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REMEDIAL MEASURES FOR THE FOUNDATION OF A DIESEL GENERATOR

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INTRODUCTION

Punjab Government has installed a power house of 2.2 MW capacity at Patran, Punjab. There are two German make Diesel engine generator sets of capacity 1.1 MW each. Both the sets are founded on a combined foundation. During erection, the anchor bolts of one of the engines were painted with bitumen and as soon as the engine was started the anchor bolts of the above engine failed in bond. This resulted in excessive vibrations and the engine had to be stopped. The second engine in which the bolts were not painted and developed good bond is functioning well.

After removing the engine the foundation was examined and a cold joint was suspected at a depth of 800 mm from the top of the foundation. Unfortunately without conducting tests to confirm it, a portion of block 4.49 m × 3.6 m × 0.8 m deep was removed as shown hatched in Fig. 1. The problem was referred to the authors at this stage for checking how significant was the cold joint, if any, in the dynamic behaviour of the foundation and what remedial measures could be adopted to restore the footing to near original characteristics before installing the engine again. The observations taken and remedies suggested are described herein.

SCOPE OF WORK

For ascertaining the cold joint, if any, measurement of accelerations above and below the suspected joints were made under steady state condition of the running of the second engine. Similar measurements were also made after the repair work was completed. The suggested remedial measures include the provision of stitching bolts at appropriate places.

VIBRATION MEASUREMENTS BEFORE REPAIRS

When the second engine (Set No. 2) was running on load, the acceleration measurements on block were taken with the help of Millar acceleration pickup, Brush Amplifier and Brush Ink writing oscillograph. The acceleration was measured at 4 locations, A_1 to A_4 as shown in Fig. 1, below and above the suspected horizontal cold joint at a depth of 800 mm from top of the block in the three directions X, Y, Z perpendicular to each other. Table 1 shows the acceleration amplitudes at these locations in various directions before the repair work was carried out.

From Table 1, it is observed that there is no marked difference between the accelerations below and above the suspected cold joint at any location in any direction. This indicates that the block was infact behaving as one unit and the cold joint suspected was not really 'cold'.

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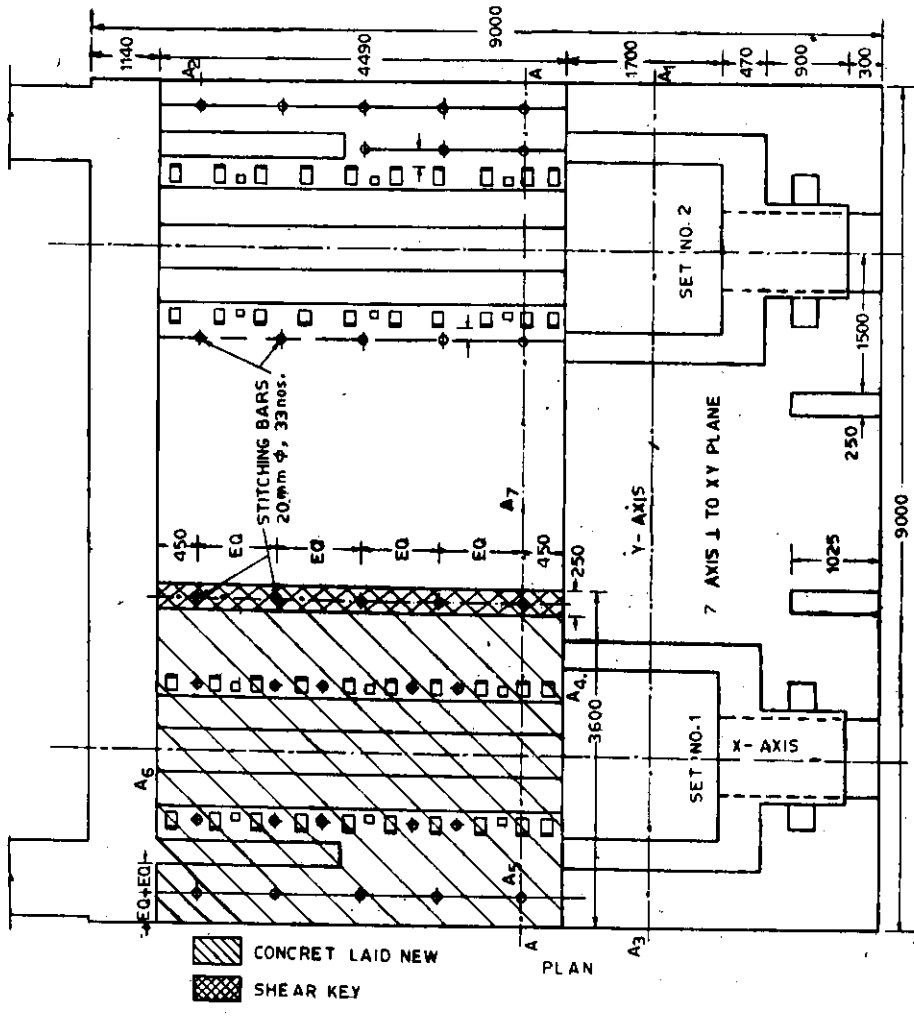

