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International
Journal
Of Modern Engineering Research (IJMER)

Effect of Impulsive Loads on G+3 RCC Building

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ABSTRACT: *The study of response of structures subjected to impulse loads is of utmost importance in civil engineering. These are the forces with large magnitude that act for relatively very short interval of time. These forces are dynamic in nature that may impart out of plane deformations to the building and hence the stability of the building may be under scrutiny. Bomb blast is the best example for impulsive load. In this paper an attempt has been made to determine the response of a G+3 RCC building modeled in STAAD Pro subjected to triangular, rectangular and sinusoidal impulsive force for 0.5 seconds with maximum magnitude of 100kN. The effect of such loads on front, roof and side surface of the building was studied. It was observed that the critical deformations were obtained on the front and roof surface of the building. The variation of deformation along the height of the building were parabolic in nature with maximum deformations at the top surface of the building. It was also concluded that sufficient reinforcement should be provided in beam, columns and slabs to impart ductility to the building against impulse loads..*

I. INTRODUCTION

Building structures are frequently subjected to loads that are arbitrary in nature. Impulsive loading is a special form of dynamic loading of the system. These are the forces that act for very short duration of time and produce rapid changes in motion. These are also known as shock load. Bomb blast is the best example for impulsive load. Severe impulsive loads can originate from many sources. Impulse load on a structure may be due to collision of heavy vehicles with buildings or with bridge piers, rock falls in mountainous regions or falling of heavy masses during construction which have the potential to cause severe damage.

The structure's response to an impulse load can be broken into two parts:

i. Forced vibration reponse (when the structure is under load)
ii. Free vibration response (when the loading dissipates)

Since the load duration is very short, therefore the maximum response is either within the forced vibration phase or soon after it. Damping has much less significance in controlling the maximum response of the structure to impulsive loads because the maximum response to an impulsive loading will be obtained in a very short time, before the damping forces can absorb energy from the structure. Therefore, damping can be neglected for the response of impulsive loading.

The response of the structure to impulse excitations does not reach the steady state conditions. The response of the structure to such pulse excitations can be determined using various software packages or by one of the several analytical methods [1]:

i. Classical methods for solving differential equations
ii. Evaluating Duhammel's integral
iii. Expressing the impulse as the superposition of two or more simpler functions for which response solutions are easier to evaluate.

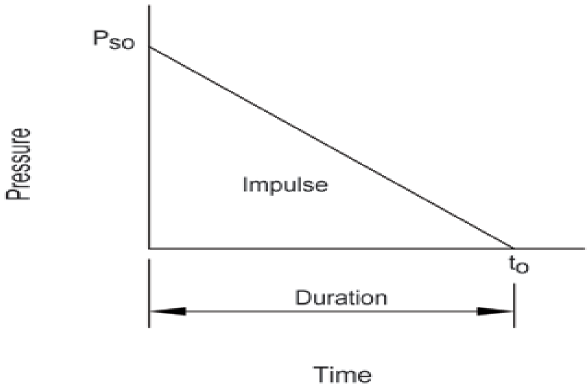

Fig. 1: Triangular impulse

II. LITERATURE REVIEW

Blast and impact situations are the most commonly encountered impulsive loads and it is the response of the structure to these types of loads that will be the primary focus of this paper. Several experimental and analytical works have already been conducted in past to study the response of structure subjected to these impulse loads. Remennikov [2] studied the methods for predicting the effect of bomb blast on buildings. A building was subjected to blast load produced by the detonation of high explosive device. Simplified analytical techniques were used for obtaining conservative estimates of the blast effects on buildings. Numerical techniques include Eulerian, Lagrangian, Euler-FCT, ALE and finite element modeling were used for accurate prediction of blast loads on commercial and public buildings.

Damasceno et al [3] analyzed the behavior of RC beams with steel fibers under impact loads. The first RC beam was casted without steel fiber and rest 3 with 0.5%, 1% and 2% of steel fibers respectively. It was found that section inertia was reduced from about 30% to 60% in beams with steel fibers hence resulting in failure of flexural reinforcements at higher load and increasing the ductility. It was also observed that the beam steel fibers presented less damage on the upper surface of concrete than those without fibers. I. K. Khan [4] analyzed the performance of reinforced concrete beam under point impact loading. An impact load was applied at the mid span of the RC beam by dropping a free falling 25.4 kg steel weight. It was observed that with the increase in grade of concrete, crack width and number of cracks were reduced in tension zone. It was also observed that for same grade of concrete minimum deflection was there for over reinforced beams.

