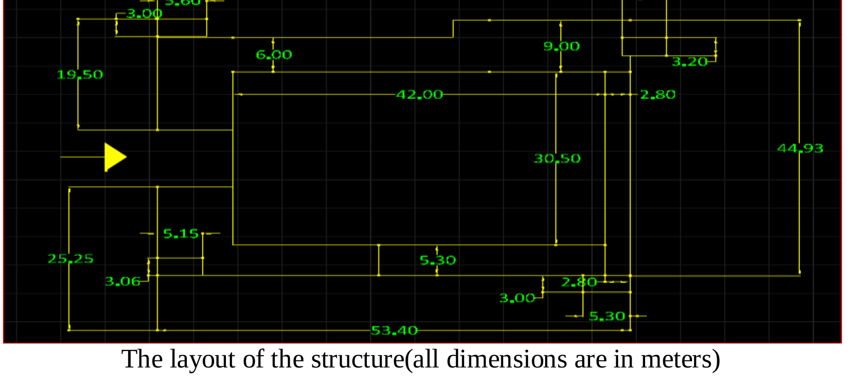
The words structure itself says that it is the union of different flexural and compression components like beams and columns. Assessment of this structure is essential to verify the functioning of the building. Generally buildings of age greater than 35, there is a declination in strength due to Wear and tear of materials. A Further loss in strength may lead to severe destruction, and hence auditing is carried out to inspect the overall performance of construction. For old structures such as historical monuments, it is necessary to know the service life in order to preserve the Nation's culture and heritage. The service life of a structure is firmly defined by its design, construction, and aging and safeguarding during it's use. Currently, several tools are available in the field of civil engineering to ascertain the structure safety for various levels of destruction.The technique adopted dependsupon the parameters when it completely achieves the position of deficiency in a structure in economical way.

A Most essential task in the monitoring of historic monuments is definitely the safeguarding of original materialMostly, Non-Destructive Testing (NDT) tests are employed to know the service life of a structure.These tests are chosen in such a way that they should felicitate rapid results in an economical way. Those techniques which are in use forsupervising structures for the types, causes, and level of distresses are also ought to be recognized. Typically, common type of distresses include cracks, spalls, efflorescence, surface erosion, salt or moisture influences or irregularities which may derive from a variety of factors from difference in loading to material heterogeneity or microstructure etc.,

II BACKGROUND OF THE HERITAGE STRUCTURE

Sri seetha Rama Chandra SwamyDevasthanam is Located a few kilometers to the east of shamshabad village of the national highway .The Sri seetha Rama Chandra SwamyDevasthanamof ammapally village,narkhoda located in shamshabad mandal of Rangareddy district, is located on a spreading area with an ensemble of buildings constructed over the centuries. The idols of deities date from the 11th century and were installed at ammapally in the 14th century as per information provided by the custodians.

Fig 1 Front face of the historical structure



The layout of the structure(all dimensions are in meters)

III METHODOLOGY ADOPTED FOR THE STUDY

The strength of the structure can identify by two methods destructive and non destructive methods

Destructive testing: To authenticate the reliability of a module, it is always viable to cut apart the components and inspect the exposed surfaces. Components can be strained and hassled until failure to find out their properties of strength and stiffness. Materials can be chemically treated to verify their composition of a structure. These are some methods used in destructive testing. Unfortunately, this methodology of destructive testing yields the component cab be useless for its deliberate use as against non-destructive testing which can be performed on the structural components and machines without affecting their overhaul performance.

Non Destructive testing

Non-destructive testing (NDT) is a most treasured analysis practice used in the production industry to approximate the properties of a material, component or system without causing deterioration to it. The terms Non-destructive examination, Non-destructive inspection and Non-destructive evaluation are most commonly used to exemplify this technology because NDT does not transform the component after being inspected, it is a immensely valid technique that can save currency as well as period in assessing, troubleshooting, and in research related activities. Commonly NDT methods comprises of ultrasonic, magnetic particle, liquid penetrate, radiography, remote visual inspection (RVI), eddy current testing, rebound hammer etc.,

By visual inspection of the current structure the following are the techniques adopted for the contemporary study.

