Non Linear Analysis of Single Storey RC Front Wall under Blast Loading

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Abstract

In modern days many civilian structures need shielding against blast effects. Past incidences of terrorist activities have increased the awareness towards the structural design to mitigate the effect of explosion and prevention of collapse of the building. The objective primary of blast resistant design is to prevent the collapse of the structural system and to maintain structural integrity through ductile and redundant behaviour. The primary aim of present work is to analyze the RC wall having SDOF with both end fixed under blast loading using ANSYS software.

Keywords—Blast load, single degree of freedom system, ANSYS software.

1. Introduction

If the threat of terrorist action cannot be stopped, Damage to the assets, loss of life and social panic are factors that have to be minimized. Also designing the structures as fully blast resistant is not a realistic and also not economical, however current engineering knowledge can enhance the new and existing buildings to reduce the effects of an explosion. The term blast is commonly used to describe any situation in which rapid release of energy occurs from a chemical, mechanical or nuclear source. However, from the point of view of the effects of explosions upon structural systems, there exists a set of fundamental characteristics which must be defined and considered, irrespective of the source. Conventionally buildings are constructed very differently than military structures and as such are generally very vulnerable to blast and ballistic threats. In order to design structures which are able to withstand explosions it is necessary to quantify the effects of such explosions.

2. Evaluation of Transformation Factor

2.1 Biggs shape function

Biggs shape functions are the functions which are used to find the load factor, mass factor and load – mass factor.

Consider a simply supported beam having a uniformly distributed load(udl).

Figure 1: Simply Supported beam having udl

$$M = \frac{Wx}{2}(L-x) \tag{1}$$

$$\frac{d^2y}{dx^2} = \frac{M(x)}{EI} \tag{2}$$

Deflection at each point

$$y = \frac{W}{24EI}\left(\frac{L^4}{16} - \frac{L^4}{4} + \frac{L^4}{2}\right) \tag{3}$$

Maximum deflection

$$ymax = \frac{5}{384}\left(\frac{wl^4}{EI}\right) \tag{4}$$

Shape function

$$\emptyset = \frac{y}{ymax} = \frac{16}{5L^4}(L^3x - 2Lx^3 + x^4) \tag{5}$$

Transformation factor

As per IS:4991-1968, the transformation factor is given as

$$KLM = KM/KL \tag{6}$$

$$KM = \frac{1}{Mt}\left\{\sum_{r=1}^{n} Mr\emptyset r^2 + \int m\emptyset^2(x)dx\right\} \tag{7}$$

$$KL = 1/Pt\left\{\sum_{r=1}^{j} pr\emptyset r + \int p(x)\emptyset(x)dx \right. \tag{8}$$

Where,

Mt = Total actual mass

N = Number of concentrated masses

Mr = Concentrated mass at point r

Φr = Deflection at point of an assumed deflected Shape for concentrated loads

m = Distributed mass intensity per unit length

φ(x) = Deflection at point x of an assumed deflected shape for distributed loads.

P(t) = Total Dyanmic load

j = Number of concentrated load points

Pr = Concentrated dynamic force at point r

P(x) = Intensity of distributed dynamic load per unit Length.

For the simply supported beam the load factor, mass factor and load mass factor are calculated as:

$$KL = \frac{1}{L}\int_0^L \emptyset(x)dx \qquad\qquad (9)$$

$$= 0.64$$

$$KM = \frac{1}{L}\int_0^L \emptyset^2(x)dx \qquad\qquad (10)$$

$$= 0.50$$

As per equation (6),

$$KLM = 0.78$$

3. Blast Load Calculation For the Front Wall

The problem data is given by L&T Chiyoda Limited which is mentioned below:

Building Height H = 5.7 m (above ground)

Building Width B = 38.4 m

Building Length L = 17.225 m

The blast wave parameters are mentioned below:

Peak over pressure Pso: 65.0 kPa

Time duration td : 0.15 sec

Clearing distance, S

S = H or B/2 whichever minimum = 5.7 m

Ambient Pressure P0 = 100.0 kPa

Shock velocity = 424.27 m/sec

Length of wave Lw = 63.65m

Peak Dynamic Wind Pressure, q0 = 13.5Kpa

The front wall is spanning vertically from foundation to roof. The design is typical wall segment 1m wide.