S. Tachibana et al [5] established a performance based design method for reinforced concrete beams under perpendicular impact load. Impact experiments were performed using RC beams of varying span length, cross-section and main reinforcement. It was obtained that the impulse of the impacting mass is proportional to the momentum of the impacting mass and the maximum displacement is in proportion relation to the impact energy divided by the mean impact force.

III. BUILDING MODEL

The structure selected for this study is G+3 storey RCC building subjected to impulse load on the front surface of the building (in +X-direction). The overall length and width of the building is 8.0m and height of the building is 13.0m. The column dimensions used are 300mm x 300mm and the beam dimensions used are 250mm x 230mm and thickness of the slab is taken as 230mm. The building was modeled in STAAD Pro and was further analyzed for rectangular, triangular and sinusoidal impulse loads. The STAAD model of the building is as shown below in Fig. 2.

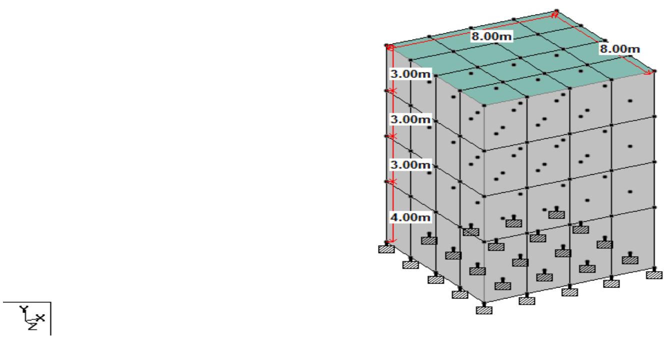

Fig. 2: STAAD model of G+3 RCC building

The unit weight of concrete is taken as 24 kN/m^3 and Poisson's ratio is taken as 0.17. The building is partially enclosed and the bottom portion of the wall is considered as fixed. Building is assumed in zone III according to IS 875 Part 3[6] for calculation of wind load on the building and the basic wind speed is taken as 47 m/sec.

IV. ANALYSIS OF THE BUILDING MODEL

In this model, the coordinate system has been considered as length of the building along X-direction, width along Z-direction and height of the structure along Y-direction. The building is subjected to triangular, rectangular and sinusoidal impulse load on the front surface of the building. The impulse load applied on the building has the maximum magnitude of 100kN. The front surface of the building was divided into 16 equal parts and each part was subjected to load history of impulse forces. The RCC building was modeled in STAAD Pro and was further analysed to obtain the results.

4.1. Triangular Impulse

The load-time history for triangular impulse load is shown below in Fig. 3.

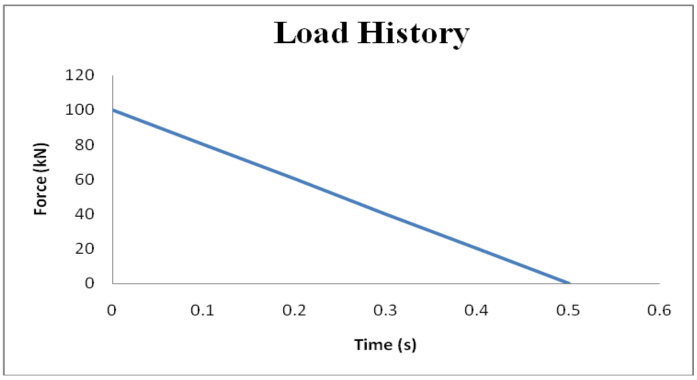

Fig. 3: Load history of triangular impulsive force

The critical deformation on the front surface occurs at the centre of the top surface of the building. The time-displacement curve is presented in Fig. 4.

