SEISMIC DESIGN EVALUATION OF EXISTING UNREINFORCED MASONRY STRUCTURES USING IS CODE RECOMMENDATIONS

Rashmi Sakalle[1,] Nitin Tiwari[2], Asra Amin Shah[3]

[1,2] Assistant Professor, [3]M.tech Scholar

[1,2,3]Dept. of Civil Engineering, T.I.E.I.T, M.P, India

Abstract: **The earthquake resistant design of structures as indicated by the existing design philosophy aims to guarantee that amid their lifetime, the structures resist the extreme possible tremor without collapse. This philosophy disregards the fact that for the allowable damage towards the end of the design life, it is important to represent the seismicity of the area in an extensive way i.e., in terms of magnitude with appropriate spatial distributions around the site. Interest for structural masonry has expanded essentially in recent years. Therefore, further advanced codes of practice for the design of structures in masonry have been presented in numerous countries. The threat of seismic tremors have underlined the requirement for wide monitoring and safety assessment of architectonical heritage. The research work is on examining the seismic vulnerability of a particular monumental masonry building: RANI MAHAL, at Islam Nagar in Bhopal, M.P (India). The seismic behavior is assessed by the equivalent static analysis, as indicated by IS 1893:2002(PART-1). Design of base shear for the palace with the data available after visual inspection of the palace determines the seismic strength/shortcoming of this sort of building to endure broad harm under earthquakes. The need of examining the structural behavior can further permit the identification of an appropriate retrofitting procedure if any harm is caused to the building by seismic tremors during its lifetime.**

Keywords: **Old Masonry Structures, Earthquake damages, Seismic design, Base shear, IS code provisions.**

I. INTRODUCTION

Brick and stone Masonry are the most utilized construction technique of ancient buildings other than wooden work. Stone/Brick Masonry has been utilized in a Wide assortment of structures for public and residential structures in the past thousands of years. From the Tower of “Babylon” which ought to have reached the sky on the off chance that it had been finished, to the Great Wall of China, which is the main man-made structure noticeable from the Moon. An incredible number of very much protected old masonry structures still exist, demonstrating that masonry can effectively bear loads and environmental impacts, along these lines giving shelter to individuals and their goods for a significant period of time, if sufficiently considered and constructed. In acknowledgment of their significance and value, huge numbers of those structures have been positioned among the assets of the most noteworthy classification of mankind's historical and cultural heritage.

A. DAMAGE TO HERITAGE STRUCTURES IN INDIA DUE TO EARTHQUAKES, IN THE SPAN OF LAST 15 YEARS

India has witnessed six earthquakes of moderate intensity, even if moderate in intensity, these earthquakes have caused to a great extent huge amount of losses to property, which highlights the exposure of the infrastructure to earthquakes. The trembling of 1993 and the Bhuj quake of 2001 which caused big injure to properties highlighted the need to focus upon long-term seismic improvement and attentiveness in series to moderate the money-spinning losses caused because of earthquakes. The 26 January Bhuj shaking was the largest devastating one which scaled actual high-level in conditions of deficit of property. This shaking is the initial most important upheaval to batter an urban area of India in the last 50 yrs. Several heritage structures in Ahmedabad, Kutch, Bhuj, Anjar and Bachau and surrounding villages were harshly damaged during this quake. A 600 years old monument Jhulta Minara in Ahmedabad was amongst the dozens of ancient monuments, which partly collapsed or dented during the quake. In Bhuj, the Raolakha Chhatri constructed in the 18th Century and survived the vast 1819 Kachchh Earthquake, but succumbed to the 2001 Earthquake. It has oldest, largest and mainly elaborate of these assets land memorials to precedent Maharajas.

However, the September 1993 upheaval that struck Maharashtra in central West India that claimed about 12,000 lives, was not a remarkably tough event, but caused such damage for the reason that of other factors. The Marathwada region has an extended history stretching from antediluvian times ‘As a result; the province is calorific in copious heritage structures such as forts, temples, tanks, caves, and parapet etc. which are extant evidences of assorted time periods. However, the important part of the heritage are accepted settlements with ’vernacular housing’ as a principal component. This has traditionally built using materials that are certainly available locally, plus take the stones out of and wood; typically, the walls completed of stone masonry, even up to 600 mm thick, with mud mortar. Cement used for sealing the uncluttered joints. All of Kashmir’s ancient temples (constructed 750-950AD) have also resisted some damage. Although largely not recognized, it is probable that generally of this damage initiated by earthquakes. An ordinary story is the damage of the monolithic capstone roofs of temples, whereas the walls in spite of everything post without the gain of mortar. Examples of tossed capstones are set up at Naranag. a number of temples cover subsequently been quarried for stone used in later on re-construction (Parihansapura).Few have been partly re-assembled by the Archaeological survey of India (Shiva and Naranag). An exceptional few stay evidently in the state they left following earthquake shaking (Sugandhesa, Payar).

