HERITAGE AT RISK: NATURAL DISASTERS-EARTHQUAKES

CASE OF PRAG MAHAL AT BHUJ, GUJARAT

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Abstract:

***IndexTerms* – Disaster, Heritage, Reconstruction, Seismic Rehabilitation**

INTRODUCTION

Natural disasters have always posed a significant threat to mankind. Despite worldwide efforts to mitigate their effects through warning systems, disaster preparedness and management programs, the increase in frequency and intensity of natural disasters today has caused governments to place a major emphasis on the protection of human life and, increasingly, cultural property. Although numerous studies on disaster mitigation have produced novel ways to reduce the vulnerability of human populations, the effort needed to protect threatened monuments of historical and archaeological importance continues to grow. Earthquakes are a major destructive force of cultural heritage sites, with the capacity to cause irreparable damages or even turn ancient sites into piles of rubble. The secondary effects of earthquakes--tsunamis, landslides, ground fractures, etc. pose an equally great, if not larger, threat in terms of their potential to subject heritage sites to conditions site managers were not prepared to handle. Many historic cities have witnessed these catastrophic happenings in the past few centuries, and a few have managed to thrive while keeping their history intact.

TYPE OF DISASTER

Experiences of earthquakes in last decades in semi-urban & urban parts of India have caused deep concern with regards to seismic hazards and resulting risk. These devastating earthquakes in urban areas in India cause heavy economical losses in terms of loss of life, property, disruption of services and damage to environment recurrently. The damages Caused to the heritage structures during earthquakes are never given first priority and most of the times go unnoticed.

SIGNIFICANCE OF HERITAGE

Habitat of man with all its components - built and open spaces, activity areas and linkages, form a rich tapestry of his culture. Built over ages with contribution made by each generation, settlements are a living continuum of history, forging a strong linkage between the past and the present. Civilization's heritage not only consists of major works, such as monuments and works of art, but also of everyday objects, which render a value to the culture. Evaluation of heritage structures, monuments and precincts are based on certain criteria, e.g.,

•Historical – the history of the building or area and its significance. History may include association with an event or a person or a particular period.
•Physical - the architecture of the building or area, stylistic integrity, group or townscape values, uniformity of character, quality.
•Social or economic - use, way of life, commercial viability.

HERITAGE AT RISK

Since the time immortal, rich heritage buildings of India have been facing the wrath of man-made cultural invasions, natural disasters and environmental degradation. However, they are the physical evidences of rich cultural values of our glorious past, which we inherit from our ancestors and are to be preserved in their authenticity i.e. aesthetic and historical values ensuring structural safety against external actions.

SITE

Gujarat has a rich heritage of buildings built by the princely rulers of the area over the last 500 years. Some of these buildings are of international importance. Many were seriously damaged during the January 2001 earthquake. Bhuj was within 20km of the fault break, and suffered very severe damage. The palace complex is in the old walled city. It consists of a collection of buildings in a variety of styles, dating from the 18th century. Some of the buildings are of random masonry construction, and have suffered extensive damage and collapse. As there was no major occurrence of such an earthquake in the last century in this region, people in

general have got a shock of their lifetime and since it has not previously been experienced for several generations, there was a complete lack of preparedness on the part of the people at large, including the authorities and public welfare institutions.
Prag Mahal, Bhuj is a 19th century palace that is located next to the Aina Mahal in the city of Bhuj in Gujarat. It was commissioned by Rao Pragmalji II, and designed by Colonel Henry Saint Wilkins. The construction for the palace began in 1865. Prag Mahal is characterised by the Italian Gothic style of architecture, and many Italian artisans undertook its construction .The material used in the construction of Prag Mahal Palace is Italian marble and sandstone from Rajasthan.