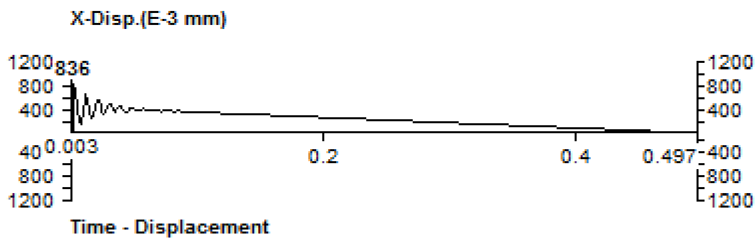

Fig. 4: Critical deformation on front surface of the building in X-direction

The maximum deformation on the roof surface occurs at the joint which joins roof and front surface of the building. The time-displacement curve is presented in Fig. 5.

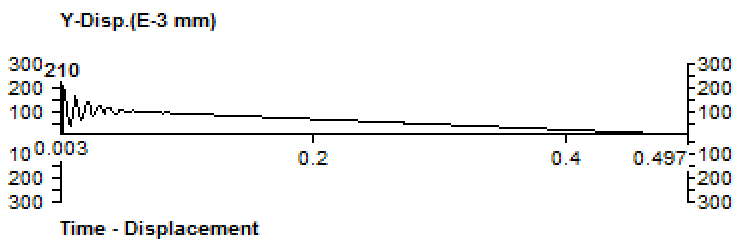

Fig. 5: Critical deformation on roof surface of the building in Y-direction

The critical deformation on the side surface occurs at height of 4m at the joint which joins front and side surface of the building. The time-displacement curve is shown below in Fig. 6.

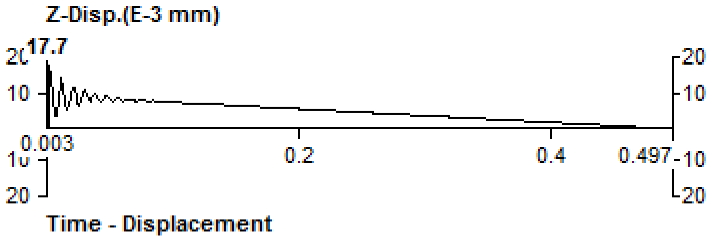

Fig. 6: Critical deformation on side surface of the building in Z-direction

4.2. Rectangular Impulse

The load-time history for rectangular impulse load is as shown below in Fig. 7.

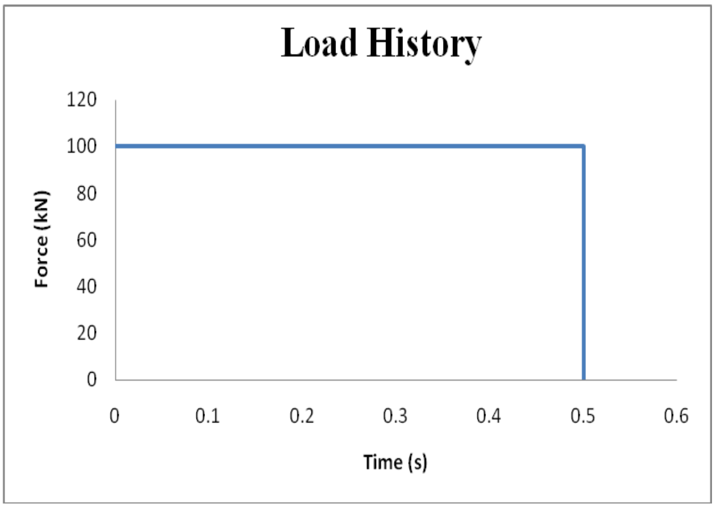

Fig. 7: Load history of rectangular impulsive force

The maximum deformation on the front surface occurs at the centre of top surface of the building. The time-displacement relation is as shown below in Fig. 8.

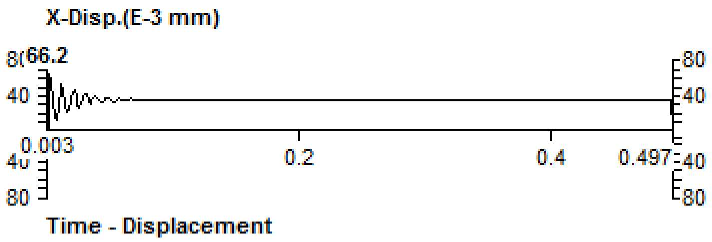

Fig. 8: Critical deformation on front surface of the buiding

The critical deformation on the roof surface occurs at the joint which joins roof and front surface of the building. The time-displacement curve is presented below in Fig. 9.