II. OBJECTIVES OF THE STUDY

Heritage structures are the essential part of the culture of any country. The reason behind their importance is that they represent masterpieces of the human creation, bearing testimony to cultural traditions of previous civilizations and illustrating prominent stages in human history with artistic works of outstanding universal significance. Thus, they require protection from the effects of all hazards because of their importance in mankind’s cultural heritage and evolution -a legacy from the past which definitely should be preserved for future generations as they are irreplaceable sources of inspiration and points of reference to human identity, intelligence and civilization. These world heritage sites represent resources of outstanding universal value, which belong to all the people of the world, regardless of the territory on which they are located and national sovereignty or ownership.

In Western and European countries, the awareness for preserving and defending the Heritage structures is in move forward put on at what time compared to in Asian countries. India is notorious for its sculpture and urbanity all along with the variety of one of its elegant heritage Structures. Countless of these structures in our country are in a territory of ruins or on the brink of ruins for the reason that of crude personal property and neglect.

Thus, the study of design criteria for any structure and the computed damage helps in getting a proper understanding about the current state of the structure, depending on which we will come to its preservation. The main objective of our work is to check the seismic design criteria of Rani Mahal, Bhopal and check whether it is safe as per I.S code to assure its safety against earthquakes in future.

A. CASE STUDY OF RANI MAHAL

The Rani Mahal or as it is called 'Queen's Palace' was built by the king Dost Mohammad Khan as a gift to his dear wife, in the year 1720. The Red Sandstone structure has beautiful balconies and a roof which contains a garden. It is located in Islam Nagar. Formerly a fortified city, Islamnagar was the capital of the Bhopal princely state for a brief period. The ruins of the palaces built by Bhopal's founder Dost Mohammad Khan still exist at the site. Rani Mahal is a double storeyed complex meant for the female residents of zenana. It is a rectangular building with deep arches. It has a beautiful baradari inside. This modest Structure emphasizes on simplicity and comfort rather than luxury. There are small rooms, with very basic dimensions and attachments, located on the ground floor. Its west opposite doorway door is finished of firewood, Close to is an unfasten square. The vaulted verandahs and 4 rooms are made on what's more planes of this square. This 3 storeyed construction is move toward into from end to end a little doorway attendance. A rectangular quad is positioned in the mid. miniature and large suburban rooms, ornamented with archway and prop, are manufactured on the 1st story. A baradari is furthermore to be found to the north of the quad, which is decked out amid hollow of flower-patterned motifs.

Their complex columns have volute multifold semicircles behavior piece of paper and flower garland in the Rajput and Mughal combination approach. Structure emphasizes on simplicity and comfort rather than luxury. There are small rooms, with very basic dimensions and attachments, located on the ground floor. Its west opposite doorway door is finished of firewood, Close to is an unfasten square. The vaulted verandahs and 4 rooms are made on what's more planes of this square. This 3 storeyed construction is move toward into from end to end a little doorway attendance. A rectangular quad is positioned in the mid. miniature and large suburban rooms, ornamented with archway and prop, are manufactured on the 1st story. A baradari is furthermore to be found to the north of the quad, which is decked out amid hollow of flower-patterned motifs. Their complex columns have volute multifold semicircles behavior piece of paper and flower garland in the Rajput and Mughal combination approach. There are release verandahs and 4 rooms on the succeeding flooring. Solitary chhatri is made on the 3 floor, which has an arched crown, at the same time as the further 2.

Fig. showing chhatri

Fig. showing column structures

Fig. showing entrance to rooms

Fig. showing view of storeys

III. METHODOLOGY

Earthquake resistant structure design procedures are provided by various Indian Standard Codes (IS Codes).After noticing Indian earthquakes for numerous years ,Bureau of Indian Standard has divided India into 5 zones as discussed earlier.IS 1893-1984 shows the various zones.

