Kiwi technology to protect Indian hospital from earthquakes

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ABSTRACT: The earthquake in Gujarat, India, in January 2001 destroyed the Bhuj District Hospital, killing almost all its 178 patients. The Indian Prime Minister's Office has decided to base-isolate the replacement hospital, following an offer of design expertise from the New Zealand Government. The replacement 300-bed hospital is being fast-tracked to have it open on the second anniversary of the earthquake. Details of the earthquake are well documented by others elsewhere. This paper describes the course of events that led up to base-isolation being adopted, and the role that the New Zealand Earthquake Technology Business Cluster played in assisting the Indian designers to meet their requirements. It is understood that this is the first significant building to be base-isolated for seismic reasons in India. The technology appears to be an ideal match for the current design and construction conditions in India.

1 THE 2001 GUJARAT EARTHQUAKE

This magnitude 7.7 event occurred on the morning of India's Republic Day, 26 January 2001. First reports described devastation of the old walled-city part of Bhuj, principal city of the Kutch region of Gujarat. While the earthquake occurred on a blind thrust-fault a considerable distance from the nearest tectonic plate boundary, the region is no stranger to earthquakes, and is zoned with the highest category of risk in the National Building Code of India. The epicentre of the earthquake appears to have been some tens of kilometres to the North-East of Bhuj. It is understood that no surface faulting associated with this particular earthquake has been identified, although there is plenty of evidence of liquefaction and slumping.

While the total death toll may never be known, best estimates suggest that at least 20,100 died that morning. It was significant that the earthquake occurred on a public holiday. For example, it was reported that many of the staff at the hospital were not in the building because they were either attending flag-raising ceremonies or observing the national holiday.

2 A SERIES OF COINCIDENCES

At the time of the earthquake, the author was Earthquake Science Specialist for an Asian Disaster Preparedness Center (Bangkok) team providing technical assistance to the Indian Government for the Asian Development Bank. This project (Strengthening of Disaster Management and Mitigation at the State Level) is assisting the northern Indian State Governments of Uttar Pradesh and Uttaranchal.

In the days after the Gujarat earthquake, the New Zealand Earthquake Technology Business Cluster considered whether the cluster could offer technology assistance to India. At the same time, the New Zealand Minister of Foreign Affairs (Phil Goff) was planning an official visit to

India in March, and was expressing interest in visiting the earthquake-devastated area. The Ministry of Foreign Affairs approached the cluster as to whether a gift of earthquake technology assistance to mark the Minister's visit would be appropriate. The management committee of the cluster agreed. The author was then asked to divert from his planned field visit to northern India to assist the joint World Bank/Asian Development Bank/USAID assessment team visiting Gujarat two weeks after the earthquake.

At this point, it was known that the public District Hospital at Bhuj had collapsed, and in concept it seemed that any re-building of it would be a likely candidate for assistance from New Zealand in the form of base-isolation. It was resolved that the author would make inquiries during the assessment mission to identify the agency responsible for the hospital re-building.

Subsequently, the author visited Ahmedabad, Gandhinagar (Gujarat's state capital near Ahmedabad) and Bhuj during the assessment mission. Information received from senior officials of the Health and Roads & Building departments of Gujarat State indicated that a new hospital would be built of a size similar to that which had been destroyed. Specific inquiries as to whether base-isolation would be considered a viable option for a replacement hospital confirmed that little was known of the concept.

The author subsequently discussed the contacts made with New Zealand's Deputy High Commissioner in New Delhi (Haike Manning), and recommended to the New Zealand Ministry of Foreign Affairs and Trade that the replacement Bhuj District Hospital was indeed a possible target for New Zealand's gift.

Foreign Affairs Minister Phil Goff subsequently made his visit to Bhuj and announced New Zealand's gift of earthquake technology assistance.

Devastation in Bhuj from the January 2001 earthquake

3 IDENTIFYING THE HOSPITAL DESIGNERS

By late April, the High Commission had been unable to identify which government agency was assuming responsibility for the hospital reconstruction and so it was arranged that the author would travel to Gujarat with the Deputy High Commissioner and progress the search. Bad weather led to missed connections, and the Deputy High Commissioner made the visit alone. Information gained from this visit lead to the discovery that the Indian Prime Minister's office had assumed responsibility for the replacement hospital which was to be funded from donations to the Prime Minister's Relief Fund. The High Commission was then able to make direct contact with the Prime Minister's office where the idea of introducing base isolation to the Bhuj Hospital was referred to the recently-appointed private sector architects E. F. N. Ribeiro Associates, New Delhi.

