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DAMAGE TO TWO RCC BRIDGES DURING DECEMBER 31, 1984 CACHAR EARTHQUAKE, NORTHEAST INDIA

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ABSTRA

Damage to two RCC Bridges within 10 km focal distance during the December 31, 1984 Sonaimukh earthquake of M_B 5.6, in Cachar region of Northeast India, has been described. Sonaimukh bridge has been damaged more compared to Rukni bridge inspite of its being at larger focal distance. The greater damage to Sonaimukh bridge is due to its transverse orientation with respect to the principal direction of ground motion. The retaining walls have also contributed to the reduction in damage for the Rukni bridge. The detailed observations indicate that the two bridges can be repaired.

Key Words : Cachar Earthquake, Earthquake Damage, Bridges, Roller Bearings, Freely Supported Spans, Retaining Walls, Orientation of Bridge & Ground Motion

INTRODUCTION

An earthquake of magnitude 5.6 occurred in the Cachar region of northeast India on December 31, 1984 in early morning such that its date changes to December 30, 1984 in UTC. The initial media reports put it in Bangladesh-India border region whereas the damage survey, after shock recording and improved location by India Meteorological Department (IMD) confirmed that the event was very much in the Indian territory (Srivastava, 1985). The earthquake parameters as reported by IMD, in Preliminary Determination of Epicentres and monthly listing by U.S. Geological Survey (USGS) are given in table 1. These locations differ by less than 10 km distance which is understandable as the IMD location

TABLE 1 : Parameters of December 30, 1984 Cachar Earthquake, North East India.

Determined by	Origin Time UTC hr	mn	sec	Epicentre lat N°	long E°	Focal depth km	magnitude
IMD	23	33	35.7	24.70	92.85	05	5.4 ML
USGS (PDP)	23	33	39.1	24.60	92.84	33	5.6 M_B
USGS (Mon. Listing)	23	33	37.7	24.64	92.89	23	5.6 M_B

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has used very near field data as well. A detailed damage survey covering all aspects and short term aftershock recording has been conducted by the author. A paper on building damage has been published (Agrawal,1985) and others will be published in due course to complete the study. This paper includes only the observations of damage to two, somewhat similar, well designed and well constructed RCC bridges which were within about 10km focal distance. The damage at such short epicentral distance is seen dominantly related to the direction of ground motion and the energy radiation pattern rather than the epicentral distance as is ordinarily considered while accounting earthquake hazard in structural design. The relative orientation of the bridges with respect to the ground motion direction accounts for more damage to one of the two bridges.

ABOUT THE AREA

A map of the earthquake affected area is given in Figure 1. The location of epicentre for December 31, 1984 earthquake, the locations of two RCC bridges under reference and other important locations are marked. The area had been subjected to severe ground shaking during the Cachar earthquake of January 10, 1869 and Assam earthquake of August 15, 1950. The elder people in the area could clearly explain the difference in shaking during the 1950 Assam earthquake and the present one. According to them, and rightly so, the present shaking was more comparable to what they had heard about 1869 Cachar earthquake The complex meandering of rivers and a number of abandoned sections of river courses clearly show the activity of the region. Both the northeast-southwest trend parallel to Arakan Yoma and northwest-southeast trend, which is perhaps younger, meet in this region. Generally moderate size earthquakes have frequently occurred in the area but mostly in the northeast quadrant with respect to the present event. Cyclonic storms entering from the Bay of Bengal are the other natural disaster and are more frequently visiting the area.

The top soil is unconsolidated and coarse grained; there are thin layers of fine and coarse grained soil at small depths and has shallow water table. All these factors make very poor foundation conditions for most structures. The land is, however, very fertile and most of it is under cultivation.

SONAIMUKH BRIDGE

A 100 m long and 4.8 m wide RCC bridge supported on six piers, 12 or 8.5 m tall on wells 12.8 or 16.3 m tall respectively, across the river Sonai at Sonaimukh was shaken by the earthquake and its general view is