Fig. 1. Plan of generator foundations

REMEDIAL MEASURES

Foundations for machines built as massive blocks are considered as absolutely rigid bodies for computations of frequency and amplitude. Cracks are likely to be caused in the blocks if discontinuity occurs in the concreting sequence or proper compaction is not used. Presence of cracks will change their natural frequency hence the dynamic behaviour. Therefore construction of foundations under such important machines as, power generators, should be carried out with utmost care, since the performance of these machines not only affects the power generation but may lead to severe loss of production in the industry or agriculture. The foundations should be concreted in horizontal lifts continuously without interruption. As a rule the placing of foundation concrete should be mechanized and a uniform distribution concrete aggregates should be assured. When repairing, rebuilding or enlarging machine foundations, care should be taken to ensure perfect bonding of the fresh and old concrete.

TABLE I

VIBRATION MEASUREMENTS BEFORE REPAIRS

(Engine Set 2 was running on load)

Location	Observation No.	Depth below top of the block* mm	Direction	Acceleration, fraction of g
A_1	(i)	750	x	0.0278
		870	x	0.036
	(ii)	750	y	0.0111
		870	y	0.0111
	(iii)	750	z	0.0416
		870	z	0.04
		0	z	0.0333
A_2	(iv)	750	x	0.025
		870	x	0.0278
	(v)	750	y	0.0333
		870	y	0.0278
	(vi)	750	z	0.0555
		870	z	0.0555
		0	z	0.05
A_3	(vii)	750	x	0.0111
		870	x	0.0104
	(viii)	750	y	0.0195
		870	y	0.0175
	(ix)	750	z	0.016
		870	z	0.0139
A_4	(x)	480	z	0.00725
		1500	z	0.007

*Suspected cold joint was at 800mm below top of block.

In the present case, the following remedial measures were suggested:

(a) In order to prevent the absorption of mixing water of fresh concrete by the old concrete, the latter must be saturated with water before placing the new concrete.

(b) The old concrete surface should be carefully brushed and cleaned and a thin layer of fresh cement slurry applied just before the new concrete is poured.

(c) Original steel bars projecting from the old in the new concrete should be thoroughly cleaned of all loose material and oil, if any.

(d) Stitching bars should be added between the new and old concrete as shown in Fig. 2, 3. There are no standard criteria available for such stitching bolts. It was

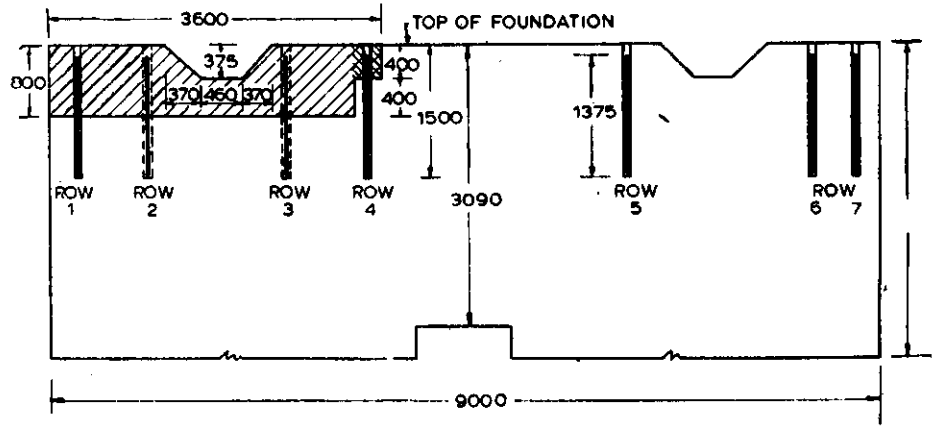

Fig. 2. Section of foundation on AA

considered that in order to keep the new concrete and lower old concrete held together, "the bolts should at least be capable of resisting in *tension* the weight of and static and dynamic load on the new concrete". High strength deformed bars are suggested to develop good bond in small length. According to placement of the engine, 15 stitching bars were provided in the portion shown shaded in Fig. 1 in 3 rows 5 in each row. These are found conservatively sufficient according to the criterion adopted.

(e) A similar scheme of bolts was suggested for the second engine also in view of the suspected cold joint as discussed earlier. Since the second engine was in position and a channel 800mm deep also existed, it permitted only 3 bolts to be provided in one of the rows. Five bolts were also provided in the shear key shown cross hatched in Fig. 1. Thus 33 stitching bolts were suggested in all at locations shown in Fig. 1.

(f) For installing the stitching bars across the joint, a drill hole 75mm in diameter should be made to a depth of 1.5 metres below top of block at the location of each bar. One deformed bar, 20mm diameter and 1.375 metres long, should be placed in each hole as shown in Fig. 2 and 3. The bottom end of the bar was to be split into two halves, spread out and the two ends welded to a 10mm diameter rod piece to avoid the closure of the ends under pulling action on the bar.