The timing of tracking down the design team enabled the author to visit the architects on his next visit to New Delhi. The benefits of base isolation and the offer of assistance to design this aspect were explained to the project architect Uday Pattanayak and the structural engineer Kamal Sabharwal.

At this point it was discovered that the hospital was to be approximately 30,000 m^2 – about ten times the area previous inquiries had indicated. Moreover, the project had acquired added importance in that it was to bypass normal state government systems and be designed and built by the private sector in time to meet a commitment to the public that a 300-bed hospital would be open on the second anniversary of the earthquake. A further public commitment had been made to make this hospital a teaching hospital. Current Indian norms require teaching hospitals to have a minimum of 500 beds.

At the conclusion of the presentation on base isolation, after a ball-park estimate of the additional costs, it was apparent that base isolation might be exactly the 'something special' that the Prime Minister's Office was keen to be part of the project. Like all modern hospitals, the cost of the structure is small compared with the cost of the fit-out and specialist equipment required.

4 DEVELOPING THE CONCEPT

As a result of the interest shown by the hospital designers, the New Zealand Ministry of Foreign Affairs and Trade discussed with the Earthquake Technology Business Cluster how to implement the assistance offer. The fast-track nature of the project meant that an early decision was needed to be taken by the designers if base isolation were to be included. It was clear that the best way to advance the process was for the project architect and structural engineer to visit Wellington, see the many examples of base isolation there, and work up a conceptual design sufficient for indicative pricing of the isolators while there.

Under ordinary circumstances, the Ministry would require competitive tendering of the consulting services for this assistance. The Earthquake Technology Cluster's offer to arrange a collaborative team of members to undertake the assistance was accepted. The cluster Chairman, Dr David Hopkins, and the author drew up a scope of works, and a budget for the visit and conceptual design including subsequent phases should the project proceed to construction. The cluster members were kept informed and backed the appointment of Holmes Consulting Group and Dunning Thornton Consultants Ltd to undertake the work.

In early July 2001, the project architect and engineer spent two weeks in Wellington inspecting base-isolated structures there, including the newly opened Wellington Hospital Accident & Emergency Department. They also met Bill Robinson, inventor of the lead-rubber bearing, and worked through the conceptual design with the New Zealand consulting engineers.

A complicating matter was the designer's requirement for the base-isolating system to be able to cope with another storey being added at a later date, without changes to the system at that time. This requirement acknowledged the reality that those responsible in the future for such an addition would not be in a position to re-address or adjust the base-isolation design.

One challenge faced was a requirement that the bearings be rodent-proof, Indian rats having a reputation of eating everything. Another was that, in accordance with common practice, the seismic loads for the non-isolated hospital concept had been calculated from the Indian seismic code using natural modes found by analysing a bare-framed building. This is, unfortunately, common practice in India for infilled frames, and meant that the beneficial reduction in design lateral loads available through base-isolation was initially seen as small.

The proposed 300-bed Bhuj District Hospital (courtesy E F N Ribeiro Associates)

5 APPROVAL TO PROCEED

Back in New Delhi, the design team put their case to their client the Prime Minister's Relief Fund, for base isolation to be incorporated in their design. It is understood that a key factor in the acceptance of the proposition was the viewing of a short video on the base isolation of New Zealand's Parliament Buildings. This is available from the visitor centre at Parliament. The final requirement of the client was that India's own experts in earthquake engineering endorse the technology. Professor Sudhir Jain of IIT Kanpur (Member of NZSEE) and Emeritus Professor Anand Arya of Roorkee were approached by the author and willingly provided the necessary endorsements.

6 DETAILED DESIGN

With approval to proceed in place, the project architect and structural engineer were then invited back to New Zealand by the NZ Ministry of Foreign Affairs and Trade to work through the detailed design of the base isolation system with the New Zealand consultants. By this time, the leading Indian contractor Larsen and Toubro Ltd had been commissioned and the construction documents for the hospital issued. To meet cost restraints, the size of the hospital had been slightly reduced (by shrinking the gridline spacings), but the requirement remained for a subsequent storey to be allowed.

