

Assessing Quality in Machine Foundation Using UPV Measurements

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ABSTRACT: The particular effectiveness evaluates associated with 40 MVA MG collection unit basis had been completed to stop this vibration associated with basis produced below operating issue on the unit in addition to developing few splits. Just for this, this strength in addition to effectiveness associated with concrete from the unit basis became improbable. To be able to improve the strength of basis, ultrasonic pulse velocity (UPV) analyzes depending on IS: 13311-1992 (Part-1) had been completed. Case study functions unveil the concrete ended up inadequate specially around bolt grouting postures as well as other a part of basis, having surprisingly low UPV ideals along with splits at first glance in addition to necessary rehabilitations operates or even strength progress actions to further improve the strength of present unit basis with it is functioning issue.

KEYWORDS: Non-destructive test (NDT), Ultrasonic pulse velocity (UPV) test, Machine foundation, Epoxy pressure grouting.

I. INTRODUCTION

The UPV exams were being performed on a machine foundation of 40 MVA MG set which is working for the past several years within Bharat Heavy Electrical Limited (BHEL), Bhopal. This kind of machine foundation obtains vibrated beneath the functioning condition and also developed a few cracks on the top and also have to have immediate repairs to further improve the overall performance so the power generation perform won't obtain hampered which within tern disturb this production device. Throughout the visual evaluation, it was uncovered that this gas leaking above entire concrete surface and also delaminating regarding concrete noticed in most of the sites. The main aim of the rehabilitation of this aged machine foundation is to sustain this aged facility for just a particular time period so that the latest foundation is usually built in those times.

II. MATERIALS AND METHODS

The complete investigation of performance analysis includes visual inspection of existing structure and to do ultrasonic pulse velocity test to focus the overall harms and in addition quality of the concrete of machine foundation. UPV test gives more sensible results to check the consistency of concrete and for monitoring changes in a concrete with time when contrasted with bounce back hammer test [1]. The principle target behind this investigation was to discover the nature of concrete and recognizable proof of concrete zone & crack detection, if any in the machine foundation utilizing NDT investigation techniques.

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III. DESCRIPTION OF STRUCTURE

The machine foundation was manufactured close around 40 years back and gets splits of areas because of its vibration under running state of the machine. The whole surface of the concrete gets oily and delamination of plasters happened in a few areas. The concrete surface gives dull ringing sound when physical tried with small hand hammer. The detailed schematic drawings of this machine foundation are shown in Figures 1, 2 and 3. Figure 1 shows the plan of the foundation having size 15.22 m (Length) \times 4.48 m (Breadth) and divided into three chambers by two intermediate walls.

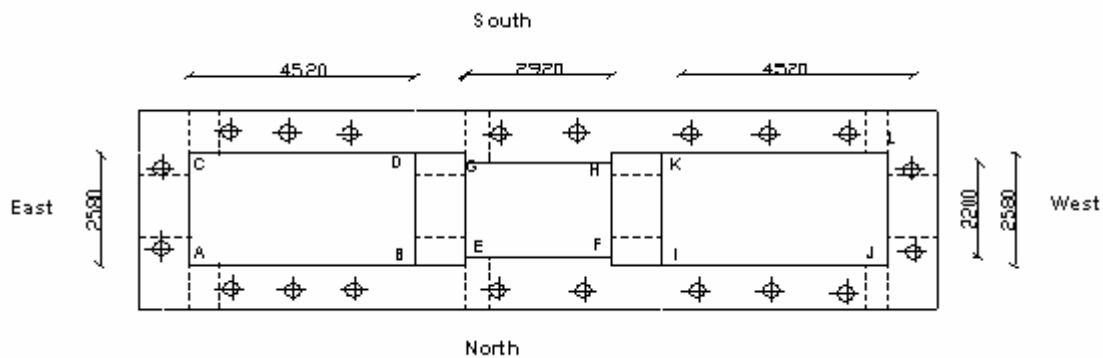


Figure 1: Plan of foundation – 40 MVA MG set

Figures 2 and 3 shows the elevation of foundation walls ABCD and IJKL respectively having internal chambers of size $4.52 \times 2.58 \times 2.28$ m in height with undulated flooring. The internal dimension of the walls is not found in uniform in size due to deterioration of wall plaster and inferior workmanship.