- Rebound Hammer Test
- Ultra Sonic Pulse Velocity Method

III.I REBOUND HAMMER TEST

Principal: When the plunger of the rebound hammer is pressed against the intended surface of the concrete, the spring controlled mechanism in rebound hammer helps to rebound the mass and the degree of rebound depends upon the stiffness of the concrete. The face resistance and therefore the rebound are considered to get the compressive strength of the concrete. The rebound is interpret with a graduated scale and is designated as the rebound index.

It consists of a spring controlled mass that slides on a plunger within a tubular casing. The impact energy required for rebound hammers for different applications is given in the following Table 1

Table 1 represents the impact energy required for rebound hammers

S.No.	Application	Approximate Impact energy required for rebound hammer(Nm)
1.	For testing normal weight	2.25
2.	For light-weight concrete or small and impact sensitive parts of concrete	0.75
3	For testing mass concrete, for example in roads, airfields pavements and hydraulic structures	30.00

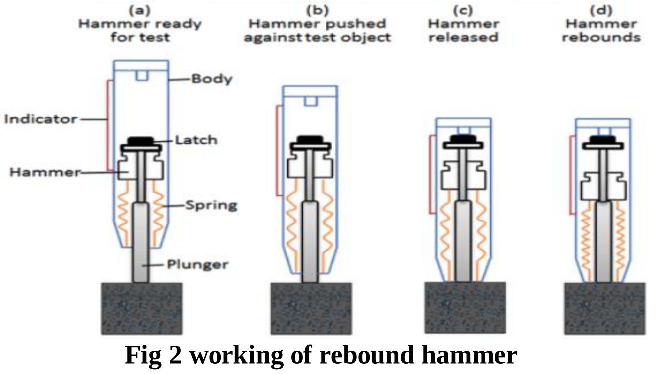


Fig 2 working of rebound hammer
(sourcehttp://www.mdpi.com/materials/images/materials-08-05368-g001.png)

Procedure : Preceding to test the facade of concrete should be dirt free, smooth and dry. If a loosely adhering face is present, this should be rubbed off with a grinding wheel or stone. Rough faces resulting from incomplete compaction, loss of grout, spalled or tooled surfaces do not generate consistent results and those should be taken care of.

The position of impact should be at least 20 mm away from any edge.

For recording a value, the rebound hammer should be held in such a way that plunger is faced at right angles to the surface of the concrete member. The test is thus performed either horizontally on vertical surfaces or vertically upwards or downwards on horizontal surfaces. If there is a difficulty in performing the job, the rebound hammer can be held at halfway angles also, but in each case, the rebound index will be different for the same concrete.

Rebound hammer test can be performed on all the points of study on all manageable surfaces of the structural element. Concrete facades 'are thoroughly cleaned before taking any measurement. Around each point of inspection, six readings of rebound indices are taken as the 2nd average of these readings after deleting outliers as per IS 8900: 1978 becomes the rebound index for the point of the study.

Note - In sight of the confines of each method of non-destructive testing of the concrete, it is vital that the outcomes of test obtained by one method should be compared by other tests and each method should be performed very carefully.

III.II ULTRASONIC PULSE VELOCITY

Object

The ultrasonic pulse velocity method could be used to verify:

- The homogeneity of the concrete,
- The existence of cracks, voids and other imperfections,chronological changes in the concrete, the quality of the concrete in relation to standards.
- The quality of one element of concrete in relation with other, and
- The values of dynamic elastic modulus of concrete.

Principle

The ultrasonic pulse is achieved by an electro acoustical transducer. When the pulse is stimulatedinto the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes longitudinal (compression), shear (transverse) and surface (Rayleigh)waves. The receiver detects the initiationof the longitudinal waves, which is the quickest.

Since the velocity of the pulses is almost independent of the geometry of the material through which they travel and depends solitary on its resilient properties, UPV method is aappropriate technique for scrutinizing thestructural concrete. The fundamental principle of calculating the quality of concrete is that relatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of inferior quality, minor velocities are obtained. If there is a fault, cavity or flaw within the concrete which comes in the way of transmission of the pulses, the pulse strength is lessened and it flows around the discontinuity, thereby making the path length longer. Accordingly, lesser velocities are obtained. The reliable pulse velocity obtained depends principally upon the resources and mix proportions of concrete. Density and elastic modulus of aggregate also considerably influence the pulse velocity

Apparatus

The apparatus for ultrasonic pulse velocity measurement shall consist of the following:

- Electrical pulse generator,
- Transducer - one pair,
- Amplifier, and
- Electronic timing device.