7 PROCUREMENT

Independently of any assistance from the New Zealand Government, the contractors then sought a proposal from Robinson Seismic Ltd of Lower Hutt to provide the 280 lead-rubber bearings and sliders. Their proposal was eventually accepted, and manufacturing commenced in November. As part of the contract negotiation members of the Robinson Seismic team visited the contractor's headquarters in Chennai, India, and the hospital site in Bhuj, Gujarat.

8 CONSTRUCTION

A ceremony for the commencement of the hospital foundation took place on October 2nd, Mahatma Gandhi's birthday. In January 2002, the first of the bearings had reached the site and

Adam Thornton of Dunning Thornton Consultants visited the site (as part of New Zealand's assistance) to verify that the foundation details to accept the bearings were as specified. To assist this process, Robinson Seismic had freighted a steel template for the bolt locations to Bhuj. The process of pressure grouting the underside of the bearings to the foundations had not been undertaken by the contractor's site team before, and Adam Thornton was able to train the contractor in the technique. By early February, all bearings had been manufactured and dispatched to the site. Further visits of the New Zealand design team are planned to provide verification that all bearings have been correctly installed.

A base-isolation system requires building services to be flexible where they cross the bearing zone, if they are to remain working after a significant earthquake. The project architect believes that the larger sizes of flexible piping commonly used in New Zealand installations can not be procured within India at present. The current plan is for these to be sourced from New Zealand, possibly using funds raised by concerned groups in New Zealand immediately following the January 2001 Gujarat earthquake.

9 DESIGN AND CONSTRUCTION CHALLENGES IN INDIA

While India has suffered many large losses of life in earthquakes in recent times (for example, 11-15,000 in the Latur earthquake in 1993) the Gujarat earthquake was the first to impact significantly modern multi-storey construction in an urban area. In particular, the number of recently constructed apartment buildings which failed in Ahmedabad (some 250 km from the epicentral region) highlighted the unsuitability of current design and construction practices for earthquake-prone regions.

Specialist groups in a small number of academic institutions and government organisations have worked tirelessly for many years to promote changes in seismic design for both engineered and non-engineered construction. Indian standards covering seismic provisions are in place, and a seismic zoning map is incorporated in these. Although design for earthquake is not commonly taught at undergraduate level, an increasing number of Masters-level short courses are being held.

The professional structural engineer appears to be battling traditional practices to be heard within the design team. Functional requirements of buildings often conflict with sound concepts for earthquake resistance. In a just-completed e-conference (conference by e-mail) on the draft revision of the Indian Seismic Codes, one contributor summed it up by writing, "The 75 (collapsed) buildings in Ahmedabad are the example of our honesty". There are issues of substandard materials being used (particularly reinforcing steel) and contractors unwilling to use standard details such as hooks on stirrup and hoop reinforcing. Urban space requirements have led to the proliferation of open ground floors of multi-storey apartment blocks to allow car-parking. Structural engineers have a significant challenge in coming up with suitable methods of accommodating brick-infill reinforced concrete frames in seismic areas. The length of a brick (around 230 mm) is a common limiting factor for the width of a column - the common architectural requirement being for the columns not to protrude beyond the wall surface.

All indications are that the Bhuj District Hospital will be built to a standard well in excess of that common in the Kutch region. This points to one of the solutions to breaking the cycle of non-empowered engineers and poor design and construction practices. When the client is convinced of the need for better consideration of earthquake resistance, an improved structure will follow.

10 CONCLUSIONS

By a series of fortunate coincidences and good management, New Zealand has been able to assist the Indian Government to put in place a much-needed replacement hospital in a region of

high seismic hazard. The standard of earthquake resistance that will be achieved should be a tangible example that local earthquake engineers can use to convince their own clients of the need to incorporate seismic resistant features in their structures.

Well-targeted international assistance in earthquake engineering technology can support those in India already trying so hard to raise public and professional awareness of good design practices. The aftermath of a major disaster such as the 2001Gujarat earthquake heightens awareness and reception of change by Authorities.

11 **ACKNOWLEDGEMENTS**

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This has been a team effort, with officers of New Zealand's Ministry of Foreign Affairs and Trade, Trade New Zealand, the New Zealand Earthquake Technology Business Cluster, E F N Ribeiro Associates, prominent Indian earthquake engineers and the Indian Prime Minister's Office all contributing to making it happen.