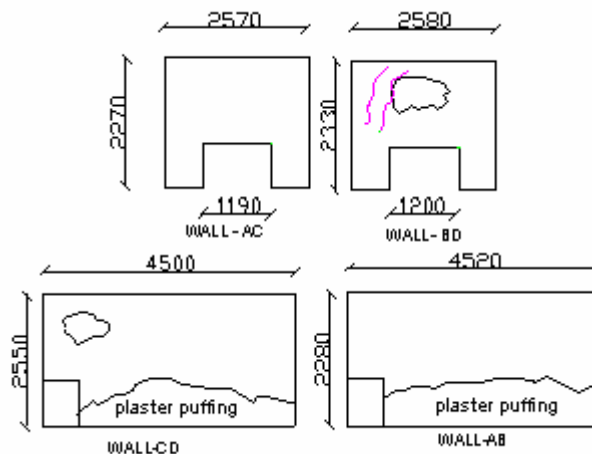


Figure 2: Elevation of foundation wall – ABCD

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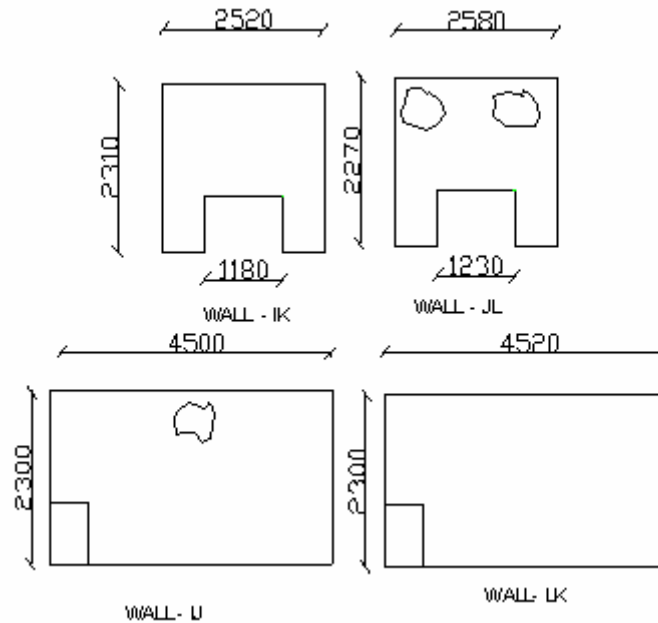


Figure 3: Elevation of foundation wall – IJKL

IV. VISUAL INSPECTION

In visual inspection it has been observed that there was oil spillage over concrete surface, likewise an excess of water and oil accumulated inside the foundation. The delamination of plaster layers furthermore poor ringing sound over delaminated plaster or concrete surfaces in choosing areas, especially at foundation bolt grouting were additionally observed. Two visible cracks were seen in which one of them is all through the wall.

V. ULTRASONIC PULSE VELOCITY

A non-destructive test is characterized as one that does not damage or impair the intended performance of the structural element or member under investigation. One such system is the ultrasonic pulse velocity test, which measures the velocity of ultrasonic pulses of longitudinal vibrations passing through hardened concrete and can be utilized for the accompanying purposes [2-5]:

- To determine the uniformity of concrete in or between members.
- To detect the presence and approximate extent of cracks & voids and other defects, if any.
- To measure the changes in the properties of concrete accruing with time.
- To correlate pulse velocity and strength as a measure of concrete quality.