Transducer Any fitting type of transducer working within the frequency limits of (20-150) kHz (see Table 1) can be employed. Piezoelectric and magneto- bound kinds of transducers may be exercised, the other being highlyappropriate for the lower part of the frequency range.

Table 1: Natural Frequency of Transducers for Different Path Length

Path Length (mm)	Natural Frequency Minimum of Transducer(KHz)	Minimum Transverse Dimensions of Members(mm)
up to 500	150	25
500-700	>60	70
700-1500	>40	150
Above 1500	>20	300

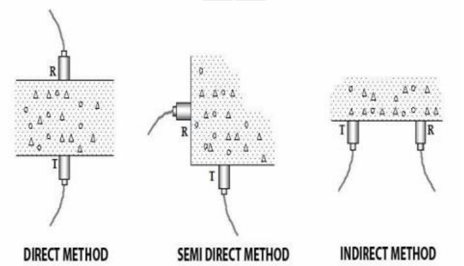


Fig :3Source:https://www.pinterest.com/pin/410038741053610215/?lp=true

Procedure

In this testing methodology, the ultrasonic pulse is generated by the transducer which is held in connection with one facade of the concrete component under test. After navigating a identifiedpath length 'Q' in the concrete, the pulsations aretransformed into an electrical signs by the other transducer held in position with the other surface of the member and an electronic 2 timing circuit facilitates the transit time (T) of the pulsation to be calculated. The pulse velocity (V) is given by:

$$V = \frac{L}{T}$$

Whenthe ultrasonic pulse encroacheson the face of the material, the utmost energy is generated perpendicular to the facade of the transmitter and finest results are, thus, achievedwhen the receiver is located on the contrary surface of the structural concrete member. However, in most situations two opposite surfacesof the structural member may not be approachable for measurements. In such cases, the receiver is also placed on the same face of the concrete members popularly known as surface probing. Surface probing is not much as efficient as cross probing, because the signal produced at the receiving transducer has amplitude of only 2-3 percent of that created by cross probing and the test results are critically inclined by the exterior layers of concrete which may have different properties from that of interior concrete. The indirect velocity is consistently inferior to the direct velocity on the same concrete member. This variance is about 5-20 % which depends mostly on theconditionof the concrete under testing. For superior quality concrete, a variationmaybe around 0.5 km/ set may typically be encountered.

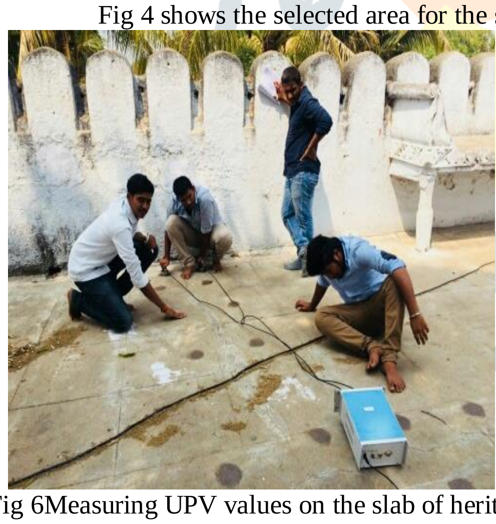
To reassure that the ultrasonic pulsationcreated at the transmitter exceedinto the concrete and are identifiedby the receiver, it is vital that there should be ample acoustical pairing in between concrete and facade of both transducers. Conventional coolants are petroleum jelly, lubricants, liquid soap and kaolin glycerol glue. At leastpath length of 150 mm is suggested in direct diffusionmethodologylinking one unmolded surface and a minor path extent of 400 mm for surface probing method along an unmolded face.

The rate of natural frequency of transducers should be around the scope of 20-150 kHz (see Table 1). In the main, high-level frequency transducers are preferred for short path lengths and low frequency transducers are for long path lengths. Transducers with a frequency of 50 - 60 kHz are handy for most all-round applications.

