Behaviour analysis of building column structure with retaining wall due to explosion load in front and side a construction

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Abstract. Analysis of the impact of explosion loads on buildings to determine the structural column reaction conditions as a result of the blast loads. The model building structure is a three-story structure with a height of 10.5 meters. At distances between 10 and 15 meters from the source of the blast, the analysed explosive weight of 500 kg TNT was converted to a static load. SAP2000 software was used to conduct the analysis. The analyses' results in the form of a moment force that compares a building's column structure's response. Based on this analysis, it can be concluded that the conditions in the structure without restrained walls are insufficient to withstand the blast load, while the structure with restrained walls is capable of receiving explosive loads.

1. Introduction
There is a design method of civil building in building construction, and the loading factor is an absolute study that is very significant in planning. These loads are classified as dead loads, live loads, wind loads, earthquake loads, and explosion loads. Explosion loads are rarely included in the construction design planning phase, even though blast loads may have a fatal effect on building construction [1-3].

The model will be adjusted based on the difference in distance explosions of 10 meters and 15 meters on the side and front of the structure, with the same bomb mass at both distances. The moment force produced by the explosion load will be compared in two structural models, according to the results of the study [4-6].

The research result is a study of the strength behaviour of columns under explosion loads to see which are stronger at avoiding structural failures. This research aims to determine the effect of waves on the building structure of columns caused by an explosion load at a distance of 10 and 15 meters. The benefits of this study are meant to provide information about building damage caused by explosion loads, and from the research's findings, it can be built into recent knowledge to attempt some explosion load analysis.

The research is based on the following assumptions:

1. For structural modelling, a three-story residential building frame was used.
2. The analysis relied on the SNI 1727-2013 and SNI 2847-2013 criteria.
3. An explosive charge of 500 kg TNT was used at a distance of 10 meters and 15 meters.
4. The bomb was detonated on the structure's side and in front of it.
5. The bomb that is being investigated is external (outside the building),
6. Structural loading simulation using SAP2000 software.
7. The difference in the building structure's moment due to the blast load at 10 meters and 15 meters is the calculated parameter.
8. The following are the structure dimensions: a. The element dimensions and the form of the structure as shown in the diagram:

The element dimensions and the shape of the structure are shown in figure 1 to figure 3.

Figure 1. 3-Dimensional View of The Building

Figure 2. Floor Plan of The Building

Figure 3. Side View of The Building

a. Concrete compression strength, $f_{c'} = 21$ MPa
b. The quality of main reinforcement, $f_y = 400$ MPa
c. The quality of shear reinforcement, $f_y = 240$ MPa
d. Column dimensions = 0.35 m x 0.55 m
e. Beam-1 dimensions = 0.25 m x 0.35 m
f. Tie beam dimensions = 0.35 m x 0.55m

g. Sloff beam dimensions = 0.20 m x 0.25m

h. Ringbalk-1 dimensions = 0.25 m x 0.40m

i. Plate dimensions = 0.12 m

The number of floors = 3 floors with the height of the building is 10.5 meters.

2. Materials and Methods

2.1 Materials

The materials needed in this research is Microsoft Excel software for calculating the distribution of blast waves and SAP2000 software to analyse building structures due to explosion loads [7] as given in Figure 4 and Figure 5.

![Figure 4. Microsoft Excel Software](image1)

![Figure 5. SAP2000 Software](image2)

2.2 Methods

There are several methods used in this research, among others: literature studies, testing of building structures due to blast loads, and analysis of test results. With the following data:
2.2.1 Primary data. Primary data needed in this study include data on the R (Wavelength until it hits the joint point), Z (Scaled distance), Pr (Parameters of the explosion load process), and P (the strength of the explosion wave) [8].