The velocity of the ultrasonic pulse is affected by those properties of concrete, which focus its elastic stiffness and mechanical strength. The variations acquired in an arrangement of pulse velocity measurements made along distinctive ways in a structure reflect a corresponding variation in the state of the concrete.

At the point when a district of low compaction voids or damaged material is available in the concrete, a comparable decrease in the calculated pulse velocity happens and this enables the approximate extent of the defects to be resolved. A pulse of longitudinal vibrations is created by an electro – acoustical transducer that is held in contact with one surface of the concrete under test. In the wake of navigating a known path length, L, in the concrete the pulse of

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vibrations is converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time, T , of the pulse to be measured and displayed on a digital scale [6]. There are three basic ways in which the transducers can be arranged as demonstrated in Figure 4.

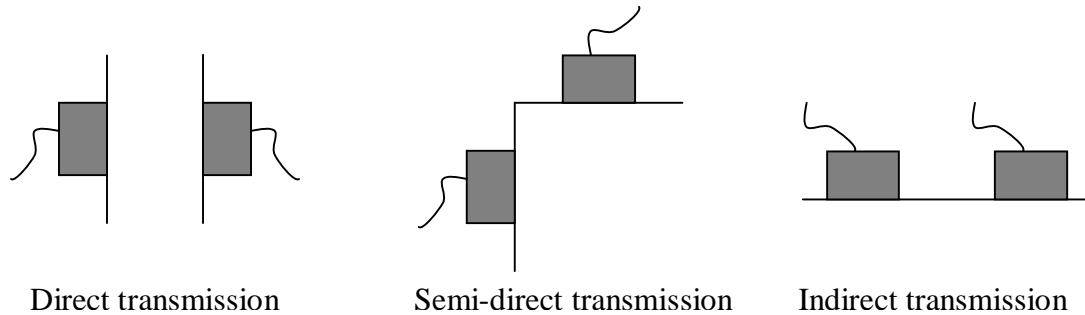


Figure 4: Arrangements of transducers

Direct Transmission: Placement of transducer and receiver on opposite faces of the member

Semi Direct Transmission: Placement of transducer and receiver on adjacent faces of the member.

Indirect Transmission: Placement of transducer and receiver on same faces of the member.

Where possible the direct transmission arrangement should be used for the transfer of energy, between direct oppositely placed transducers has maximum and the accuracy of the velocity determination is governed principally by the accuracy of the path measurement. The measured transit time data are most reliable in this case.

The semi direct arrangement can a few times be utilized satisfactory, if the angle between the transducers is not too great, and if the path length is not large. The indirect arrangement is definitely the least satisfactory, since the received signal amplitude may be less than 3 % of that for a comparable direct transmission. The received signal is dependent upon scattering of the pulse by discontinuities and is the highly subjected to errors.

There should be adequate acoustical coupling between the concrete and the faces of each transducer. To ensure this a very thin layer of a coupling medium such as petroleum jelly, grease, soft soap or kaolin – glycerol paste is applied to the transducer. Repeated readings of transit time should be made until a minimum value is obtained so as to allow the coupling layer to become thinly spread. A rough surface of the concrete should be smoothed and leveled before the transducer is placed against it. Once the velocity is determined, an idea about quality, uniformity, condition and strength of concrete tested can be attained [7]. The ultrasonic pulse criteria for the classification of concrete according to IS: 13311-1992 (Part-1) is given in the Table 1.

Table 1: Pulse criteria for quality grading of concrete

Pulse velocity (km/s)	Quality of concrete
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

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The UPV testing was carried out by using the portable ultrasonic non-destructive digital indicating tester (PUNDIT). The UPV can be calculated as per the formula given in equation 1. The pulse velocity, V, in Km/sec is given by;

$$V = L / T \quad (1)$$

Where,

L = path length, mm,

T = time taken by the pulse to traverse the given length, microseconds.