The following IS codes are of utmost significance for the structural design engineers:

- IS 1893-2002: Criteria for Earthquake Resistant Design of Structures (5^{th} revision)
- IS 4928-1993: Code of practice for Earthquake Resistant Design and Construction of buildings(2^{nd} revision)
- IS 13827-1992: Guidelines for improving Earthquake Resistance of Resistance of low strength masonry building.
- IS 13920-1997: Code of practice for Ductile Detailing of Reinforced Concrete Structures subjected to seismic forces.
- IS 13935-1993: Guidelines for repair and seismic strengthening of buildings.

"But, at the time of the construction of Rani Mahal, there were no as such IS codes being published by the Bureau of Indian standards that could guide the Architects to construct the seismo resistant masonry structures. All the above codes came into being mostly in 80's.

Thus, the aim of my work is to analyse the seismic design of Rani Mahal and to check whether it satisfies the seismic design criteria as stated by IS 1893-2002 code."

A. PROCEDURE FOR INVESTIGATING THE SEISMO RESISTANT CAPACITY OF A BUILDING

EQUIVALENT STATIC FORCE ANALYSIS:-

Depending on the location of the building site, on identifying the seismic zone and assigning zone factor (Z), follow the below steps;

- CALCULATION OF BASE SHEAR:-

Base shear is the maximum expected lateral force that will occur due to seismic ground acceleration at the base of the structure. The base shear, or earthquake force given by the symbol "V_b". The weight of the building given as the symbol "W".

$$\mathbf{V_b = Ah \times W}$$

V_B = Base Shear, Ah= Horizontal Seismic Coefficient W = Total Weight of Structure And

$$Ah = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

For Zone -2; as per IS 1893:2002(Part-1)

Where, Z= zone factor=0.10(LOW)

I= Impotence factor=1.5

R=Response Reduction factor=3

Sa/g= spectral Acceleration coefficient= 2.5

- DESIGN LATERAL FORCE AT EACH FLOOR:-

Design Lateral force, Vb that shall distributed along the height of the building using below equation;

$$\mathbf{{}^{n}Q_{i} = V_b W_i h_i^2 / \sum W_j \times hj^2}$$

j=1

Where, Q_i = Design lateral force at floor, i

W_i = Seismic weight of floor,i

h_i = Height of floor,I measured from base

n= Number of storeys in the building

Type-II Soil medium type, for which average response acceleration is as follows:-

$$Sa/g = \begin{cases} 1 + 1.5T, 0.00 \leq T \leq 0.10 \\ 2.50, 0.10 \leq T \leq 0.55 \\ \frac{1.36}{T}, \quad 0.55 \leq T \leq 4.00 \end{cases}$$

- TIME PERIOD CALCULATIONS:-

The estimated fundamental natural period of a masonry building can be designed from the clause7.6.2 of IS 1893(part-1); 2002 as under

$$T_{a} = 0.09\frac{h}{\sqrt{D}}$$

Here, h= height of the building in meters (i.e., height of first storey + height of second storey)

And, d= Base dimension of the building at the plinth level, in meters, alongside the considered direction of lateral force (supposing earthquake in East-West direction)

IV. RESULT ANALYSIS & DISCUSSION

- The weight of columns is calculated by the following formula,

  W= Density * volume [Here, density of material used is taken as per IS 875- Part 1].

- The dead load of stair is calculated by the following formula,

  Total dead load= Dead load of all steps + Dead load of flight + Dead load of landing.

- The weight of walls is calculated by the following formula,

  W= Density of Masonry * Volume (KN/m^3)

  Here, D is taken as per IS 875- Part 1

- Base Shear= Total Seismic Weight *Ah [Here, Ah= (Z/2)*(I/R)*(Sa/g)].