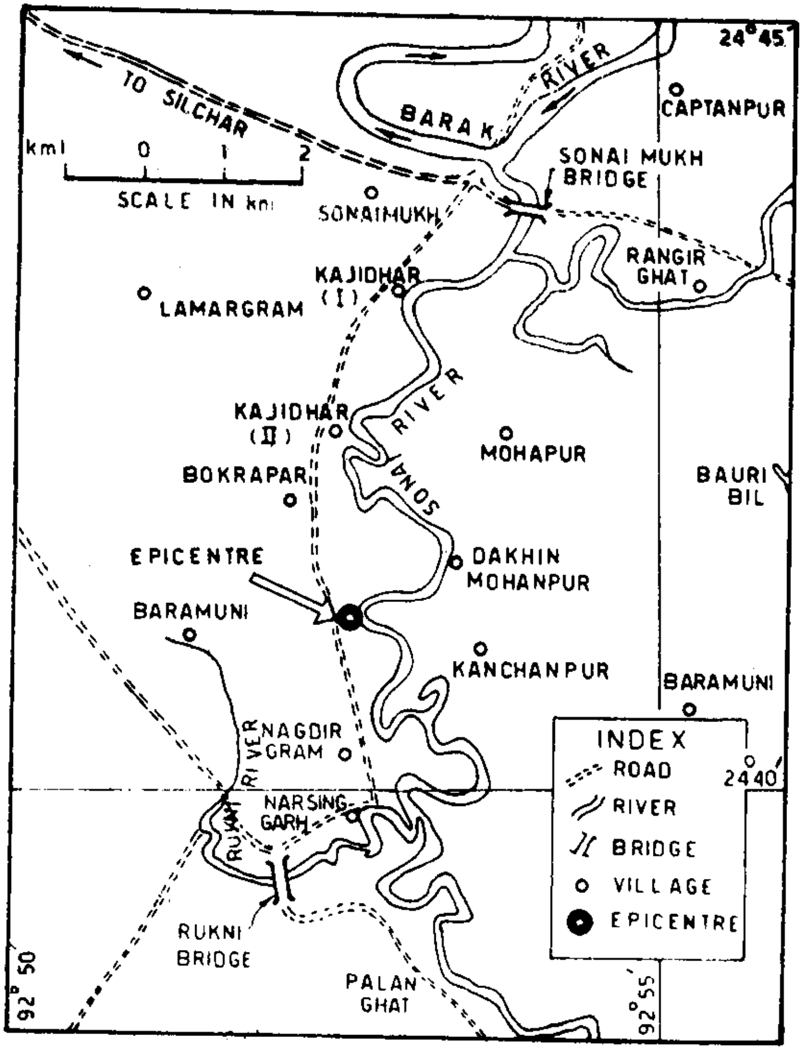


Fig. 1 The map of the area showing location of epicentre of Dec. 31, 1984 earthquake, the two damaged RCC bridges and the villages

shown in the Figure 2. The bridge is oriented N 80°W. It consists of three equal, identical and supported; and two equal free spans about little less than half the length of supported spans. The supported spans rest on rocker and roller bearings. The longitudinal and transverse sections of the bridges are shown in the Figure 3 (a) & (b) respectively. The height of the road above the lowest flood level is 15.6 m. The Sonaimukh end of the bridge directly spans the suitably cut river bank and the other end has about 10 m long timber bridge for landing the river bank.

The bridge has been damaged to the extent that it had to be closed for traffic. The damage details are presented here with the help of photographs. The Figure 4 shows the damage to the well cap of the fourth pier from the Sonaimukh side. It is possible that the well has not been damaged. However, the relative displacement and rubbing between well cap and well have also been evidenced by chipping of concrete at their contact. This has been caused due to excessive transverse shaking of the deck and resulting eccentric loads. The plan of the deck is no longer straight. The span joints have opened up but not equally along their length as is seen in the Figure 5. The larger opening of the successive joints is on opposite margins. However, cummulative joint opening is more on the north. At both the ends of the bridge, the deck has moved down relative to ground or timber bridge (Figure 6) by 15 cm and 30 cm, respectively. This is due to loss in the deck height at the roller ends where it has been dislodged from them. The relative lateral displacement of 45 cm between RCC and timber deck is seen in the Figure 7. Although the permanent residual lateral displacement can be accounted for by the displacement of RCC deck itself but the timber section had also vibrated causing snapping of steel bar and flat ties fixing timber beams and columns as seen in the Figure 8.

The spacing between the pair of edges, facing each other, of the supported spans has been widened at the road level and narrowed down at the bottom due to loss of height of the other end of one of the spans due to damage to rollers. The freely supported spans have just escaped being dropped from their supports on fixed spans. The widening of one of the gaps between free and fixed spans at road level is seen in the Figure 9 The Figure 10 shows the damage to rollers and drop in height of this end. Another photograph of the same end from back side, in the Figure 11 shows even the chipping of concerete below roller plates. The Figure 12 is close up of only one end to show clearly the lateral displacement of deck by about 45 cm.

