Restoration of hammer foundations in forging industry — a case study

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Restoration of damages in machine foundations is one of the most challenging assignments in structural restoration. It is usually so on account of complex nature of forces acting on the foundation, lack of accessibility, time constraint in shutdown, lack of maintenance of mechanical components such as bearings and spillage of oils, lubricants and other chemicals which are harmful to concrete. The case study reported, gives an analysis of the problem, development of scheme of repairs and execution and post repair performance.

The case study reported here pertains to a set of hammer foundations in a forging industry. There were three hammer foundations laid in a row. First hammer was of 500 kg capacity, second was of 1000 kg capacity. The third block was of 1500 kg capacity. A hammer foundation typically has a frame through which the hammer of that weight falls through a design height, which is about 2 m, freely on the anvil. The entire assembly of the frame, anvil, etc is supported on a block of reinforced concrete (RC). Directly under the machine, either wooden sleepers or neoprene or other synthetic rubber pads are placed to dampen the blows. To ensure the working level (above finished floor level) of about 600 to 750 mm, the foundation is always laid below the ground. In order to avoid transmission of vibration to adjacent machines, floors and even to the enclosing structure, a clear gap is maintained between walls of the foundation block and the surrounding earth. This is achieved by constructing an enclosure of RC/ brick masonry walls around the foundation with a gap of about 500 mm.

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Problems

Of the three foundations, two foundations, namely, the 500-kg and 1500-kg hammer foundations developed a tilt. This resulted in increased thickness of forging jobs on one side, consequently adding to rejection. *Figs* 1 and 2 show the plan and section of a foundation with the tilt. The settlement in 500-kg hammer foundation was uniform and about 100 mm. That in the case of the 1500-kg hammer was 50 to 150 mm tilting towards one side.

In case of 1500-kg hammer, the problem of tilt was first noticed nearly two and half years after putting the foundation to use. Thereafter for six months the tilt went on increasing. The lubricant used as flux for first two and half years was LD oil. The detection of problem coincided with the time of changing from LD oil to a special flux supplied by a manufacturer, which was environment and human friendly, as claimed.

Foundation of 1000-kg hammer showed a problem of different type. It developed two right-angle cracks below

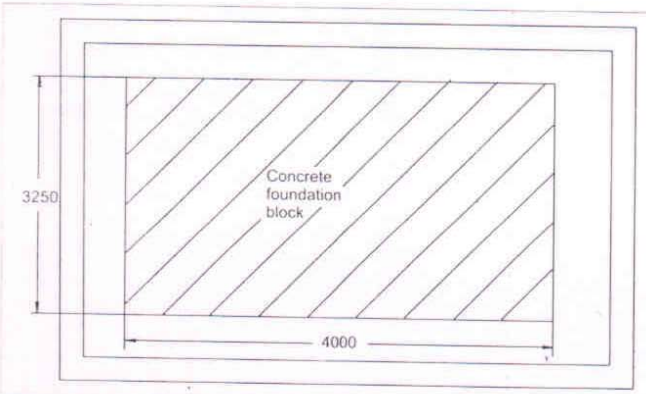

Fig 1 Plan of 1500-kg hammer foundation

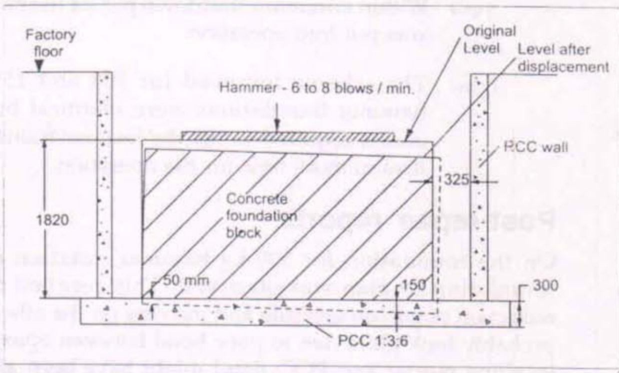

Fig 2 Section though 1500-kg hammer foundation

the anvil. The cracks were noticed after removing 200-mm deep concrete below the anvil. The cracks were about 1 to 1.5 mm wide.

Investigation of the tilt

Samples of plain cement concrete (PCC) having proportion 1:3:6 below the foundation, sample of the flux, samples of concrete in cracked portion of 1000-kg foundation, sample of mud as well as water accumulated in the gap between foundation blocks and surrounding RC wall (this is the mixture of all the waste accumulated and mixed with oil and flux), were extracted and tested. The results in brief are highlighted below.

(i) Flux solution 20 percent showed a pH of 8 to 8.5, indicating alkaline nature and very unlikely to have affected the concrete. Also, if it had any tendency to affect and weather concrete it would have happened to concrete foundation top also, which was not the case.

(ii) Sample of concrete from cracked portion showed fracture through matrix and not along the interface of cement paste and aggregates.