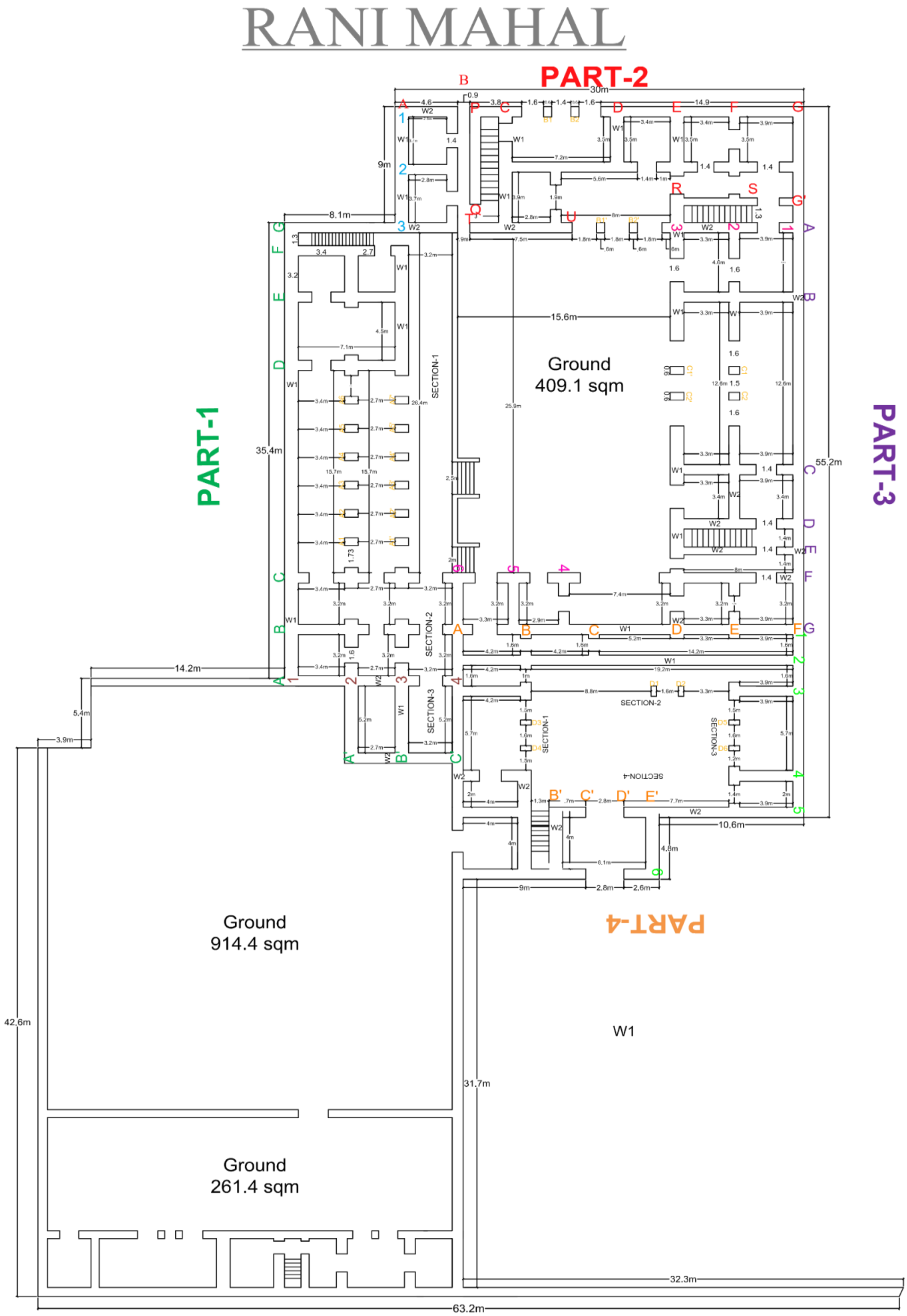
  Z= Zone Factor, I= Impetance Factor,R=Response Reduction Factor, Sa/g=Spectral Acceleration Coefficient

- Lateral Force= $Q_i = VB*W_i h_i^2 / \sum_{j=1}^{n} W_j*h_j$
- Total Seismic Weight Of Building= Total weight Of Walls + Weight Of Floors.
- Weight Of Floor= Weight Of Slabs + Weight Of Beams.
- Total Weight Of Walls= Weight Of Walls In X Direction + Weight Of Walls In Y Direction.

Table-1 :- Calculation Of Seismic Weight Of Building

Building	Weight Of Walls In X-Direction(KN)	Weight Of Walls In Y-Direction(KN)	Total Weight Of Walls(KN)	Weight Of Slab(KN)	Weight Of Beam(KN)	Weight Of Floor(KN)	Live Load(KN)	Total Seismic Weight(KN)
Part 1	5315.7	2968	8283.7	1243.97168	45.6188	1289.59048	0	9573.29048
Part2								
Ground Floor	3533.244	3170.759	6704.003	881.0592	32.31	913.3692	294	7911.3722
First Floor	832.416	429.78	1262.196	60.6852	2.2275	62.9127	20.25	1345.3587
Second Floor	832.416	429.78	1262.196	60.6852	2.2275	62.9127	0	1325.1087
								10581.84
Part 3								
Ground Floor	3916.653	2945.124	6861.777	898.680384	32.9562	931.636584	299.88	8093.29358
First Floor	868.608	741.936	1610.544	184.60288	6.7648	191.36768	61.6	1863.51168
Second Floor	1302.912	1112.904	2415.816	184.60288	6.7648	191.36768	0	2607.18368
								12563.989
Part 4	5581.485	2565	8146.485	1003.95797	36.7934	1040.751368	0	9187.23637
								41906.355