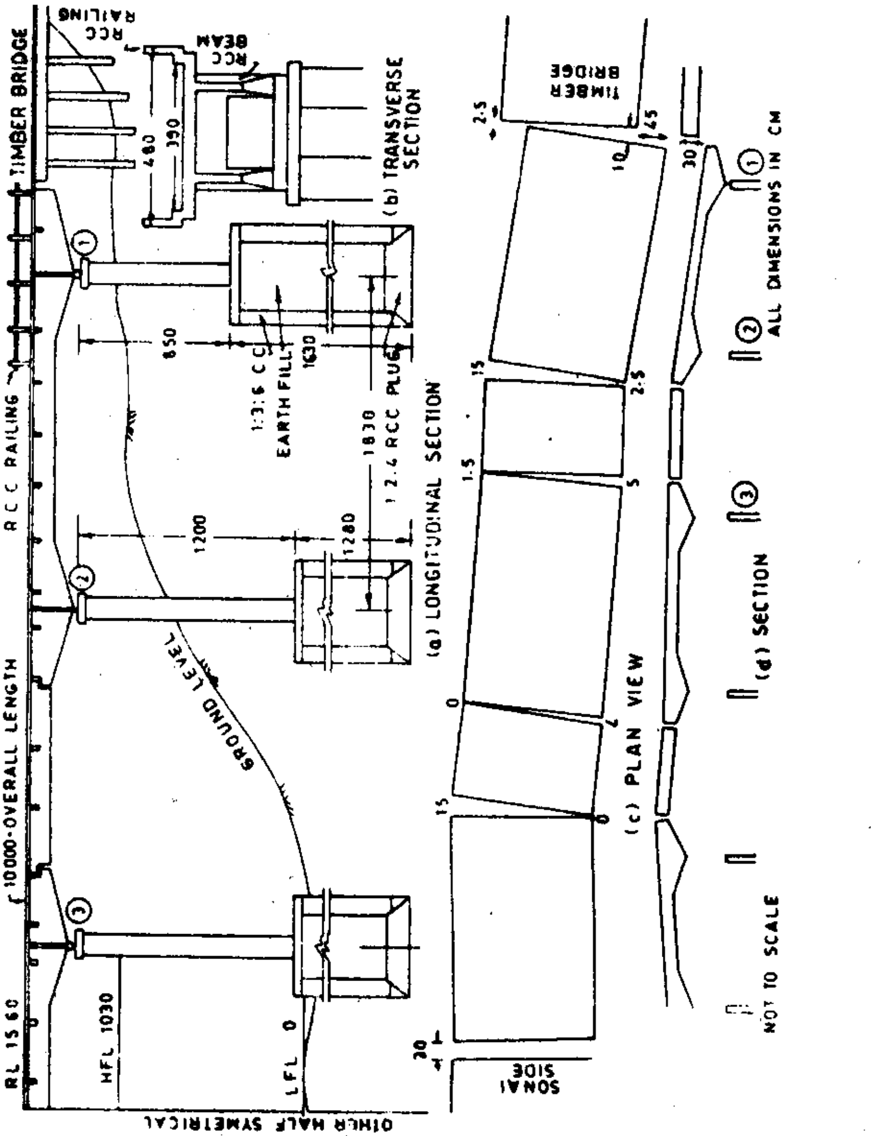


Fig 3. ***Details of Sonaimukh bridge (a) and (b) Longitudinal and transverse sections, (c) plan view of the deck and (d) section of deck after damage***

The plan view of the bridge at deck level after the earthquake is schematically shown in the Figure 3 (c). A section of the bridge deck is also given in the Figure 3 (d). The relative displacements in cm between adjacent spans, abutment and span, and spans and piers have been marked. It can easily be inferred that the direction of ground motion was largely transverse to the bridge. The bridge spans have hardly moved in longitudinal direction whereas the lateral displacement of as much as 45 cm has taken place between the pier (1) and the deck. The resulting curvature of the deck alignment shows that if the ground vibration was only little larger in amplitude or had it continued for a longer duration the central portion of deck would have fallen towards north of the bridge piers. This is in confirmity to general observation for fall of east-west oriented walls/objects towards north. The principal direction of the ground motion has been largely N-S.

RUKNI BRIDGE

The Rukni bridge with identical design as Sonaimukh bridge was only about 65 m long. The bridge is roughly oriented N-S, consists of two fixed spans on four piers and only one central freely supported span as shown in the Figure 13. The height of the road above the lowest flood level was not measured but is estimated to be about 3 to 4 m less than that of Sonaimukh bridge. Another distinctive feature of this bridge was the construction of retaining walls at both the abutments as is seen in the Figure 14 and 15. It could not be confirmed if these were specially constructed for the present bridge or pre-existed for an earlier suspension bridge at the same location.

There were clear evidences that the bridge deck was moved dominently in longitudinal direction, more towards Sonaimukh side, i.e., towards north. The two junctions between free and fixed spans showed evidence of their hammering against each other during vibration and a small opening (2 cm) only at one of the two junctions, which was towards west side, had occurred The Figures 14 and 15 show the opening and closing of the gaps between retaining walls and deck at the two ends, respectively, which is a clear evidence of northerly movement of the deck. The chipping of concrete at the contact of retaining wall and the deck was seen only for retaining wall in the Figure 15. The retaining wall in the Figure 14 has moved towards north since the road behind and along it had slumped whereas the other one in the Figure 15 was, at its top, pushed into the ground.