Since size of aggregates affect the pulse velocity measurement, it is optional that the minimal path length should be of 100 mm for concrete in which the nominal upper limit of aggregate is 20 mm or less and 150 mm is for concrete in which the nominal maximum size of aggregate is between 20 to 40 mm.

In sight of the inbuilt variability in the test results, adequate number of readingsis calculated by isolating the entire structure in suitable grids of 30 x 30 cm or even smaller. Each link point of the grid becomes a point of scrutiny. Transducers are placed on corresponding points of observation on contrarysurfaces of a structural element to measure the ultrasonic pulse velocity by direct transmission, i.e., cross probing. If one of the facades is not- manageable ultrasonic pulse velocity is calculated on one face of the structural element by surface probing. Surface, probing in general gives lower pulse velocity when compared to the cross probing and it depends on the number of parameters, the difference could be of the order of about 1 km/set.

Fig 4 shows the selected area for the study Fig 5 represents markings on the slab



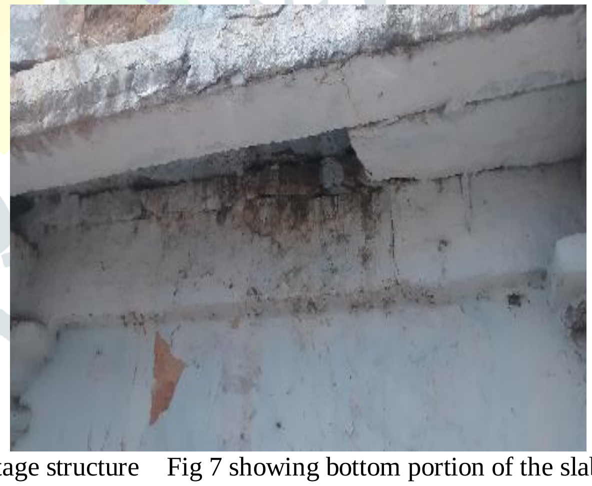


Fig 6Measuring UPV values on the slab of heritage structure Fig 7 showing bottom portion of the slab

Results and Discussion

The site is tested with non destructive testing methods and values are recorded these values represent the strength of the structure if they are sound the values lies in between 3-5 and if it is less than 2 they cannot sustain the loads and large deformations occur in the structures.

Table 2 represents the measurements taken at 40 selected points in the study area

S.No	Rebound Hammer Readings	Ultra Sonic Pulse Velocity Measurements
1	3.2	2.44
2	3.02	2.307
3	3.18	2.04
4	2.8	2.66
5	3.32	2.1666
6	3.36	1.948

7	3.58	2.068
8	2.585	2.272
9	2.98	5.4
10	3.6	2.255
11	2.96	5.357
12	3.18	1.574
13	3.24	2.173
14	3.7	1.2
15	3.64	1.88
16	3.28	2.764
17	3.5	1.621
18	3.06	3.125
19	2.54	7.5
20	3.7	2.765
21	3.94	4.45
22	3.56	2.912
23	3.62	2.608
24	3.42	1.25
25	3.56	2.238
26	3.82	1.534
27	3.84	2.127
28	4.24	2.97
29	3.5	2.803
30	3.92	1.973
31	3.52	1.851
32	4.52	1.339
33	4.04	1.719
34	4.04	2.02
35	4.42	1.47
36	3.82	2.62
37	4	2.02
38	3.5	2.15
39	4.04	2.43
40	3.72	2.44

Table 3showing the measurements taken at next set selected points in the study area

S.No	Rebound Hammer Readings	Ultra Sonic Pulse Velocity Measurements
41.	3.84	2.205
42.	3.96	1.923
43.	4.24	1.038
44.	3.3	2.238
45.	4.2	1.916
46.	3.58	2.23
47.	4.3	2.17
48.	4.18	2.1
49.	4.08	1.563
50.	3.8	1.754
51.	4.14	1.345
52.	3.78	2.083
53.	1.5	2.419
54.	2.68	1.595
55.	2.98	2.054
56.	3.96	1.941
57.	3.66	1.98
58.	4.32	2.02
59.	3.64	2.272
60.	3.46	2.739
61.	3.42	1.685
62.	3.72	2.033
63.	3.66	1.98
64.	2.88	1.829
65.	4.26	1.234
66.	3.68	2.281