1. R (Wavelength until it hits the joint point)
The first step in performing an explosion wave analysis is to determine the R-value.

   a. To find the value of R on the ground floor in meters, use the following formula:

   \[ R (m) = \sqrt{\text{Explosion load distance}^2 + \text{Beam length}^2} \]

   b. To find the R-value on the 1st floor to 3rd floor, use the following formula:

   \[ R (m) = \sqrt{\text{Building height}^2 + \text{R ground floor}^2} \]

   c. To calculate the value of R in ft, use the following formula:

   \[ R (ft) = \sqrt{R (m)} \times 3.28 \]

2. Z (Scaled distance)
After calculated the R-value, use the following formula to determine the Z value:

\[ Z = \frac{R(ft)}{W^3} \]

3. Pr (Parameters of the explosion load process)
Pr is calculated using a graphic by drawing a straight line up in conjunction with the Z value until the Pr wave line is formed, then drawing a straight line to the left to obtain the Pr value [9-10]. The result is given in Figure 6.

After getting the Pr value, the Pr value is converted into Kpa, Mpa, and Newton units. With the following formula:

\[ \text{Pr}(KPa) = \text{Pr}(PSI) \times 6.89 \]
\[ \text{Pr}(MPa) = \frac{\text{Pr}(KPa)}{1000} \]
\[ \text{Pr}(N) = \text{Pr}(MPa) \times \text{column dimensions} \]

4. P (the strength of the explosion wave)
The P-value data is the final data that will be used to calculate the blast wave value that will be inputted into the building structure. The following formula is used to calculate the P-value:

\[ P = \frac{\text{Pr}(N)}{9.8} \]
Figure 6. Surface explosion wave parameters [11]

2.2.2 Secondary data. The secondary data required for this study is wall material data, which will be inputted into SAP2000 as a comparison in two cases, namely structures with confined walls and without confined walls.

2.3 Data Processing. Calculations with Excel Microsoft software can be used to collect primary and secondary data, which can then be analysed with SAP2000 software.

Wave data was generated as a result of two separate explosion loads, one on the front centre side of the building structure and the other on the side of the structure with a 500kg TNT blast load, both at a distance of 10 meters and 15 meters.

The measures used to calculate the waves are as follows:

a. Microsoft Excel
   1) Prepare the data for the explosion wave analysis that has been collected.
   2) Comprehend the data, as well as any supporting data.
   3) Calculation of the data collected to obtain R, Z, and Pr results
   4) Once Pr has a result, it is recalculated to produce a P result.
   5) After the P results have been collected, the results can be analyzed using SAP2000 software to assess the structure's strength.

b. SAP2000
   1) On SAP2000, pick a new model from the available toolbar to create a building template.
   2) Next, enter the data in conjunction with the structure to be evaluated, such as the building's height, length, and width.
   3) Once the initial structure drawing is complete, use the toolbar to identify material to enter the material data in the form of reinforcement and consistency used in the structural data.
4) Then, in the define-frame section toolbar, enter the column, beam, and other supporting details.
5) Finally, enter the loading combination so that the results match your expectations.
6) The loading input is in the form of a dead load on the frame and a live load on the floor plate, with the loading results, are written on SNI 2013.
7) Once you’ve done, run the structure's results without using P or wave loads to see if the moment that happens is sufficient.

3. Results of the Study
The sketch of the bomb located in the analysed model variations can be seen in Figure 7. The mass of the TNT bomb used was 500 kg with 10 meters and 15 meters distance in front of the structure.

![Figure 7. Sketch of Bombs on The Structure](image)
The sketch of the bomb located in the analysed model variations can be seen in Figure 8. The mass of the TNT bomb used was 500 kg with 15 meters distance on side of the structure.

Figure 8. Sketch of Bombs on The Structure

The explosion waves that hit the structure would run into the waves propagation which was modelled at each joint point that worked. The following table recapitulated the calculation of wave distribution for the two explosion distances on the front of the structure which can be seen in Tables 1 and 2.