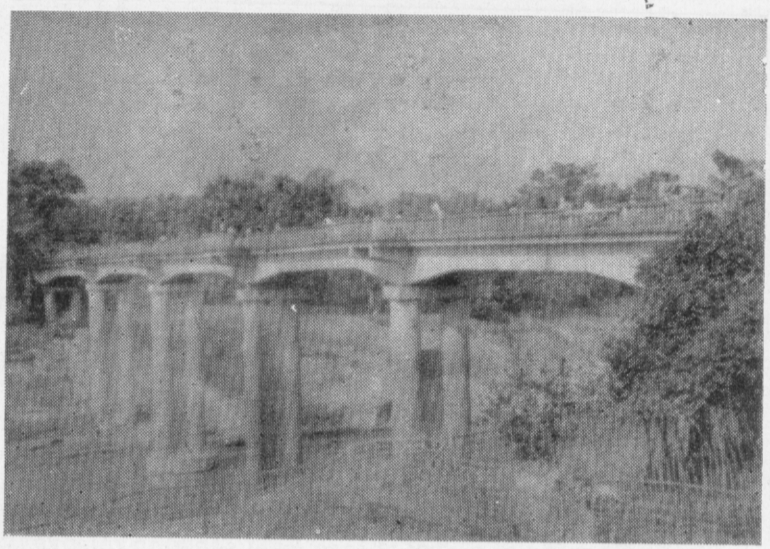


Fig. 2. General view of the Sonaimukh RCC bridge which was damaged by Dec. 31, 1984 earthquake, Sonaimukh town is beyond left end.

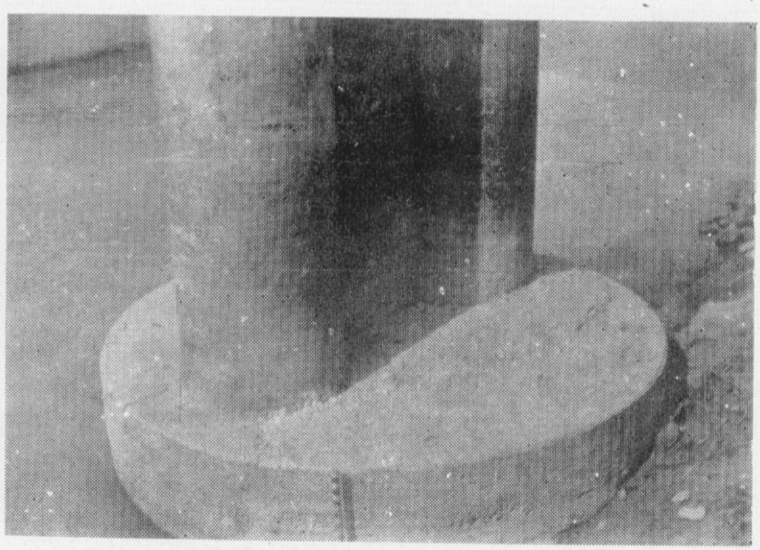


Fig. 4. Damage to the well cap below the second pier from right in the Figure 2.

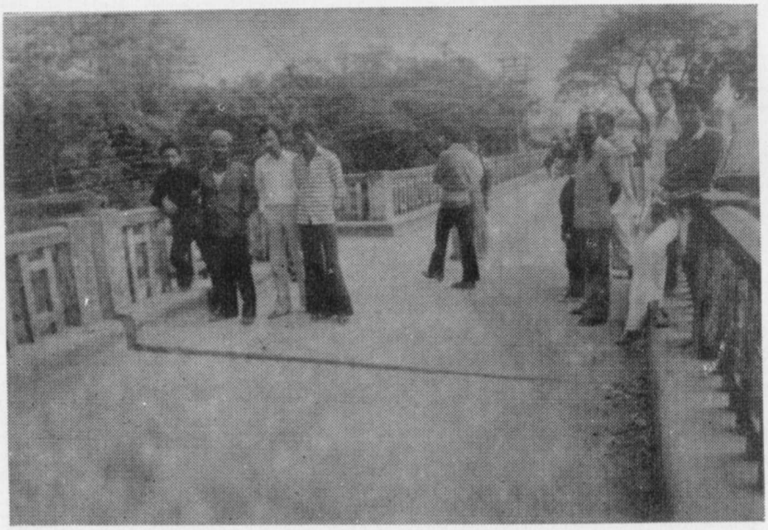


Fig. 5. Opening of a joint at road level showing relative lateral displacement of deck spans.