The crack determination of the concrete surface can be measured by using the following equation;

$$C = X_1 [\sqrt{(4T_1^2 - T_2^2)} / (T_2^2 - T_1^2)] \quad (2)$$

Where,

C = Crack depth in mm.

X_1 = Position of transducers from crack (200 mm).

$X_2 = 2X_1$.

T_1 = Transit time when transducers are at position X_1 .

T_2 = Transit time when transducers are at position X_2 .

Using the above equation, crack depth in wall BD comes out to be 1242 mm, which is crossing from one face to another face and inclined towards the center of the wall.

The arrangement of transducers for the UPV test on the foundation wall 'LK' and 'IK' are as shown in Figures 5 & 6. The UPV test was conducted at 18 and 11 different locations in wall 'LK' and 'IK' respectively. The position of the transducer and receiver are placed directly to each other.

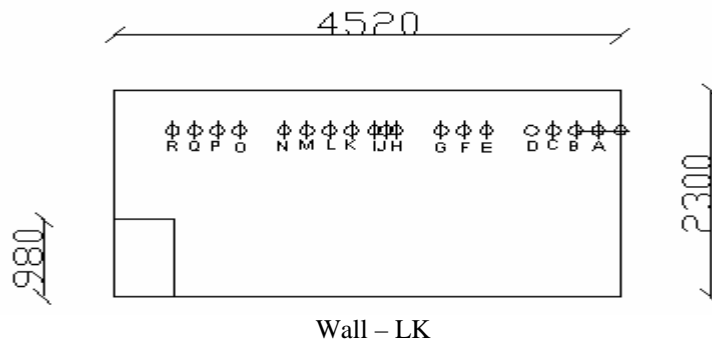


Figure 5: Transducers arrangement in wall - LK

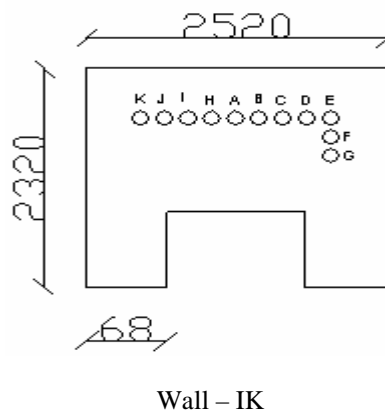


Figure 6: Transducers arrangement in wall - IK

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The UPV test results for walls LK and IK are shown in Tables 2 & 3. Some UPV results on wall IK were not measured due to severe honeycombing.

Table 2: Ultrasonic data of wall - LK (By Direct transmission Technique)

S. No.	Code No.	Path length (mm)	Transit time (μ sec)	Pulse velocity (Km/s)	Remarks
1	A	950	499	1.90	0.2 m from corner
2	B	950	231	4.11	0.2 m from A
3	C	950	222	4.28	0.4 m from A
4	D	950	226	4.20	0.6 m from A
5	E	950	229	4.15	1.4 m from A
6	F	950	225	4.22	1.6 m from A
7	G	950	226	4.20	1.8 m from A
8	H	950	270	3.52	2.0 m from A
9	I	950	486	1.95	2.2 m from A
10	J	950	460	2.07	2.1 m from A
11	K	950	228	4.17	2.4 m from A
12	L	950	225	4.22	2.6 m from A
13	M	950	439	2.16	2.8 m from A
14	N	950	467	2.03	3.0 m from A
15	O	950	219	4.34	3.40 m from A
16	P	950	224	4.24	3.6 m from A
17	Q	950	227	4.19	3.8 m from A
18	R	950	229	4.15	4.0 m from A

Table 3: Ultrasonic data of wall - IK (By Direct transmission Technique)

S. No.	Code No.	Path length (mm)	Transit time (μ sec)	Pulse velocity (Km/s)	Remarks
1	A	940	211	4.45	Center point of wall
2	B	940	209	4.50	0.2 m right from A
3	C	940	469	2.00	0.4 m right from A
4	D	940	229	4.10	0.6 m right from A
5	E	940	456	2.06	0.8 m right from A
6	F	940	367	2.56	0.2 m bottom from E
7	G	940	225	4.18	0.4 m bottom from E