| Joint (m) | v  | W (lb)   | R (m) | R (ft) | Z   | Pr (N)   | P (Kg)   |
|----------|----|----------|-------|--------|-----|----------|----------|
| 0        | 3.5| 1102.32  | 10    | 32.00  | 3.175| 737919   | 75297.86 |
| 4        | 3.5| 1102.32  | 10.770| 35.327 | 3.420| 612521   | 62502.14 |
| 8        | 3.5| 1102.32  | 12.806| 42.004 | 4.066| 397897.5 | 40601.79 |
| 12       | 3.5| 1102.32  | 15.620| 51.235 | 4.960| 359313.5 | 36664.64 |
| 16       | 3.5| 1102.32  | 18.868| 61.887 | 5.991| 110929   | 11319.29 |
| 20       | 3.5| 1102.32  | 22.361| 73.343 | 7.100| 67522    | 6890.00  |
| 24       | 3.5| 1102.32  | 26    | 85.280 | 8.256| 45818.5  | 4675.36  |
| 24       | 3.5| 1102.32  | 10.770| 35.327 | 3.420| 612521   | 62502.14 |
| 8        | 3.5| 1102.32  | 12.806| 42.004 | 4.066| 397897.5 | 40601.79 |
| 12       | 3.5| 1102.32  | 15.620| 51.235 | 4.960| 359313.5 | 36664.64 |
| 16       | 3.5| 1102.32  | 18.868| 61.887 | 5.991| 110929   | 11319.29 |
|   |   | 1102.32 | 22.361 | 73.343 | 7.100 | 67522 | 6890.00 |
|---|---|---------|--------|--------|-------|-------|---------|
| 20| 3.5|         |        |        |       |       |         |
| 24| 3.5| 1102.32 | 26     | 85.280 | 8.256 | 45818.5 | 4675.36 |
| 0 | 3.5| 1102.32 | 10.595 | 34.751 | 3.364 | 595640.5 | 60779.64 |
| 4 | 3.5| 1102.32 | 11.325 | 37.145 | 3.596 | 504003.5 | 51428.93 |
| 8 | 3.5| 1102.32 | 13.276 | 43.545 | 4.215 | 359313.5 | 36664.64 |
| 12| 3.5| 1102.32 | 16.008 | 52.506 | 5.083 | 177245.25 | 18086.25 |
| 16| 3.5| 1102.32 | 19.190 | 62.943 | 6.093 | 101283 | 10335.00 |
| 20| 3.5| 1102.32 | 22.633 | 74.236 | 7.186 | 68727.75 | 7013.04 |
| 24| 3.5| 1102.32 | 26.235 | 86.049 | 8.330 | 47024.25 | 4798.39 |
| 4 | 3.5| 1102.32 | 11.325 | 37.145 | 3.596 | 504003.5 | 51428.93 |
| 8 | 3.5| 1102.32 | 13.276 | 43.545 | 4.215 | 359313.5 | 36664.64 |
| 12| 3.5| 1102.32 | 16.008 | 52.506 | 5.083 | 177245.25 | 18086.25 |
| 16| 3.5| 1102.32 | 19.190 | 62.943 | 6.093 | 101283 | 10335.00 |
| 20| 3.5| 1102.32 | 22.633 | 74.236 | 7.186 | 68727.75 | 7013.04 |
| 24| 3.5| 1102.32 | 26.235 | 86.049 | 8.330 | 47024.25 | 4798.39 |
| 0 | 7  | 1102.32 | 12.698 | 41.651 | 4.032 | 352079 | 35926.43 |
| 4 | 7  | 1102.32 | 13.314 | 43.668 | 4.227 | 332787 | 33957.86 |
| 8 | 7  | 1102.32 | 15.008 | 49.227 | 4.765 | 262853.5 | 26821.79 |
| 12| 7  | 1102.32 | 17.471 | 57.306 | 5.548 | 147101.5 | 15010.36 |
| 16| 7  | 1102.32 | 20.427 | 67.000 | 6.486 | 92842.75 | 9473.75 |
| 20| 7  | 1102.32 | 23.691 | 77.706 | 7.522 | 57876 | 5905.71 |
| 24| 7  | 1102.32 | 27.152 | 89.060 | 8.621 | 39789.75 | 4060.18 |
| 4 | 7  | 1102.32 | 13.314 | 43.668 | 4.227 | 332787 | 33957.86 |
| 8 | 7  | 1102.32 | 15.008 | 49.227 | 4.765 | 262853.5 | 26821.79 |
| 12| 7  | 1102.32 | 17.471 | 57.306 | 5.548 | 147101.5 | 15010.36 |
| 16| 7  | 1102.32 | 20.427 | 67.000 | 6.486 | 92842.75 | 9473.75 |
| 20| 7  | 1102.32 | 23.691 | 77.706 | 7.522 | 57876 | 5905.71 |
| 24| 7  | 1102.32 | 27.152 | 89.060 | 8.621 | 39789.75 | 4060.18 |
| 0 | 10.5| 1102.3  | 16.477 | 54.045 | 5.232 | 177245.25 | 18086.25 |
| 4 | 10.5| 1102.3  | 16.956 | 55.615 | 5.384 | 143484.25 | 14641.25 |
| 8 | 10.5| 1102.3  | 18.317 | 60.079 | 5.816 | 130221 | 13287.86 |
Table 2. Distribution of Explosion Waves 15 Meters Distance on The Front of The Structure