PLAN OF RANI MAHAL, BHOPAL, M.P, INDIA



W1=1m

and W2=0.8m

Table-2:- Calculation Of Base Shear And Lateral Force

For Seismic Zone 2											
Building	**Zone Factor(Z)**	**Importance Factor(I)**	**Response Reduction Factor(R)**	**Av. Response Acceleration Constant(Sa/G)**	**Ah**	**Total Seismic Weight**	**Base Shear(Vb) KN**	**Height(H) M**	**Base Dimension (D) m**	**Time Period(Ta)**	**Lateral Force(Q) Kn**
Part-1	0.1	1.5	3	1.06	0.0265	9573.29048	**253.6922**	3	42.2	0.04156306	**253.6922**
Part-2 Ground Floor	0.1	1.5	3	2.5	0.0625	7911.3722		3	30	0.04929503	
First Floor	0.1	1.5	3	2.5	0.0625	1345.3587	**661.36498**	6			**661.36498**
Second Floor	0.1	1.5	3	2.5	0.0625	1325.1087		9			
Part-3 Ground Floor	0.1	1.5	3	2.5	0.0625	8093.29358		9			
First Floor	0.1	1.5	3	2.5	0.0625	1863.51168	**785.24931**	6	30.6	0.14642806	**785.24931**
Second Floor	0.1	1.5	3	2.5	0.0625	2607.18368		3			
Part-4	0.1	1.5	3	1.079	0.026975	9187.23637	**247.8257**	3	25.8	0.0531562	**247.8257**

A. DATA OBTAINED AS PER IS (1893-2002) PART-1 & IS-875(PART-1)

FOR PART-1 OF RANI MAHAL, BHOPAL;

- The dead load of columns= 126.72 KN
- The dead load of walls in X-direction= 5315.7 KN
- The dead load of walls in Y-direction= 2968 KN
- The dead load of slab= 1243.97168 KN
- The dead load of steel used in beam= 45.6188 KN
- The dead load of stairs= 231.336625 KN
- Total seismic weight= 9573.29048 KN
- TOTAL BASE SHEAR=TOTAL LATERAL FORCE=253.692 KN

FOR PART-2 OF RANI MAHAL, BHOPAL;

The dead load of columns= 42.24 KN

- The dead load of walls in X-direction, For ground floor= 3533.24 KN

  For first floor= 832.416 KN

For second floor= 1248.624 KN

Total= 5614.284 KN

- The dead load of walls in Y-direction, For ground floor= 3170.7585 KN

  For first floor= 429.78 KN

For second floor= 429.78 KN

Total= 4030 KN

- The dead load of slab= 1002.4296 KN
- The dead load of steel used in beams= 36.765 KN

The dead load of stairs, For ground floor= 525.70765 KN

For first floor= 525.70765 KN

- Total seismic weight, For ground floor = 7911.3722 KN

For first floor = 1345.3587 KN

For second floor = 1325.1087 KN

- TOTAL BASE SHEAR=TOTAL LATERAL FORCE=661.364975 KN

FOR PART-3 OF RANI MAHAL, BHOPAL;

The total dead load of columns=42.24KN

- The dead load of walls in X-direction, For ground floor=3916.653 KN

For first floor= 868.608 KN

For second floor= 1302.912 KN

Total= 6088.173 KN

- The dead load of walls in Y-direction, For ground floor= 2945.124 KN

For first floor= 741.936 KN

For second floor= 1112.904 KN

Total= 4800 KN

- The dead load of slab= 1267.886144 KN
- The dead load of steel used in beams= 46.4858 KN
- The dead load of stairs= 500.07165 KN
- Total seismic weight, For ground floor = 8093.293584 KN

For first floor = 1863.51168 KN

For second floor = 2607.18368 KN

- TOTAL BASE SHEAR=TOTAL LATERAL FORCE= 785.249309 KN

FOR PART-4 OF RANI MAHAL, BHOPAL;

The total dead load of columns=63.36 KN

- The dead load of walls in X-direction= 5581.485 KN
- The dead load of walls in Y-direction= 2565.1 KN
- The dead load of slab= 1003.957968 KN
- The dead load of steel used in beams= 36.7934 KN
- The dead load of stairs= 195.427375 KN
- Total seismic weight= 9187.236368 KN
- TOTAL BASE SHEAR=TOTAL LATERAL FORCE= 247.825701 KN

➢ Seismic forces are basically the lateral forces (external force) which in turn will generate total reactive forces at the column base in the direction opposite to lateral load i.e., (sum of lateral loads= base shear), This overall reactive force is base shear.