FOCUS OF STUDY

Reconstructive Heritage Site with Structural Aspect .The focus of the research is to highlight the problems and prospects connected with structural restoration and seismic protection in the areas of earthquake with special reference to the problems of the structure. Among the many critical modes of failure of heritage structure Prag Mahal at Bhuj, Gujarat during earthquakes, the aspect observed in recent effect are as follows:-

STRUCTURAL ASPECTS

The Prag Mahal at Bhuj is made up of masonry of varied rubble joined with mud/lime/surkhi mortars with cementations materials of good quality. However, this building seemed to perform badly during past earthquakes. The basic reasons has been the intrinsic weaknesses of masonry i.e. its weight and low tensile strength, which is further aggravated by deterioration due to weathering. An important aspect of the masonry used in the structures is its significant variations in its quality among different structural members and even within the same member. Also, absence of integral connectivity of different masonry structural members causing widespread damage of such structure in case of ground motion.
Overturning of Long Walls:- The most commonly mode of failure during past earthquakes has been overturning of the walls due inertia forces and normally precipitated by the outward thrust of the roof
.Failure of roof:- the roofs of Prag Mahal are jack-arched, vaulted shape. The majority of failure starts with the separation of wall from its transverse supports as cantilever of increasing length. Finally the walls overturn or open enough to loss the support of the roof, leading to its collapses.
Diagonal Cracking:- The shear failure in walls through diagonal cracking is not very frequent in heritage structures, though, because the more thickness of walls of the monuments gives relatively significant capacity to resist shear forces, even if their unit shear strength is low, but in case of Prag Mahal the shear failure is commonly associated with walls with large openings. The shear capacity of masonry piers may not be enough to resist lateral loads imposed by earthquake forces.
Tensile Failure of Structures:- there is an artistic roof tops in Parag Mahal during the vibration of the structure tensile stresses arise in roof that could generate large cracks, actually separating the structure in parts leading to partial to total collapse.

SEISMIC REHABILITATION

Seismic rehabilitation is used as a term to include all the concepts of repair, restoring and strengthening. the seismic rehabilitation means is to preserve and reveal the aesthetic and historical values of the heritage structure and at the same time ensuring structural safety against external actions i.e. earthquakes.
the seismic rehabilitation of heritage structures must address the following:

- Respect for original material and authentic documents
- Respect to the valid contributions of all periods to the building
- Replacements of missing parts must integrate harmoniously with the whole, but at the
- same time must be distinguishable from the original
- Additions/Alteration cannot be allowed except in so far as they do not detract from
- the interesting parts of the building, its traditional setting and its relation with the
- surroundings
- The use of traditional techniques and materials are clearly preferable for seismic
- rehabilitation
- Modern techniques and materials are admissible where adequate capacity cannot be ensured by traditional techniques.

In this case durability and compatibility of the interventions should be adequately proven; otherwise, the modern techniques and Materials should be used only in a manner that will permit easy corrective action at a
Later date if necessary, without compromising original historical, cultural architectural Features.

METHODOLOGIES FOR REPAIR, RESTORATION AND RETROFITTING

Elements to be Added/Enhanced for Improved Seismic Behaviour of Structure for improved seismic performance, a rigid diaphragm was required to be put in place at both the floor levels. The diaphragm action was proposed to be developed by means of introducing diagonal bracing elements on the underside of the first floor .Such a diagonal bracing would ensure that there was a well-defined path for transfer of the lateral inertia forces from the slab to the walls in their stiffer direction. The detailing of the diagonal bracing was complicated due to the presence of the cornice element. As a result bracing in the form of a complete truss (in plan) spanning between the cross walls was proposed. The brace elements were connected to the steel joists for lateral support. A different strategy was adopted for the roof slab as explained later.

Enhancing Strength of the Structure

From the failure pattern, it was quite apparent that the stone masonry walls with their poor bonding were unable to provide the adequate lateral strength. It is not possible to improve the existing mortar. Hence an alternative means of improving seismic performance was required. Various options were considered. These were: introducing vertical diagonal bracing, introducing new shear walls, strengthening existing walls, and providing base isolation.