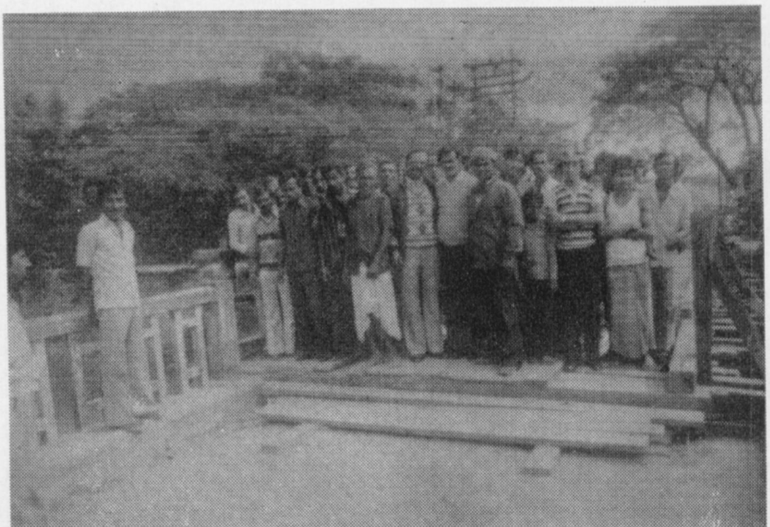


Fig. 6. 30 cm relative vertical displacement of the RCC deck with respect to timber bridge.

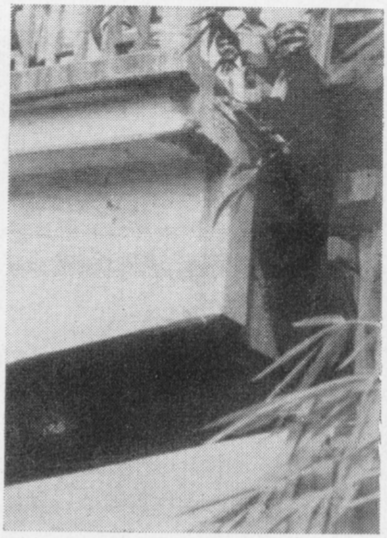


Fig. 7 45 cm lateral displacement of the RCC deck with respect to timber bridge.

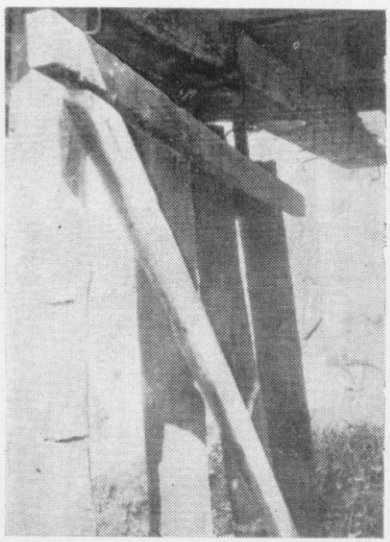
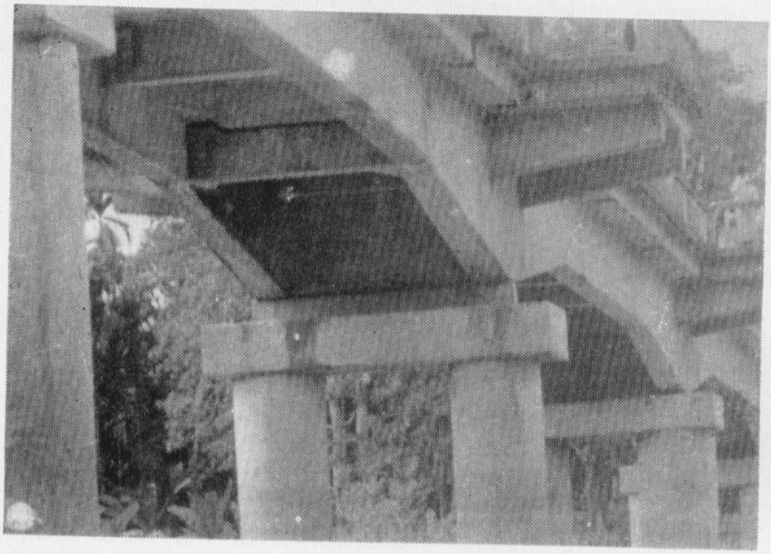


Fig. 8. Dislodging of timber bridge's vertical support, nearest to RCC deck, from their position by about 60 cm in the direction longitudinal to the bridge.



Fig, 9. Opening anu closing of deck joint at ro1d and base level respectively due to relative down ward movement of the other end of the span.