➢ But, this load is not applied on base alone. As the lateral load applied along, the height of the building and building in turn has different stiffness and masses along its height in different storeys. Thus, the reactive force in each storey because of lateral load varies and this reactive force is storey shear i.e., (sum of storey shear= base shear).

V. CONCLUSIONS

Based on the various inspection and seismic analysis, following observation are made in the existing historical building.

1. Based on the equivalent earthquake analysis, it has been observed that the building is performing at the level of life safety under zone II due to heavy stone foundation.
2. Base shear is equally distributed in the building, hence performance of the building under lateral forces is in acceptable limit.
3. In Visual inspection, it has been pointed out that there are various major cracks in the wall element of the building hence, it is advised to use centre core method for retrofitting.
4. Stone masonry foundation has been used in the building. As, due to weathering bond between the stones get loosen up hence, it is advised to use shotcrete technique for retrofitting.

VI. FUTURE SCOPE

The historic structures pass on a message coming through the ages and it is the accountability of the present generation to carry it forward to the coming generations. This gift may be lost if the integrity of the unique structure is destroyed to meet the current demands. As these buildings are closely linked to the local social and economic conditions, methods that may be less destructive and of original fabric, need to be formulated to approach such issues. There is a great educational and practical potential to understand the area of restoration. An architectural, engineering, management and social approach is required for such type of endeavour. Proper education and training for such kind of works is the need of the hour. Contribution of more practitioners and technical professionals is needed. The prospective of this field is needed to be recognized by integrating and contextualizing the scopes and work of conservation, not only as a self-contained science or technological endeavour but also as a social practice.

REFERENCES

[1] Kapil Sharma, Prof. Praveen Sing Tomar, et al (2016), “case study of site characterization for seismic micro zonation of Bhopal”, international journal of innovative research in technology, Volume 3 Issue 3 | ISSN: 2349-6002.

[2] Mulyani R, Ahmadi R, Pilakoutas k, et al, (2015), “A multi-hazard risk assessment of buildings in Padang city”, procedia Engineering (2015) 125 1094-1100.

[3] Asteris P,Chronopoulos M,Chrysostomou C, et al(2014), “Seismic vulnerability assessment of historical masonry structural systems Buildings”, Engineering structures(2014) 62 118-134.

[4] Debranjan (2014), “seismic evaluation of un-reinforced masonry structures” Department of Civil Engineering National Institute of Technology Rourkela Odisha -769 008, India.

[5] C.V.R Murty, Rupen Goswami et. al (2013), “some concepts in earthquake behaviour of buildings” Gujarat State Disaster Management Authority (GSDMA), Government of Gujarat, Gandhinagar (Gujarat, India).

[6] N.G. Maldonado, P.E.Martín (2012), “Structural Rehabilitation Studies of Masonry Building Heritage under Near Fault Earthquake: A Case Study” 15 WCEE, LISBOA.

[7] Paulo B. Lourenço (2011), “Dynamic identification and monitoring of cultural heritage buildings” WCCE-ECCE-TCCE Joint Conference 2 Seismic ProtecΘ on of Cultural Heritage October 31-November 1, 2011, Antalya, Turkey.

[8] Srikanth T, Kumar R, Singh A et al, (2010),”Earthquake vulnerability assessment of existing buildings in Gandhidham and Adipur cities kachchh, Gujarat(India)” European journal of scientific research (2010) 41(3) 1450-216.

[9] Robert Reitherman, Sue C. Perry (2009), “Unreinforced Masonry Buildings and Earthquakes” FEMA P-774/October 2009.

[10] Rajshree Kamat, Dr. Ashutosh (2008), “seismic vulnerability of Hoshangabad town of Madhya Pradesh, India” The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[11] Edoardo Fusco, Andrea Penna et al. (2008), “seismic assessment of historical natural stone masonry buildings throughnon-linear analysis” The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[12] V-H. kwok and A. H-S. ang (1987), “seismic damage analysis and design of unreinforced masonry buildings” civil engineering studies structural research series no. 536, UILU-ENG-87 -2007, ISSN: 0069-4274.