69.	2.44	2.173
68.	1.52	2.91
69.	1.5	3.296
70.	2.76	1.96
71.	1.52	3.125
72.	2.84	1.69
73.	2.98	2.097
74.	1.7	2.678
75.	3.6	1.923
76.	1.9	2.38
77.	2.92	2.307
78.	3.78	1.648
79.	3.22	1.57
80.	2.88	1.986

Table 4 represents the location of minimal points along with their recorded values of rebound hammer and ultra sonic pulse velocity

S.No	Station points	Rebound values	Ultra sonic pulse velocity values
1	6	3.36	1.948
2	12	3.18	1.574
3	14	3.7	1.2
4	15	3.64	1.88
5	17	3.5	1.621
6	24	3.42	1.25
7	26	3.82	1.534
8	30	3.92	1.973
9	31	3.52	1.851
10	42	3.96	1.923
11	45	3.3	1.916
12	50	3.8	1.754
13	54	2.68	1.595
14	57	3.66	1.98
15	61	3.42	1.685
16	64	2.88	1.829
17	70	2.76	1.96
18	72	2.84	1.69
19	79	3.22	1.57
20	80	2.88	1.986

The observations in Ultra sonic Pulse Velocity test and Rebound hammer are considered, from both of these minimal points are identified.

IV RETROFITTING TECHNIQUES

Epoxy injection

It is used to re establish the structural health of buildings, bridges, and dams where cracks are latent or cannot be permitted from moving advance. Cracks as narrow as 0.002 inch can be sealed by the epoxy injection. The method generally holesare drilled at prescribed intervals along the fissure, and insert the epoxy under pressure. For certain particular epoxies, this method cannot be used if there is a leakage althoughdamp cracks can beinjected; water or other pollutants in the split will decrease the efficiency of the epoxy heal. The essential steps required for injecting epoxy are:

1. Clean the fissure
2. Close the surface
3. Install the entrance ports
4. Blend the epoxy.
5. Insert the epoxy into the fissures
6. Detach the surface seal

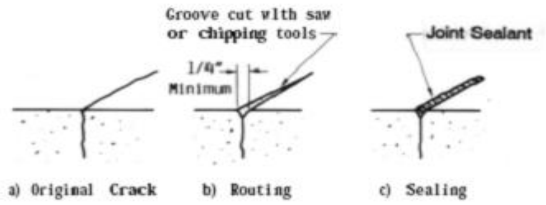


Fig. 3.1-Repair of crack by muting and sealing (Johnson 1965)

Source:http://construction-site-vn.blogspot.com/2011/11/methods-of-crack-repair.html

Recorded values after the repair technique

Epoxy injections are selected for the repair, since the cracks are small and deep from the observations, 20 minimum points are taken and they are treated with the epoxy after treating the cracks with this technique the following values are obtained.

Table 5 projects the final observations after applying the retrofitting technique

S.No	Station points	Rebound values	Ultra sonic pulse velocity values
1	6	3.61	4.51
2	12	3.43	4.26
3	14	3.95	4.36
4	15	3.89	4.50
5	17	3.75	4.29
6	24	3.67	4.26
7	26	4.07	4.50
8	30	4.17	4.60
9	31	3.77	4.39
10	32	4.77	4.35
11	33	4.27	4.39
12	35	4.67	4.46
13	42	4.21	4.32
14	43	4.49	4.30
15	45	3.55	4.49
16	49	4.33	4.43
17	50	4.05	4.36
18	51	4.39	4.31
19	54	2.93	3.51
20	56	4.21	4.64
21	57	3.91	4.55
22	61	3.67	4.51
23	63	3.91	4.60
24	64	3.13	4.35
25	65	4.51	4.40
26	70	3.01	4.55
27	72	3.09	4.53
28	75	3.85	4.52
29	78	4.03	4.41
30	79	3.47	4.51
31	80	3.13	3.99

From the above table it is observed that there is strength gain in the values of NDT methods, this method is effectively fill the voids in the walls and hence there is a significant gain in strength.

V. CONCLUSIONS

From the study it is concluded that the preserving the cultural heritage structures can be possible by applying the proper repair and rehabilitation techniques

There is a significant strength gain in the structure before and after the test. From the table it is concluded that there is a 46% strength gain in almost all the points and micro cracks are well sealed with epoxy grouting.

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