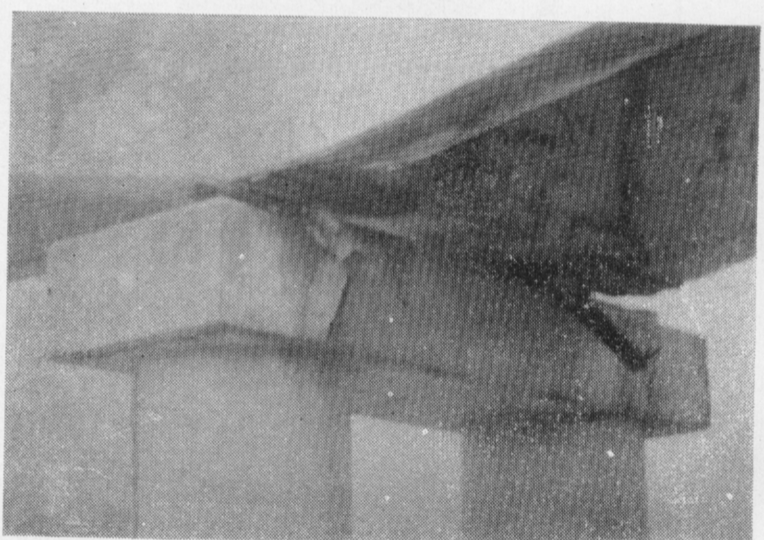


Fig. 10. Lowering of one end, of the span, first from right but not seen in the Figure 2, by 30 cm due to its being dislodged from the roller bearings.

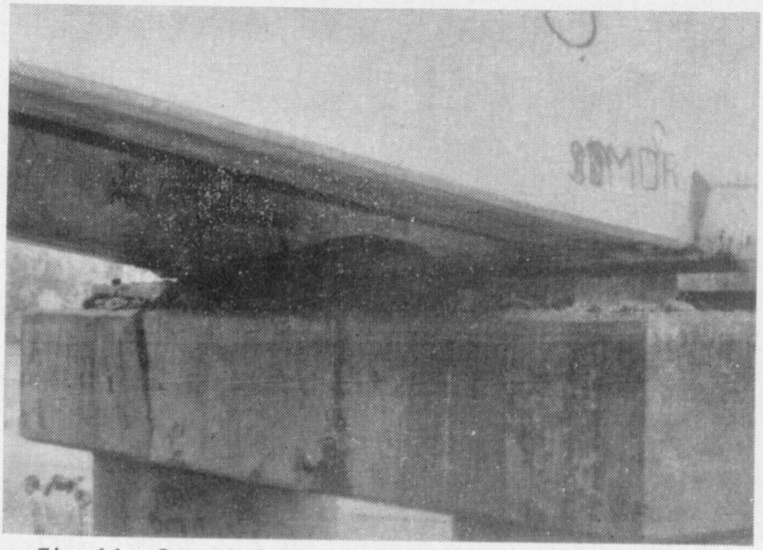


Fig. 11. Same pier as in the Figure 10 but its view from the back side

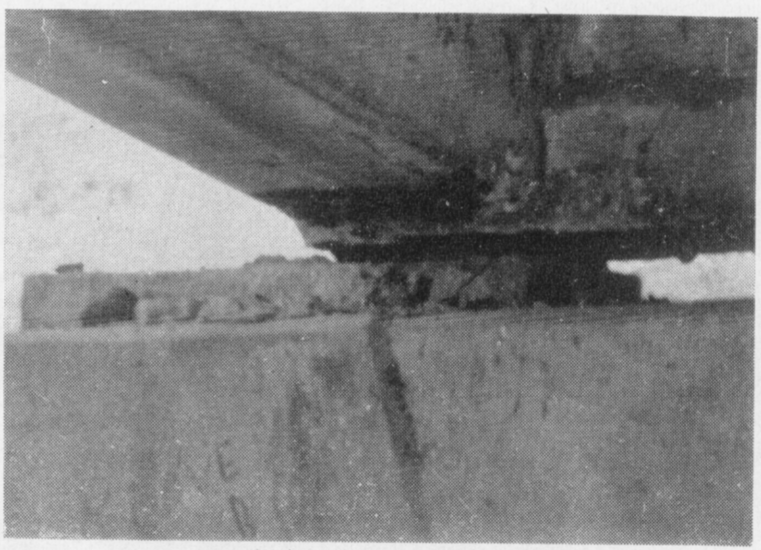


Fig. 12. Close up of the left end in the Figure 11 to show about 45cm relative horizontal displacement of deck with respect to pier.