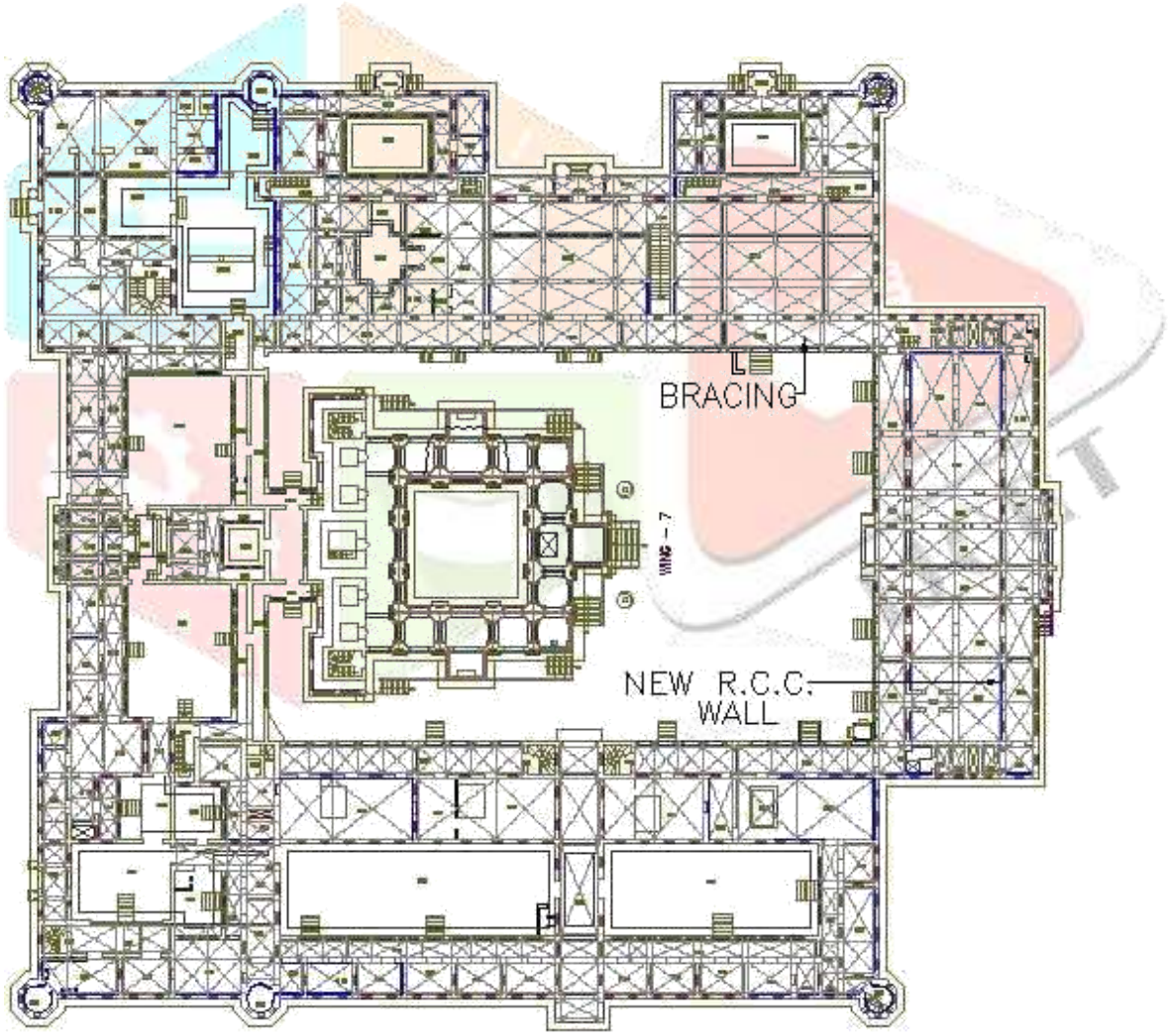

Figure 1. Location of Proposed Bracings and R.C. Skin Walls at First Floor Level.