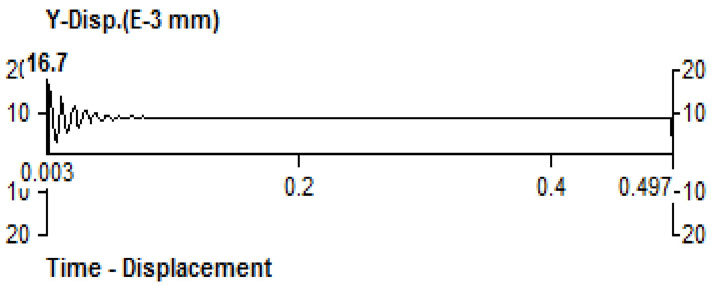

Fig. 9: Critical deformation on roof surface of the buiding

The critical deformation on the side surface occurs at height of 4m at the joint which joins front and side surface of the building. The time-displacement relation is presented below in Fig. 10.

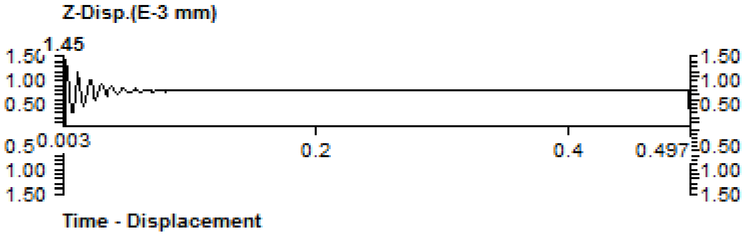

Fig. 10: Critical deformation on side surface of the buiding

4.3. Sinusoidal Impulse

The load-time history for sinusoidal impulse load is as shown below in Fig. 11.

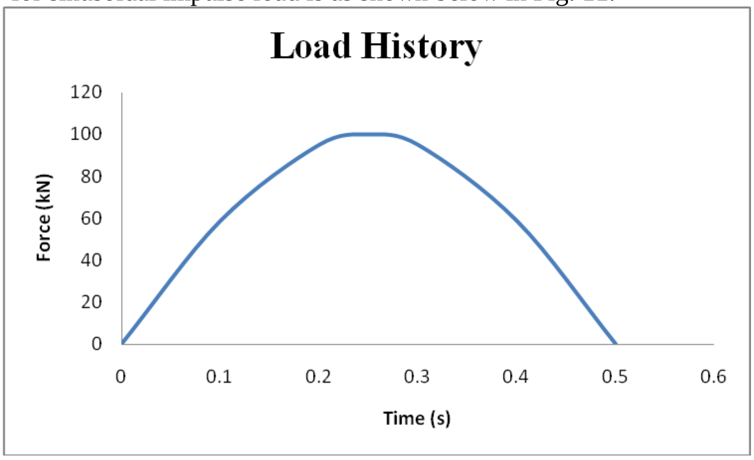

Fig. 11: Load history of sinusoidal impulsive force

The critical deformation on the front surface occurs at the centre of the top surface of the building. The time-displacement curve is presented below in Fig. 12.

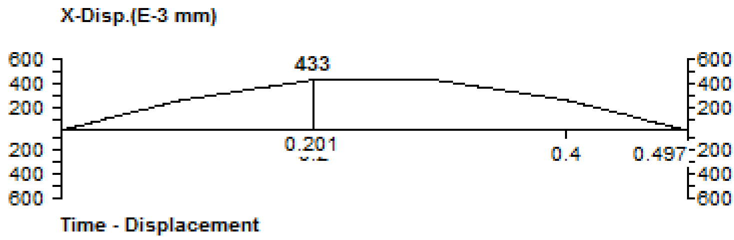

Fig. 12: Critical deformation on front surface of the buiding

The critical deformation on the roof surface occurs at the joint which joins roof and front surface of the building. The time-displacement curve is shown below in Fig. 13.