| Joint (m) | v   | W (lb) | R (m) | R (ft) | Z     | Pr (N) | P (Kg)   |
|-----------|-----|--------|-------|--------|-------|--------|----------|
| 0         | 3.5 | 1102.32| 15    | 49.200 | 4.763 | 237532.75 | 24238.04 |
| 4         | 3.5 | 1102.32| 15.524| 50.919 | 4.929 | 225475.25 | 23007.68 |
| 8         | 3.5 | 1102.32| 17.000| 55.760 | 5.398 | 186891.25 | 19070.54 |
| 12        | 3.5 | 1102.32| 19.209| 63.007 | 6.099 | 108517.5  | 11073.21 |
| 16        | 3.5 | 1102.32| 21.932| 71.936 | 6.964 | 74756.5   | 7628.21  |
| 20        | 3.5 | 1102.32| 25.000| 82.000 | 7.938 | 53053     | 5413.57  |
| 24        | 3.5 | 1102.32| 28    | 92.830 | 8.986 | 40995.5   | 4183.21  |
| 4         | 3.5 | 1102.32| 15.524| 50.919 | 4.929 | 225475.25 | 23007.68 |
| 8         | 3.5 | 1102.32| 17.000| 55.760 | 5.398 | 186891.25 | 19070.54 |
| 12        | 3.5 | 1102.32| 19.209| 63.007 | 6.099 | 108517.5  | 11073.21 |
| 16        | 3.5 | 1102.32| 21.932| 71.936 | 6.964 | 74756.5   | 7628.21  |
| 20        | 3.5 | 1102.32| 25.000| 82.000 | 7.938 | 53053     | 5413.57  |
| 24        | 3.5 | 1102.32| 28    | 92.830 | 8.986 | 40995.5   | 4183.21  |
|   |   |   |   |   |
|---|---|---|---|---|
| 24 | 3.5 | 1102.32 | 28.518 | 93.538 | 9.055 | 35931.35 | 3666.46 |
| 4  | 3.5 | 1102.32 | 15.914 | 52.197 | 5.053 | 231504   | 23622.86 |
| 8  | 3.5 | 1102.32 | 17.357 | 56.930 | 5.511 | 178451   | 18209.29 |
| 12 | 3.5 | 1102.32 | 19.526 | 64.044 | 6.200 | 97665.75 | 9965.89  |
| 16 | 3.5 | 1102.32 | 22.209 | 72.846 | 7.052 | 69933.5  | 7136.07  |
| 20 | 3.5 | 1102.32 | 25.244 | 82.800 | 8.015 | 47024.25 | 4798.39  |
| 24 | 3.5 | 1102.32 | 28.518 | 93.538 | 9.055 | 35931.35 | 3666.46  |
| 0  | 7   | 1102.32 | 16.919 | 55.494 | 5.372 | 190508.5 | 19439.64 |
| 4  | 7   | 1102.32 | 17.385 | 57.024 | 5.520 | 178451   | 18209.29 |
| 8  | 7   | 1102.32 | 18.715 | 61.385 | 5.942 | 110929   | 11319.29 |
| 12 | 7   | 1102.32 | 20.742 | 68.035 | 6.586 | 89225.5  | 9104.64  |
| 16 | 7   | 1102.32 | 23.286 | 76.379 | 7.394 | 62699    | 6397.86  |
| 20 | 7   | 1102.32 | 26.196 | 85.924 | 8.318 | 45818.5  | 4675.36  |
| 24 | 7   | 1102.32 | 29.364 | 96.314 | 9.324 | 33761    | 3445.00  |
| 4  | 7   | 1102.32 | 17.385 | 57.024 | 5.520 | 178451   | 18209.29 |
| 8  | 7   | 1102.32 | 18.715 | 61.385 | 5.942 | 110929   | 11319.29 |
| 12 | 7   | 1102.32 | 20.742 | 68.035 | 6.586 | 89225.5  | 9104.64  |
| 16 | 7   | 1102.32 | 23.286 | 76.379 | 7.394 | 62699    | 6397.86  |
| 20 | 7   | 1102.32 | 26.196 | 85.924 | 8.318 | 45818.5  | 4675.36  |
| 24 | 7   | 1102.32 | 29.364 | 96.314 | 9.324 | 33761    | 3445.00  |
| 0  | 10.5| 1102.32 | 19.912 | 65.312 | 6.323 | 98871.5  | 10088.93 |
| 4  | 10.5| 1102.32 | 20.310 | 66.617 | 6.449 | 95254.25 | 9719.82  |
| 8  | 10.5| 1102.32 | 21.459 | 70.386 | 6.814 | 80785.25 | 8243.39  |
| 12 | 10.5| 1102.32 | 23.249 | 76.256 | 7.382 | 60287.5  | 6151.79  |
| 16 | 10.5| 1102.32 | 25.544 | 83.785 | 8.111 | 47024.25 | 4798.39  |
| 20 | 10.5| 1102.32 | 28.222 | 92.569 | 8.961 | 40995.5  | 4183.21  |
| 24 | 10.5| 1102.32 | 31.185 | 102.287| 9.902 | 28938    | 2952.86  |
The following table recapitulated the calculation of wave distribution for the explosion distances on the side of the structure which can be seen in Table 3.

