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Seismic Vulnerability Assessment of Gravity Designed Reinforced Concrete Frame.

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Abstract —*This research focuses upon the seismic assessment of gravity designed frame. We frequently see that the structures around us are designed for gravity loads only neglecting lateral or seismic loads. This results in serious damages to the buildings in cases of earthquakes. Our research comprises of a model that is designed for gravity loads and is tested for lateral and seismic loads to see for the deficiencies found in the structure against seismic loads. Also data is being noted and analyzed to see for future betterment prospects. Shake table testing is being conducted for the production of seismic loads and data noted and processed in terms of base shear and roof displacement to construct a capacity curve that may serve as a reference for future work to be executed with standard curves for different constructions and localities.*

Keywords- *Seismic Loads, Shake Table Testing, Accelerogram, Seismic Response, Capacity Curve, Base Shear, Seismic Hooks, Accelerometer, Displacement Transducer.*

1. INTRODUCTION

We see that many buildings designed in almost all localities in rural neighborhood do not have proper designing for seismic or lateral loadings. It results in the poor response of these structures against seismic loads. Whenever an earthquake strikes, it produces lateral loads, for which the structure is not properly designed resulting in huge damage to the structure and inhabitants. Assessment of such gravity designed construction is targeted in this research work to see for all the potential damages caused by seismic loadings to gravity designed structures and how remedies must be taken to reduce damages caused to gravity designed structures by lateral or earthquake loads.

2. LITERATURE REVIEW

Different works done by different authors have been studied prior to the commencement of our work to get an insight into the work proposed. The details are mentioned below:

2.1. Vulnerability Assessment

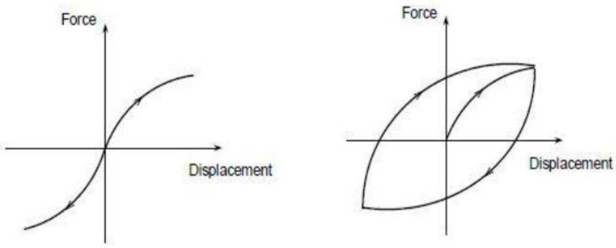
In order to properly address the problems caused by different loads including seismic loads, it is pertinent to note that the causes may first be investigated. Such practices are termed as assessment practices. If the extent of the damage is to be found about, the process thus followed is called vulnerability assessment. There are many techniques that are adopted to do the vulnerability assessment of structures. In our case, we have gone for experimental testing. In this regard, a model having gravity design is constructed and is then tested against seismic loadings to find out the potential damages seismic loads can cause to this gravity designed frame and we have worked to point out all such damages giving way to vulnerability assessment of the structure.

2.2. Lateral Mechanism Analysis

This is an important factor in the assessment of structures. Lateral loads come in bulks and damage the structure. There must be a proper criterion for the analysis of lateral mechanism. Different mechanisms including Beam-sway, Column-sway and other such mechanisms are used for the assessment of lateral forces upon structures and their responses are thus noted accordingly.

2.3. Non-linear Seismic Response

Almost all the times we note that structures designed for gravity loads do not show a satisfactory performance against seismic load activity. This is due to the fact that there is not much of the material or reinforcement that may be utilized during the seismic activity. This results in the non-linear response of the structures. Cyclic seismic loads can further cause larger damages to the structures when they strike as the response of the structure is non-linear.



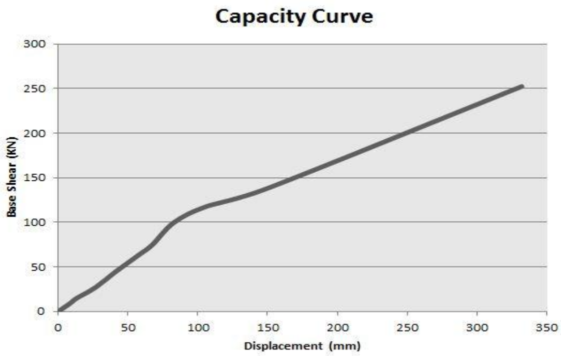
(Fig 2.1 Non-linear behavior of structures)

2.4. Direct Displacement Based Design

This is one of the simplest methods that are used for calculating the response parameters in case of lateral loads. Unit displacement is considered in the structure when it sways in the lateral loads and accordingly the work and energy are calculated using appropriate equations. By comparing the equations, the relevant base shear can thus be calculated. Also the drift obtained can be converted into displacement and thus it is easier to construct capacity curve for certain structures numerically.

2.5. Capacity Curve

Capacity curve for a structure is obtained by plotting the displacement caused by lateral loads on the x-axis and base shear of the structure on the y-axis respectively. As discussed earlier, we have used shake table analysis by incorporating Northridge accelerogram of 1994 earthquake to get values of displacement and base shear experimentally. The data is used for plotting capacity curve of our respective structure. Accelerometers installed gave us acceleration data multiplying which with the mass gave us forces in base shear while displacement transducers installed gave us the displacement data. The data is processed for different percentages of the accelerogram and was analyzed to get data of base shear and displacement step by step and for different percentages og the intensity of the accelerogram used. A sample capacity curve looks like the following figure.