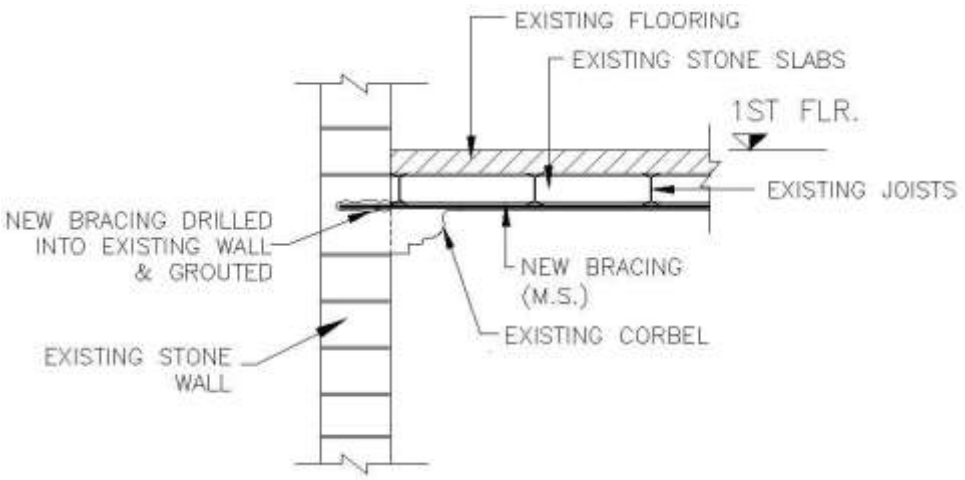

Figure 2: Sectional Details of Anchoring of Diagonal Floor Bracing in Walls

Anchoring of Diagonal Floor Bracing in Walls

The option of diagonal bracing was an attractive one as it meant the least intervention into the existing structure and could be designed as a sleek, honest and aesthetically pleasing retrofit. However due to the existing wall foundations, it was not possible to provide foundations for the large axial tension and compression forces generated at the base of the braces. Hence this option was discarded. Typically,
concreting in India is limited to a thickness of 40 mm primarily due to equipment limitations. The option of base isolation was considered to be a very expensive one and is not available indigenously; hence this option was not considered. Thus, the process of elimination lead to the choice of additional reinforced concrete skin shear walls.

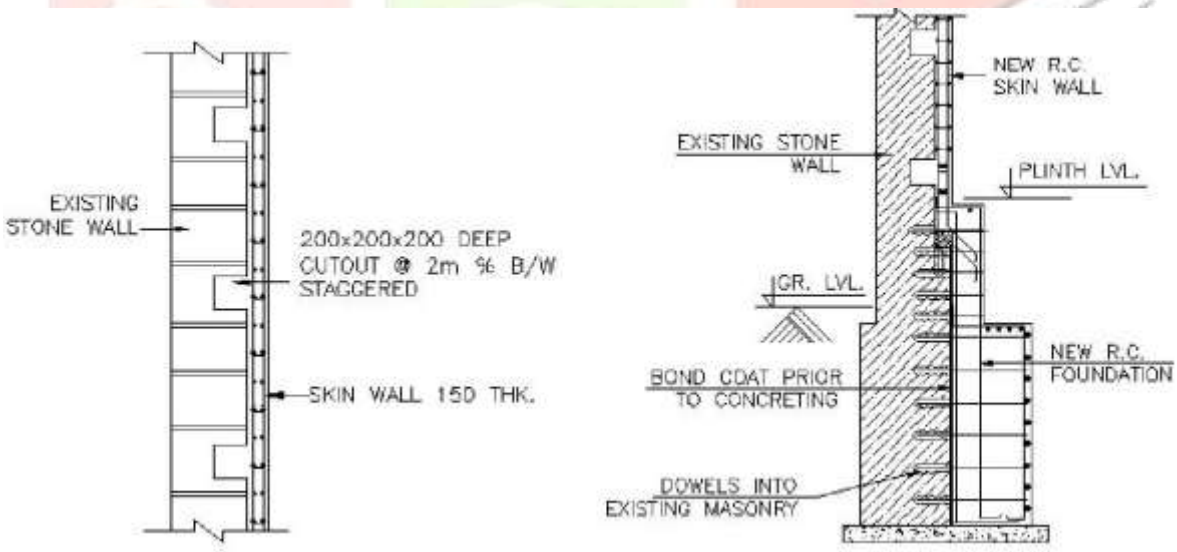

Figure 3: Details of New R.C. Skin Wall (a) R.C. Skin Wall Nogged in to Masonry Wall, and (b) New R.C. Skin Wall Foundatio

Strengthening of Arches

The arches suffered three types of failures: dislocation of keystone, severe cracking of arches and movement of supports. Two retrofit details for arch strengthening have been recommended based on the type of damage. Where there is movement of support and the

arches are internal, a stainless steel tie with a turnbuckle is proposed (Figure 11a). In areas where there is no discernible movement of supports, the keystone is tied back into the wall above by means of stainless steel rods . A lintel is formed by means of providing stainless steel reinforcing bars in the courses between the stones above the arch.