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8	H	940	227	4.14	0.2 m left from A
9	I	940	*	*	0.4 m left from A
10	J	940	*	*	0.6 m left from A
11	K	940	*	*	0.8 m left from A
* Unable to link due to severe honeycombing					

VI. RESULTS AND DISCUSSION

The statistical parameters, for example, the number of readings, minimum velocity, maximum velocity, mean velocity, standard deviation and characteristic velocity corresponding to 90 percent confidence limit were calculated ($V_{ck} = \text{Mean} - 1.64 \times \text{SD}$) given in Table 4. From Table 4, the UPV values of machine foundation were found in the ranges of 1.90 – 4.5 Km/s. It was further noticed that the UPV values at some foundation bolt locations as well as at poor ringing sound zones come out to be in the range of 1.90 – 2.56 km/sec (i.e. At points A, I, J, M and N of wall LK as well as points C, E and F of wall IK) which implies that the quality of concrete is poor in those places, which is also verified by drilling hole of 25 mm diameter in a concrete and observed that the drilling was made very comfortably without any resistance which shows that the quality of concrete is poor as well as having honeycombing at particular locations.

Table 4: Statistical parameters of UPV values of foundation walls

S. No.	Structural Members	No. of points	Ultrasonic pulse velocity (km/s)			Standard deviation	Coefficient of variation	V _{ck} (km/s)
			Min.	Max.	Mean			
1	Wall - LK	18	1.9	4.34	3.56	1	28.01	1.92
2	Wall - IK	8	2	4.5	3.5	1.09	31.2	1.71

The status of pulse criteria is given in Table 5, as per this table the overall percentage of doubtful and good quality of concrete were 30.77 % and 69.23% respectively.

Table 5: Status of pulse criteria

S. No.	Particulars	Total locations	No. of locations			
			Doubtful	Medium	Good	Excellent
			V < 3.0 km/s	V = 3.0 - 3.5 km/s	V = 3.5 - 4.5 km/s	V > 4.5 km/s
1	Wall - LK	18	5	0	13	0
2	Wall - IK	8	3	0	5	0
3	All	26	8	0	18	0
4	Overall Percentage (%)		30.77	0.00	69.23	0.00

The histogram of UPV values of machine foundation and its pulse criteria is shown in Figures 7 and 8. This study revealed that strength of machine foundation can be regained by adopting some minor strength recommendation suggested for improvement in its strength.

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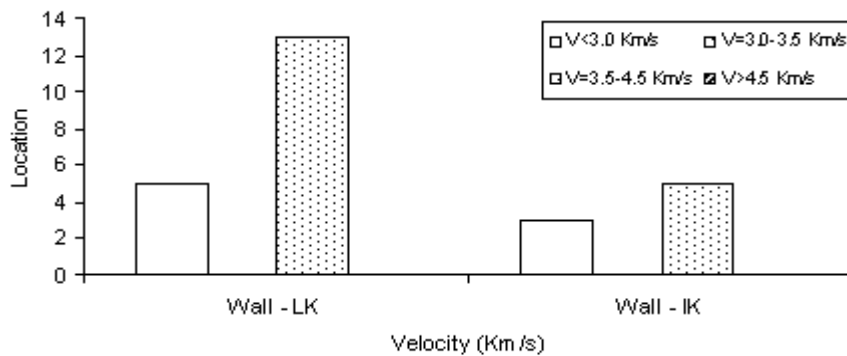


Figure 7: Histogram on UPV values of Machine foundation

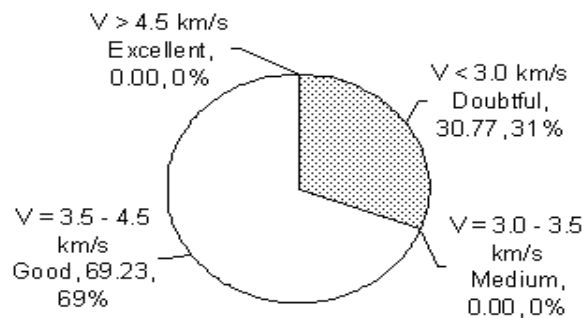


Figure 8: Pulse criteria of Machine foundation

Based on overall investigations, the following recommendations were suggested to renovate the existing machine foundation of 40MVA MG set to regain its strength.