| Joint | W (lb) | R (m) | R (ft) | Z | Pr (N) | P (Kg) |
|-------|--------|-------|--------|---|--------|--------|
| 0     | 1102.32| 18.9670767 | 62.21 | 6.02 | 62699 | 6397.857143 |
| 3.5   | 1102.32| 19.583156 | 64.23 | 6.22 | 57187 | 5833.074 |
| 6     | 1102.32| 20.2854628 | 66.54 | 6.44 | 52364 | 5341.128 |
| 8     | 1102.32| 21.1541958 | 69.39 | 6.72 | 44096 | 4497.792 |
| 10    | 1102.32| 23.3130865 | 76.47 | 7.40 | 33072 | 3373.344 |
| 14    | 1102.32| 18.3098334 | 60.06 | 5.81 | 83369 | 8503.638 |
| 0     | 1102.32| 16.5529454 | 54.29 | 5.26 | 188338.15 | 19210.4913 |
| 3.5   | 1102.32| 16.9189243 | 55.49 | 5.37 | 183032.85 | 18669.3507 |
| 6     | 1102.32| 17.6068169 | 57.75 | 5.59 | 171095.925 | 17451.78435 |
| 8     | 1102.32| 18.3847763 | 60.30 | 5.84 | 124674.55 | 12716.8041 |
| 10    | 1102.32| 19.3390796 | 63.43 | 6.14 | 1167166 | 11905.0932 |
| 14    | 1102.32| 21.6794834 | 71.11 | 6.88 | 84884.8 | 8658.2496 |
| 0     | 1102.32| 15.4029218 | 50.52 | 4.89 | 259959.7 | 26515.8894 |
| 3.5   | 1102.32| 15.795569 | 51.81 | 5.02 | 248022.775 | 25298.32305 |
| 6     | 1102.32| 16.5302753 | 54.22 | 5.25 | 237412.175 | 24216.04185 |
| 8     | 1102.32| 17.356555 | 56.93 | 5.51 | 222822.6 | 22727.9052 |
| 10    | 1102.32| 18.3643677 | 60.24 | 5.83 | 204254.05 | 20833.9131 |
| 14    | 1102.32| 20.8146583 | 68.27 | 6.61 | 90190.1 | 9199.3902 |
| 0     | 1102.32| 15 | 49.20 | 4.76 | 120333.85 | 12274.0527 |
| 3.5   | 1102.32| 15.4029218 | 50.52 | 4.89 | 118163.5 | 12052.677 |
| 6     | 1102.32| 16.1554944 | 52.99 | 5.13 | 108155.775 | 11031.88905 |
| 8     | 1102.32| 17 | 55.76 | 5.40 | 89225.5 | 9101.001 |
| 10    | 1102.32| 18.0277564 | 59.13 | 5.72 | 76565.125 | 7809.64275 |
| 14    | 1102.32| 20.5182845 | 67.30 | 6.51 | 41839.525 | 4267.63155 |