Cross-Pinning of Corridor Columns

The columns in corridors towards the interior courtyards were significantly damaged during the 2001 Bhuj earthquake. The columns are made of three or more pieces of stone and negligibly socketted into each other. It is proposed to connect these stones to each other by cross-pinning (Figure 12a).

Stitching and Grouting of Cracks in Walls The cracks in the walls are to be grouted with a low-strength grout compatible with the stone. Walls with diagonal cracks are to be stitched using stainless steel bars before the cracks are grouted (Figure 12b). The grout needs to be tested before use for its compatibility with the stone.

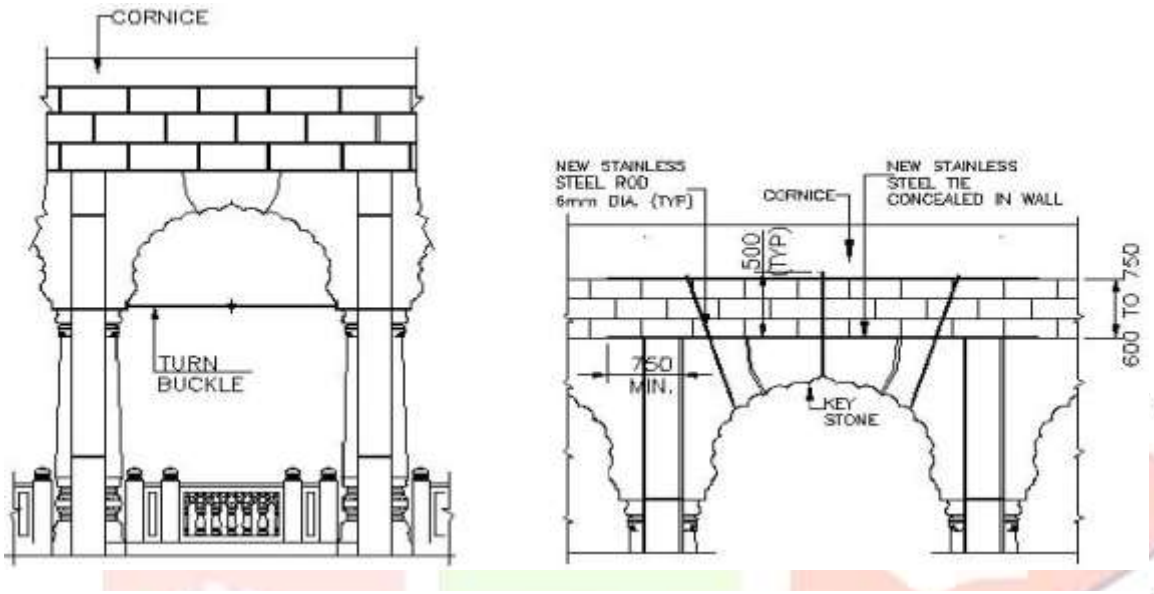

Figure 4Detail of interventions in arches :(A) strengthening of Arches using Ties, and (B) strengthening ogee arches by pining and Reinforcement band.