- Removal of plaster from entire walls.
- Cleaning of entire walls with alkaline solution.
- Proper arrangement for collection of spill over oil in foundation.
- Epoxy pressure grouting particularly at foundation bolt location 600X600 mm area and grouting nozzle should be inserted 150 mm c/c after drilling about 450 mm hole of 16mm diameter from both faces. Epoxy materials used for structural repairs should conform to ASTM C881 Type-VI. The repairs of cracks should be done as per procedure recommended by the American Concrete Institute Committee reports ACI 224.1R-93 [8].
- If there are no financial constraints, epoxy pressure grouting could be made at 200mm spacing on entire walls.
- Re-plastering of entire walls and floor with 1:3 cement mortar after grouting.

VII. CONCLUSION

The suggested recommendation for rehabilitation works of this machine foundation were carried by the BHEL authority with the help of a third party. The epoxy grouting on powerless zones were done at an interval of 200 mm center to center and after that it was observed that the issue of vibration of machine foundation get stop absolutely under its running condition. Accordingly, the strengthening of the existing machine foundation was accomplished. Apart from that construction of a new foundation with high grades of concrete and proper arrangements for collection

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of spill over oil, inspection gallery and cable laying duct can likewise be worked after keeping in perspective of future requirements to enhance the production capacity of the factory.

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REFERENCES

- [1] Prabhakar J., Ramanjaneyulu K., Chellapan A., Srinivasan P., Mohammed Firdous M.Z., and Annamali S., "Investigation of a prilling tower – A Case Study", The Indian Concrete Journal, Vol. 77, pp. 1354-1360, October 2003.
- [2] IS: 13311(Part 1) - 1992, Method of Non-destructive Testing of concrete, Ultrasonic Pulse Velocity, Bureau of Indian Standards, New Delhi, 1992.
- [3] BS 1881(Part 203) – 1986, Recommendations for measurement of velocity of ultrasonic pulses in concrete, British Standard, London, 1986.
- [4] Mohammed Firdous M.Z., Chellapan A., Prabhakar J., and Srinivasan P., "Assessing quality of in-situ concrete in turbo generator foundation using UPV measurement", The Indian Concrete Journal, Vol.70, No.2, pp. 41-46, February 2005.
- [5] Shishir Kumar Sahu, "Assessment of concrete quality from Pulse Velocity test", CE and CR, pp. 43-45, August 1998.
- [6] Shiv Kumar, "Bridge inspection and maintenance", Indian Railways Institute of Civil Engineering, pp. 71-73, December 2005.
- [7] ASTM C 597 – 83, Standard test method for pulse velocity through concrete, American Society of Testing and Materials: Annual Book of ASTM Standards, Vol. 4.02, Philadelphia, PA, September 1984.
- [8] ACI 224.1R-93, Cause, evaluation and repair of cracks in concrete structures, American Concrete Institute, Detroit, MI, 1993.

BIOGRAPHY



Dr. Rajesh K. Morchhale is a principal scientist in CSIR-AMPRI, Bhopal. He is actively involved in research, development and consultancy projects in the area of reinforced concrete structures for more than 20 years. His main areas of interest include NDT analysis, durability of concrete structure, building materials testing and characterization. Presently, Dr. Morchhale is working on the development of alternative building materials from industrial wastes and design and development of instant house for disaster management.



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