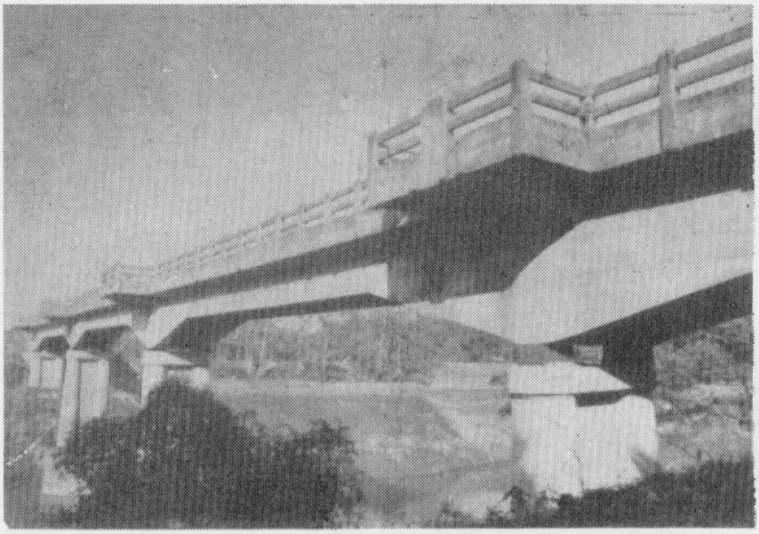


Fig. 13 General view of the Rukni RCC bridge from Sonaimukh end.

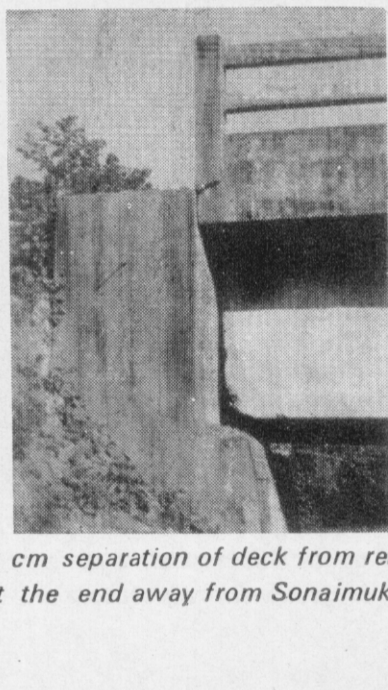


Fig. 14. 5 cm separation of deck from retaining wall at the end away from Sonaimukh.

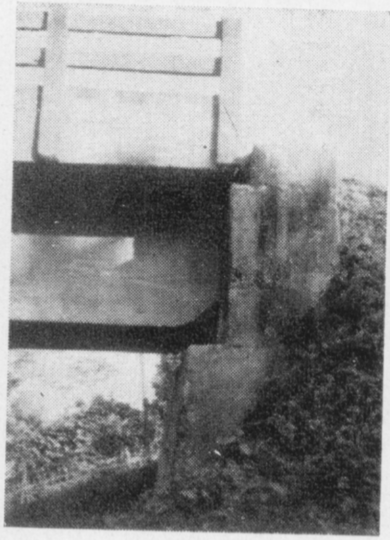


Fig. 15. Hitting and closing of joint between deck and retaining wall at road level at the end close to Sonaimukh.

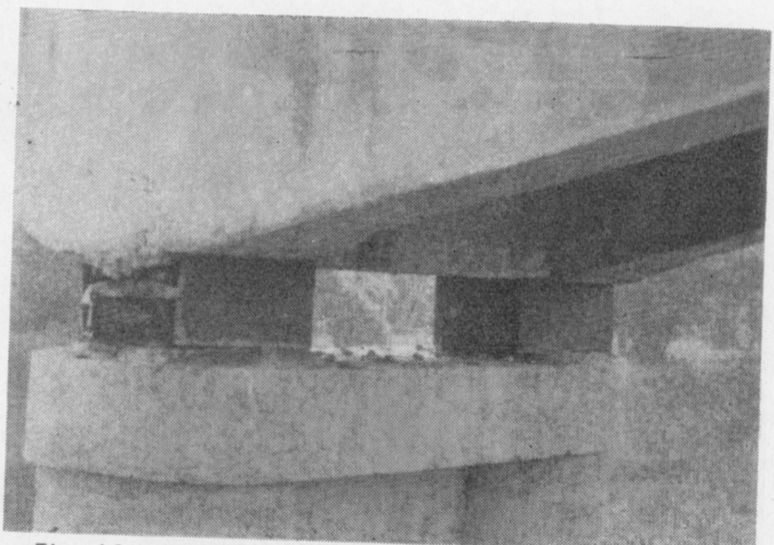


Fig. 16. 16.5cm laterlal (forward) displacemen ot the deck with respect to pier (first pier from left in Figure13)