Peak Reflected Pressure Pr = 160.84 kPa

Clearing time tc = 0.0403sec

Drag coefficient Cd = 1

Stagnation pressure Ps = 78.52 kPa

Front wall Impulse lw = 7.55 kPa-sec

Effective duration te = 0.094 sec

4. MODELLING

A Single storey RC front wall model is shown below having following material properties:
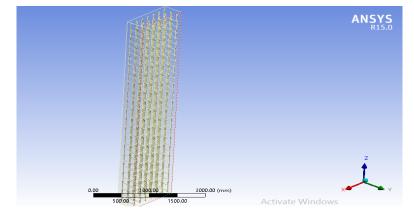

Figure 2: Model of RC wall

Material Properties:

Elasticity of steel Es = 205000 N/mm2

Elasticity of concrete Ec = 25635 N/mm2

Poisson's ratio = 0.3

Main steel Dia = 20 mm

Spacing = 150 mm

Boundary condition: Both ends are fixed.

5. ANALYSIS AND RESULT

Here non- linear analysis is done and time stepping method is used for calculating force at each time period having interval of 0.002 sec and that blast force is applied on the RC front wall.

Displacement in X, Y and Z direction are obtained from the ANSYS Software and the results are shown below
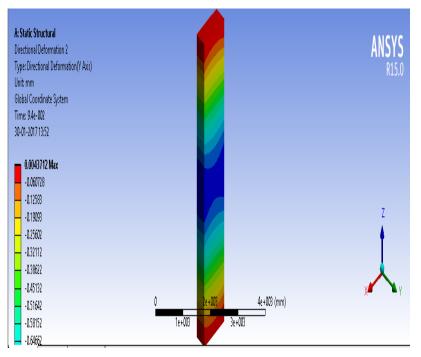

Figure 3: Displacement in the X-direction

	Time [s]	✔ Minimum [mm]	✔ Maximum [mm]
1	2.e-005	-2.3484	4.7859e-003
2	4.e-005	-2.3492	4.7986e-003
3	7.e-005	-2.3487	4.8e-003
4	1.e-004	-2.3489	4.8001e-003
5	4.8e-004	-2.3428	4.7983e-003
6	8.6e-004	-2.3367	4.7963e-003
7	1.43e-003	-2.3275	4.7935e-003
8	2.e-003	-2.3183	4.7907e-003
9	2.4e-003	-2.3122	4.7889e-003
10	2.8e-003	-2.3061	4.787e-003
11	3.4e-003	-2.2969	4.7842e-003
12	4.e-003	-2.2877	4.7814e-003
13	4.4e-003	-2.2816	4.7796e-003
14	4.8e-003	-2.2755	4.7776e-003
15	5.4e-003	-2.2663	4.7748e-003
16	6.e-003	-2.2571	4.772e-003
17	6.4e-003	-2.251	4.7702e-003
18	6.8e-003	-2.2448	4.7683e-003

Figure 4: Maximum and minimum displacement in X-direction

From the fig.3 it was seen that the maximum displacement is on the top most and the bottom most of the wall in the x-direction. It signifies that end portion of the wall gets affected more if the displacement is considered in the X-direction.

Fig.4 shows the maximum and minimum displacement of the RC front wall under blast loading and the deformation that is getting is very low. So it is safe in design.

Similarly the deformation in the Y-direction is considered and regarding to that analysis is done in ANSYS software.
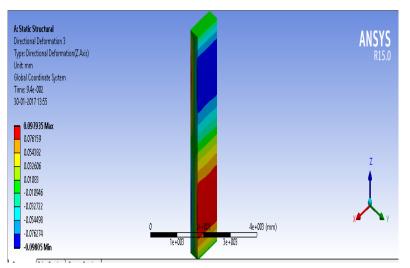

Figure 5: Displacement in the Y-direction

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From fig.5 lit was clearly seen that the maximum deformation is occurring in the lowest most region of the RC front wall considering the deformation in the Y-direction.