(g) The drill hole with the bar in it should be filled with non-shrinking concrete of 1:1½:3 nominal mix, either using expanding cement or ordinary cement mixed with aluminium powder 5% by weight of cement. Maximum size of the coarse aggregate should be limited to 10mm and the slump as 5 cm.

(h) Finally, the foundation bolts of the engine should be cleaned of the bitumen paint thoroughly and reinstalled and embedded in the new concrete as usual.

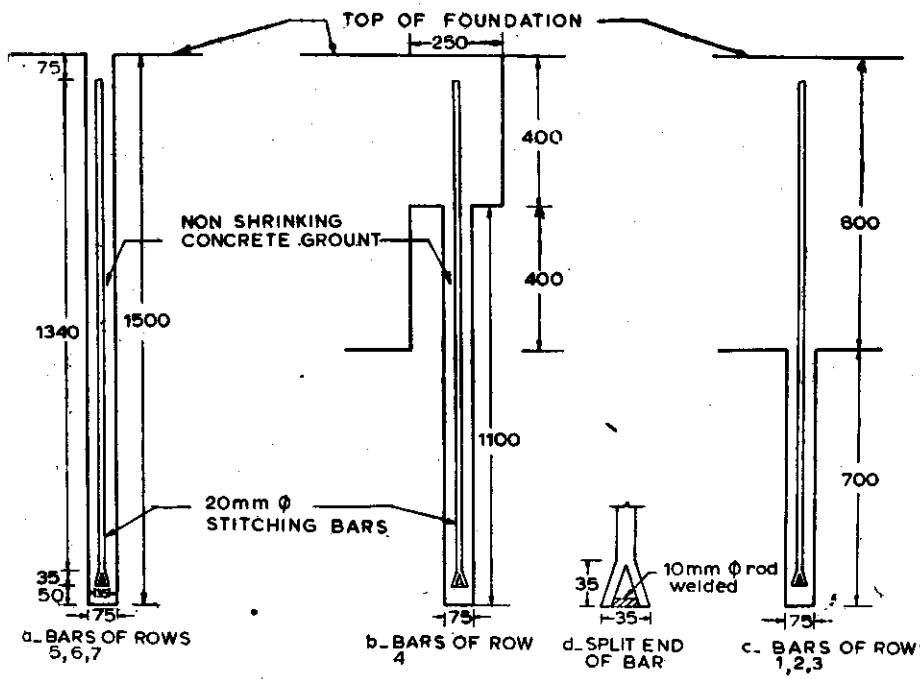

Fig. 3. Sections through typical stitching bars

VIBRATION MEASUREMENT AFTER REPAIRS

After the repair works were completed as suggested above, vibration measurements were again taken at locations A_3 to A_7 (Fig. 1) below and above the joint between old and new concrete in the three mutually perpendicular directions x, y, z. Table 2 shows the acceleration amplitudes at the above location for two cases; first, when engine set No. 2 was running on load, and second, when both the engines were running on load.

From Table 2, it is observed that there is no marked difference between the acceleration below and above the joint between old and new concrete. Also the acceleration level is of the same order of magnitude as when only one engine runs. Thus it is clearly indicated that the whole foundation block is behaving as one unit and the repair works carried out are satisfactory from vibration point of view.

CONCLUSION

In conclusion it may be emphasised that even the normal small vibrations of thoroughly balanced engines can not tolerate any weaknesses or defects in the foundation bolts or the footing block. The casting of concrete should as a rule be continuous without cold joints, the bolts should be unpainted and free from all foreign material and block should have enough reinforcement in the three directions to hold the concrete together even in the event of a crack.

For detecting discontinuity in the concrete, measurements of vibration as indicated in the paper will be simple and useful. The remedial measures as suggested have proved satisfactory as shown by final vibration results.

TABLE 2
VIBRATION MEASUREMENTS AFTER REPAIRS

Location	Observation No.	Depth below top of the block* mm	Direction	Acceleration Fraction of g	Remarks
A_8	(i)	750	x	0.0114	Set two running on load
		870	x	0.0107	
	(ii)	750	y	0.01	
		870	y	0.01	—do—
	(iii)	750	z	0.0128	
		870	z	0.0138	—do—
A_4	(iv)	480	z	0.0114	
		1500	z	0.0114	—do—
A_5	(v)	0	z	0.00715	—do—
A_6	(vi)	300	z	0.0128	—do—
A_7	(vii)	0	z	0.0128	—do—
A_3	(viii)	750	x	0.0128	Sets one and two, running on load
		870	x	0.0107	
	(ix)	750	y	0.0143	
		870	y	0.0135	—do—
	(x)	750	z	0.0143	
		870	z	0.0143	—do—
A_5	(xi)	0	z	0.0185	—do—
A_6	(xii)	300	z	0.0164	—do—
A_7	(xiii)	0	z	0.0128	—do—

*Suspected cold joint was at 800mm below top of block.

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