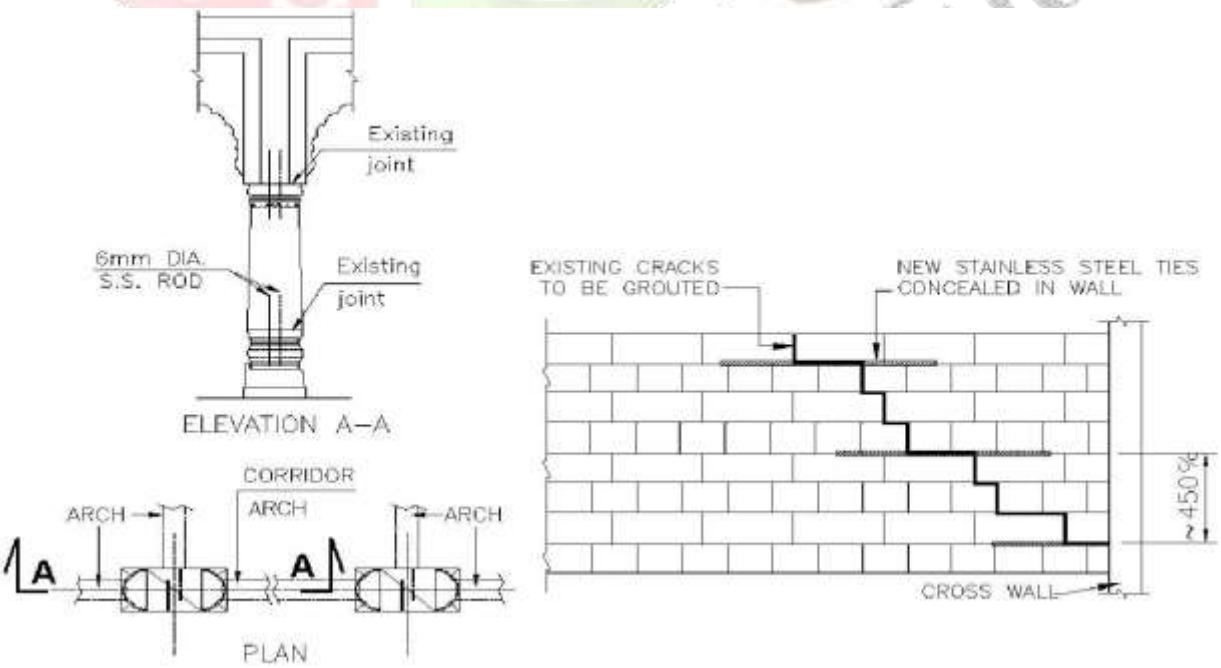

Figure 5Interventions in Vertical Elements: (a) Cross Pining of Corridor Columns, And (b) Detail of stitchng cracks in walls

CONCLUDING REMARKS

The 2001 earthquake exposed the seismic vulnerability of the Prag Mahal Complex. This was also established from the dynamic analysis of the structure using finite element modeling. The structure showed several deficiencies such as inadequate lateral strength, lack of a diaphragm action in slab, reentrant corners, poor bonding between stone blocks, vulnerable arches, unreinforced tall elevation features on roof.

A comprehensive retrofit program was formulated to address these deficiencies. Measures such as reinforced concrete skin walls, diagonal bracing on the underside of the floor slabs for diaphragm action, horizontal stainless steel reinforcement bands in existing masonry walls have been proposed to improve lateral strength and behaviour. Measures such as cross-pinning and end pinning have been recommended to improve the seismic behaviour of walls, weather sheds and stone pillars.

REFERENCES

1. Penelis G, Venkov V, Zambas C, Csak B, Popp T, Kuban D, Anicic D, Bouwkamp J. “Repair and Strengthening of Historical Monuments and Buildings in the Urban Nuclei.”

UNDP/UNIDO Project RER/79/015, Vienna 1984:3-15

2. IS 1893 : 1984. “Indian Standard Criteria for Earthquake Resistant Design of Structures.” Bureau of Indian Standards, New Delhi, India

3. IS 1893 (Part-1): 2002 “Indian Standard Criteria for Earthquake Resistant Design of Structures.” Bureau of Indian Standards, New Delhi, India

4. IS 4326 : 1993. “Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings.” Bureau of Indian Standards, New Delhi, India

5. Brookes CL, Mehrkar-Asl S. “Numerical Modeling of reinforced concrete masonry to enhance seismic resistance.” 1st Conference on Strengthening and Retrofitting of Structures, University of Amir-Kabir, Tehran, Iran, May 2002.

6. Wilson E. “Three Dimensional Static and Dynamic Analysis of Structures.” Computers and Structures Inc., April 2002: 6-1 to 15-24