(iii) Accumulated water in the gap was neutral.

(iv) Mud in the gap was mainly oily and non acidic.

(v) The sample of PCC 1:3:6 below the foundation was extracted from the gap between block and RC wall. It could be very easily extracted with a pickaxe. The PCC was weathered. Fracture was along the face of the aggregates.

Low quality concrete, probably poorly-cured, was sandwiched between the hard rock strata below and the foundation mass with a continuous hammer load and impact. The oil used in the earlier years may also have affected the interfacial bond between aggregates and cement paste and weakened it.

Repair scheme

Weakened PCC layer below the foundation had to be removed and strengthened. A fresh concrete layer was to be laid. To do this, foundation block had to be lifted up. The possibility of breaking the entire foundation was considered and rejected looking into the economics and the time factor. Details of repairs scheme are shown in *Fig* 3.

(i) Frame and anvil of the hammer was already dismantled. Top edge reinforcement of the foundation block was exposed and wire ropes turned through the reinforcement at top. A structural steel member was passed through these wire rope slings. Simple hydraulic jacks were used below each end of the projecting steel member. Because of the congested layout and roof framing, it was impossible to provide any other lifting arrangement such as crane. Weight of the block for 1500-kg hammer foundation was 60 tonnes. The weight for 500-kg foundation was 25 tonnes. It was noticed that the block itself was in sound condition without any cracks.

(ii) Once adequate working space was created below the foundation, hot water jet with detergent was used to clean the PCC bed below concrete block. This was de-watered. The process was repeated two to three times till all the oil and detergent was removed. Old PCC was completely removed.

(iii) PCC having proportion 1:1:2 was laid on the cleaned concrete surface. This PCC was admixed with 5 percent microsilica by weight of cement and or superplasticiser, 2 percent by weight of cement. Both these addition were made to make the PCC impermeable and gain strength very quickly and reduce curing time to just about four to five days. PCC was laid level and finished rough. Surface of PCC was dried with hot air blowers.

(iv) The soffit of the foundation was very uneven and oily. This surface was cleaned with steaming water and detergent along the PCC cleaning. The soffit was dried with hot air blowers. It was repaired with ready to use epoxy mortar after applying an epoxy primer. But this was not very satisfactory as the application was against gravity and working space was limited.

(v) It was essential to ensure complete bearing of the block on the newly laid PCC. For this purpose epoxy ponding, etc as discussed below was resorted to. After four days of laying PCC and repairing soffit, the block was lowered by releasing the jacks slowly. The lowering continued till the gap left between PCC and block soffit was 8 to 10 mm. Beforehand, a ponding bund was done on PCC. Then self-levelling epoxy mortar was poured from six funnels and pipes simultaneously into the gap. After that the final lowering was done. At this time the foundation was held on all jacks and levelled. This was achieved in the 45 minutes

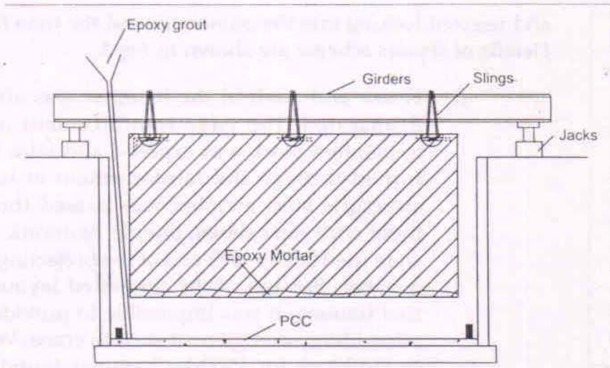

Fig 3 Repair scheme adopted for 500 and 1500-kg hammer foundation

time available for epoxy setting. Foundation block was lowered on levelled epoxy mortar bed in order to have full bearing contact and to expel excess epoxy mortar below. Poor accessibility prevented positioning the block level and then grouting the gap.

(vi) After 24 hours, anvil and frame were fixed on the foundation block, again using self-levelling epoxy. Rubber pads below anvil were also fixed with epoxy bonding agent.

(vii) Within minimum shutdown period the hammer was put into operation.

(viii) The scheme followed for 500 and 1500-kg hammer foundations were identical but the efforts required to lift the heavier foundation lead to more time for the operation.

Post-repair reports

On the foundation for 500-kg hammer, rotation of the foundation in plan was observed. This resulted in the reduction of gap on one side and increase on the other. This probably took place due to poor bond between epoxy self-levelling mortar and PCC. Bond might have been affected due to moisture entrapment. A moisture compatible mortar would have perhaps been ideally suitable. There was no settlement at all. The rotation in plan was observed after about one month. Finally, to prevent further rotation, PCC of about 300 mm was laid in the lower portion of the gap between the block and RC wall. No adverse performance has been reported after one and half years of the repairs.

On the 1500-kg hammer foundation no problem has been reported.

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