	Time [s]	✔ Minimum [mm]	✔ Maximum [mm]
1	2.e-005	-5.7007e-002	5.683e-002
2	4.e-005	-5.703e-002	5.6854e-002
3	7.e-005	-5.7015e-002	5.6842e-002
4	1.e-004	-5.7023e-002	5.6849e-002
5	4.8e-004	-5.6912e-002	5.6738e-002
6	8.6e-004	-5.6798e-002	5.6625e-002
7	1.43e-003	-5.6629e-002	5.6455e-002
8	2.e-003	-5.6459e-002	5.6285e-002
9	2.4e-003	-5.6346e-002	5.6172e-002
10	2.8e-003	-5.6233e-002	5.6059e-002
11	3.4e-003	-5.6063e-002	5.589e-002
12	4.e-003	-5.5893e-002	5.572e-002
13	4.4e-003	-5.578e-002	5.5608e-002
14	4.8e-003	-5.5667e-002	5.5494e-002
15	5.4e-003	-5.5497e-002	5.5325e-002
16	6.e-003	-5.5327e-002	5.5155e-002
17	6.4e-003	-5.5214e-002	5.5042e-002
18	6.8e-003	-5.5101e-002	5.4929e-002

Graphics   Tabular Data

Figure 6: Maximum and minimum displacement in Y-direction

In this direction the deformation is more as compare to the X-direction when the wall is subjected to the blast loading.
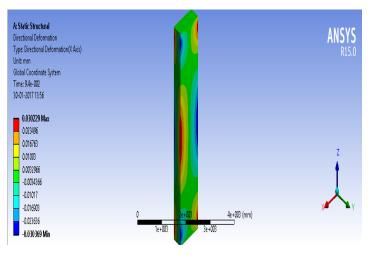

Figure 7: Displacement in the Z-direction

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]
1	2.e-005	-5.7007e-002	5.683e-002
2	4.e-005	-5.703e-002	5.6854e-002
3	7.e-005	-5.7015e-002	5.6842e-002
4	1.e-004	-5.7023e-002	5.6849e-002
5	4.8e-004	-5.6912e-002	5.6738e-002
6	8.6e-004	-5.6798e-002	5.6625e-002
7	1.43e-003	-5.6629e-002	5.6455e-002
8	2.e-003	-5.6459e-002	5.6285e-002
9	2.4e-003	-5.6346e-002	5.6172e-002
10	2.8e-003	-5.6233e-002	5.6059e-002
11	3.4e-003	-5.6063e-002	5.589e-002
12	4.e-003	-5.5893e-002	5.572e-002
13	4.4e-003	-5.578e-002	5.5608e-002
14	4.8e-003	-5.5667e-002	5.5494e-002
15	5.4e-003	-5.5497e-002	5.5325e-002
16	6.e-003	-5.5327e-002	5.5155e-002
17	6.4e-003	-5.5214e-002	5.5042e-002
18	6.8e-003	-5.5101e-002	5.4929e-002

Graphics   **Tabular Data**

Figure 8: Maximum and minimum displacement in Z-direction

In this the deformation is more on the edges and the deformation that is getting is same as the deformation in the Y-direction.

6. RESULT AND CONCLUSION

From the above analysis of RC wall under blast loading following points are observed:
1. In this paper it is observed that for SDOF system the Biggs Shape function is well defined in IS Code but not for MDOF.
2. Also the Nonlinear analysis of RC wall shows less deformation than standard mentioned in IS Code.
3. Biggs shape function was well defined in the IS: 4991-1968 and in this paper it was shown by manually calculation also.
4. The deflection in X-direction is comparatively less as compare to Y- direction and Z-direction.
5. Maximum deflection in X, Y and Z direction are 0.0047 mm, 0.0568mm and 0.0568mm respectively.
6. The same analysis can be done for different boundary condition.

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