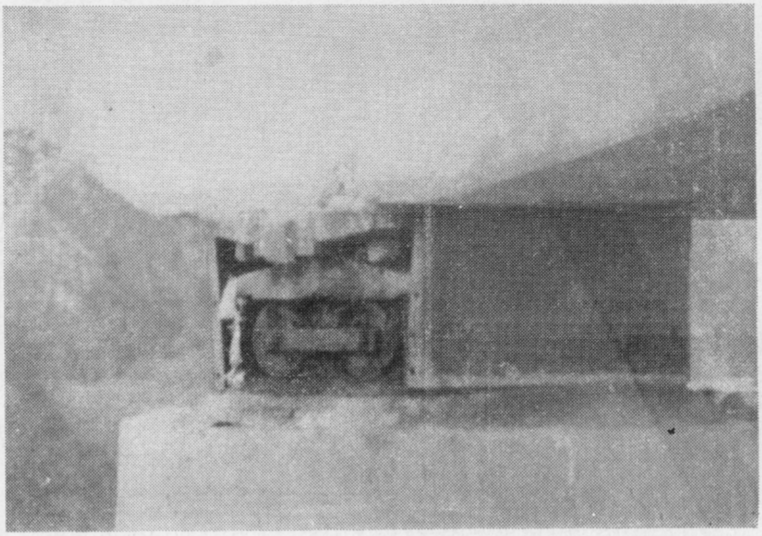


Fig. 17. Close up of roller bearing on left in Figure 16.

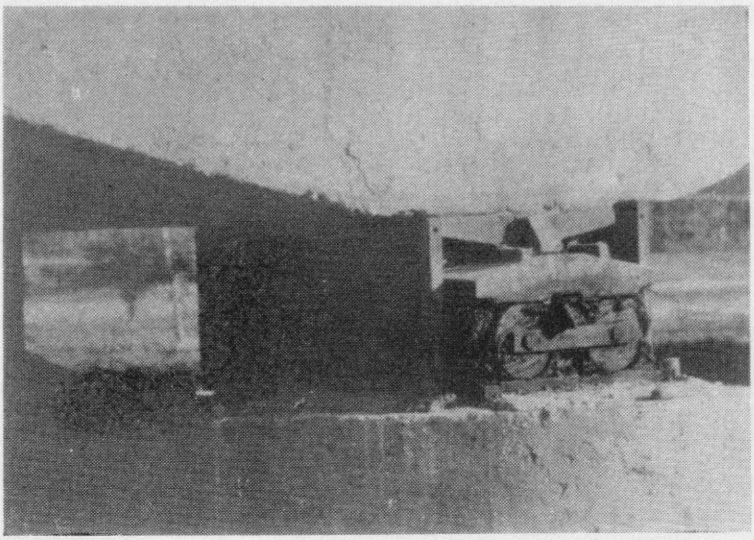


Fig 18. Close up of roller bearing on right in Figure 16.

The lateral displacement of deck with respect to pier at roller bearing end on both the fixed spans was seen. The Figure 16 shows the damage to two roller bearings on the same pier. The chipping of concrete had also occurred,and right and left bearings in the Figure 16 are given in the Figures 17 and 18, respectively. The relative lateral displacement of about 5 cm of deck towards west is clearly seen in these pictures. For a number of days after the earthquake and damage to the bridge it was continued to be fully used for traffic. However, it was recommended not to be used for very heavy traffic until the damaged bearings were replaced with the new ones.

DISCUSSION

The damage to Sonaimukh RCC bridge as compared to Rukni bridge has been more although the hypocentral distance from the location of the later is perhaps less. This can be explained by the principal direction of ground motion, which was N-S, and the relative orientation of the two bridges. Also the energy radiation does not appear to be symmetrical. The area to the north of epicentre in the vicinity of village Kajidhar(I) has experienced greater damage. Some of the small aftershocks near the mainshock's epicentre, whose sounds could be heard loudest in villages Dhakhin Mohanpur and Bokrapar, were felt at Sonaimukh and not at Narsing Garh.

The damage to these two bridges can be repaired. The broken bearings have to be replaced by new ones by suitably lifting the deck spans and restoring them to their original positions. In seismic areas where excessive displacements are possible to be experienced, the use of freely supported deck spans should be avoided. Limiting the total deck span's motion at the bearings may be required not to allow them to easily fall from the respective supports. Also providing suitable guides to restrict the lateral displacement of the deck relative to piers should also be considered.

The provision of well constructed retaining walls for the Rukni bridge has definitely contributed to the reduction in the damage to this bridge. If the orientation of a bridge is such that large longitudinal motion is likely to be experienced by it then construction of retaining walls will improve its performance during severe shaking and even in case where the bridge design does not require construction of retaining walls those are recommended in soft rock areas.

CONCLUSIONS

1. The Sonaimukh bridge has been damaged more compared to Rukni bridge inspite of its larger distance, because of its being oriented transverse to the principal direction of ground motion.

2. Use of freely supported spans may be avoided in seismic areas as those may easily fall off due to out of phase motion of their supports.

3. Provisions to limit the deck displacement both in transverse and longitudinal directions will be a good practice to be adopted in seismic areas.

4. If large longitudinal displacement are likely, construction of retaining wall even if not otherwise required will improve the bridge performance, in soft rock areas, during earthquakes.

5. The two referred bridges, which suffered damage during the earthquake can be repaired.

ACKNOWLEDGEMENTS

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