(Fig 2.2 Capacity Curve)

2.6. Model Used

Keeping in view the capacity of our shake table, that is 5ft x 5ft, we made a one third scale model for analysis. It is a one bay, two storey frame having two columns on each storey with one central and two peripheral beams. A total load of 1200 kg was superimposed on each storey slab. Furthermore the concrete used had 2000psi strength and 4, half inch reinforcement bars were used in beam while 6, half inch bars were used in column. The ties provided were nominal for gravity load only and hooks use were 90 degree hooks. The model is as follows:

(Fig 2.3 Model used)

3. RESULTS

Experimental testing of the gravity designed reinforced concrete frame yielded different results when exposed to lateral seismic loadings. Some of the results obtained are explained as follows:

3.1. Vulnerable Beam-Column Joints

It was noted during the seismic activity that with increase in intensity of the seismic loads, the beam column joints experienced gradual damage which propagated respectively. This happened as a result of deficiency in proper detailing of these joints for seismic and lateral loadings. As a result, these joints were found vulnerable to seismic activity.

(Fig 3.1 Vulnerable beam column joint)

3.2. Slippage of reinforcement bars

Another phenomenon noted during the seismic activity was the slippage of the reinforcement bars. This happened due to improper bonding of the bars and also due to provision of 90 degree hooks. The absence of seismic hooks (135 degree) caused the bars to slip from their position during the seismic activity. This resulted in poor load and action transfer of the seismic activity and caused damage to the structure.

(Fig 3.2 Slippage of reinforcement bars)

3.3. Cracking in shear force region

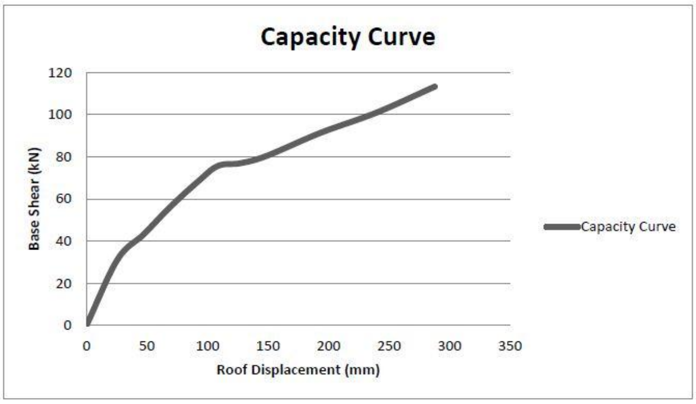
Absence of proper reinforcement and stirrup detailing for seismic and lateral forces caused the structure to behave poorly in shear loading. This resulted in the cracking of the structural members like beam and columns in shear force regions. This gives way to the failure of the structure if exposed continuously to the shear loading.

(Fig 3.3 Shear force region cracking)

3.4. Material Failure
Another major vulnerability of the structure noted against seismic activity was the material failure. As earlier stated, the concrete used is of 2000psi compressive strength. Also the reinforcement used is majorly for gravity loads only. This resulted in the failure of the material. This is also a problem in gravity designed structures and needs to be addressed in seismic designs.

(Fig 3.4 Material failure)

3.5. Capacity Curve
The data obtained from our experimental excitation of the structure yielded values for displacement and base shear which have been plotted to get capacity curve of our respected work. This curve can be used in the future for comparison with the curve of other structures and with standard values of column, beam and joint sway curves to get an insight of the behavior of the structure against seismic activity. The curve obtained is given as follows:



(Fig 3.5 Experimental Capacity Curve)

4. RECOMMENDATIONS

According to the results obtained by our research work for seismic vulnerability assessment of gravity designed reinforced concrete frames, the following recommendations are devised for proper designing and seismic response of structures, in order to avoid any harm caused by seismic activities to these and alike structures.

4.1. Beam-Column Joint Detailing
The first thing recommended from our work is that proper beam column joint detailing is utmost important in improving the seismic response of structures. This helps in the transfer of loads across different members to cater for better performance of the structure against all loadings including seismic and lateral loads.

4.2. Proper bonding and hooks in reinforcement
The next thing recommended is proper bonding of reinforcement bars to avoid their slippage in seismic activity. Also the hooks provided should be 135 degrees in stirrups to cater for the response in seismic activity. Proper bonding and hooks provision enables the reinforcement bars to act properly against all incoming loads and facilitates the structure to behave in a better manner against loadings including seismic loads.

4.3. Proper detailing of shear region
It is strongly recommended that proper detailing for shear region must be done for all members of frames that are subjected to seismic loads in order to get maximum out of all the members in response to seismic activity.

4.4. Use of high quality materials

The use of high quality materials is also highly recommended for better performance of structures against all types of loadings especially seismic loading. Better concrete and steel reinforcement adds to the strength of the structure against loading.

4.5. Use of retrofitting techniques

If there are such instances that structures are designed for gravity loads only and after construction, they are exposed to lateral loads, they need to be strengthened against such loads. In such scenarios, retrofitting techniques may be used for improving the capacity and response of the structures against all types of loads including seismic and lateral loads.

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