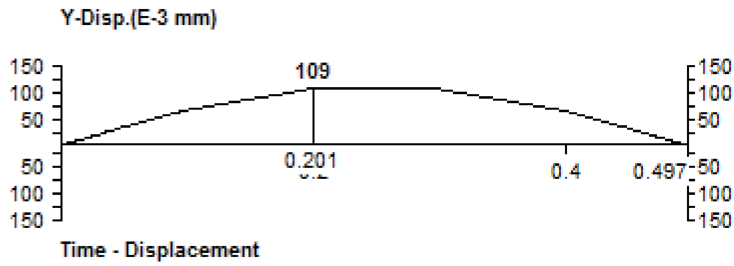

Fig. 13: Critical deformation on roof surface of the buiding

The critical deformation on the side surface occurs at height of 4m at the joint which joins front and side surface of the building. The time-displacement curve is shown below in Fig. 14.

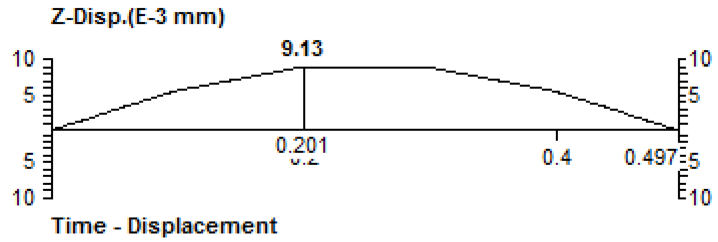

Fig. 14: Critical deformation on side surface of the buiding

4.4. Effect of Different Impulse Loads on RCC Building

To study the effect of different impulsive forces on RCC bulding the triangular, rectangular and sinusoidal impulse force with maximum magnitude of 100kN was applied on the front surface of the building. The critical deformations obtained on different surfaces of the building are tabulated below

Table I: Effect of triangular, rectangular and sinusoidal impulsive force on different surfaces of the building

Type of impulse	Triangular Impulse	Rectangular Impulse	Sinusoidal Impulse
Front Surface (mm)	0.836	0.066	0.433
Roof Surface (mm)	0.210	0.017	0.109
Side Surface (mm)	0.018	0.001	0.009

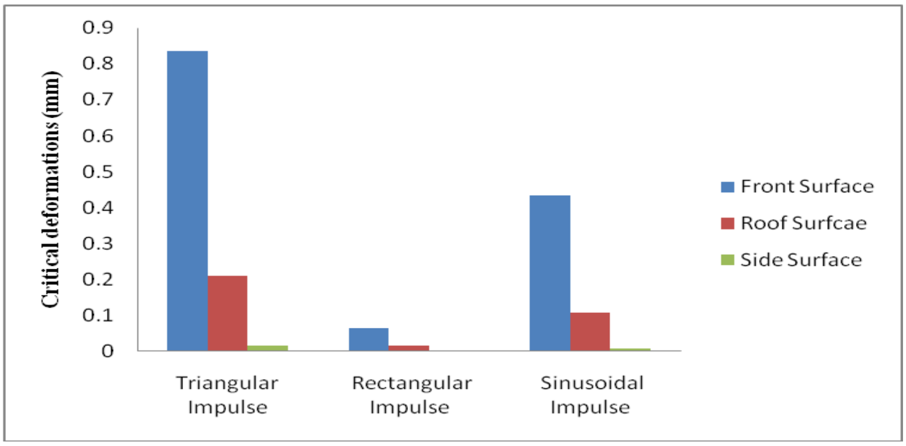

Fig. 15: Effect of triangular, rectangular and sinusoidal impulsive force on different surfaces of the building

V. CONCLUSIONS

Impulse load acting on structures may lead to the development high strain rates in RCC building. Due to the increased strain rate and dyamic nature of the load, the flexural strength of the concrete structure may be under scrutiny and strength of the building subjected to lateral forces may be reduced. Therefore, a study was conducted to study the behavior of RCC building modeled in STAAD Pro under various impulse forces and following conclusions were drawn.

- The maximum deformations obtained on the RCC building were within tolerable limits, but the velocity and acceleration with which the surfaces of the building vibrate were critical.
- Higher grade of concrete should be used for design of columns of building. Sufficient reinforcement should also be provided to impart stability against lateral impulse loads.
- The maximum deformations were obtained on the front surface of the building. The deformations obtained on the roof surface of the building were also critical.
- The variation of critical deformation along the height of the building is parabolic in nature with maximum deformations at the top surface of the building.
- Beams and slabs have to be designed as over-reinforced. Since the impulse load carrying capacity of the beam can be increased by increasing the area of steel in the building.
- Slabs should be designed as two way slab.

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