Furthermore, the force that had been obtained was inputted at each joint using SAP2000 software. Load that worked statically. The results of the load that has been inputted on the joint of the portal building structure can be seen in Figure 9, Figure 10 and Figure 11.
Figure 9. Load Input at the Joint with a Load Distance of 10 Meters

Figure 10. Load Input at the Joint with a Load Distance of 15 meters.

Figure 11. Load Input at the Joint with a Load Distance of 15 meters inside of the structure.
The distribution calculation of the explosion wave on each model with different distances using SAP2000 software assistance according to Table 1, Table 2, and Table 3. The wave parameters obtained were the weight of the load due to the generated explosion load. The output obtained from structural modeling explained how the generated wave load could cause failure in columns structures.

**Table 4. Results analysis of the 1st floor**

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C1      | 226.328  | 9458.823 | Safe   |
| C2      | 396.324  | 10201.392| Safe   |
| C3      | 455.568  | 11726.313| Safe   |
| C4      | 456.444  | 11748.87 | Safe   |
| C5      | 453.817  | 11681.241| Safe   |
| C6      | 517.641  | 13324.069| Not Safe|
| C7      | 517.434  | 15098.843| Not Safe|
| C8      | 517.641  | 13324.069| Not Safe|
| C9      | 453.817  | 11681.241| Safe   |
| C10     | 456.444  | 11748.87 | Safe   |
| C11     | 455.568  | 11726.313| Safe   |
| C12     | 396.324  | 10201.392| Safe   |
| C13     | 226.328  | 9458.823  | Safe   |

**Table 5. Results analysis of the 2nd floor**

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C1      | 146.399  | 4214.092 | Safe   |
| C2      | 253.595  | 6649.357 | Safe   |
| C3      | 283.274  | 7291.476 | Safe   |
| C4      | 283.231  | 7290.363 | Safe   |
| C5      | 280.552  | 7221.398 | Safe   |
| C6      | 332.661  | 8561.161 | Not Safe|
| C7      | 330.569  | 9214.262 | Not Safe|
| C8      | 332.661  | 8561.161 | Safe   |
The results of the column structure capacity check revealed that the moments obtained on each floor were different, with the construction moments on the first floor being larger than the second and third floors. Damage was found in columns 6, columns 7, and 8 with the successive moment magnitude, is 13324.069 KNmm, 15098.843 KNmm, and 13324.069 KNmm.

The result for the second floor, the damage was found in columns 6, and columns 7 with the successive moment magnitude, is 8561.161 KNmm, and 9214.262 KNmm. So it could be said that the column structure failed in a percentage of 4.27% for the first floor and 2.99% for the second floor. While on the third floor it could be known that the moment was smaller than the first and second floor, so the structure didn't run into failure.

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C27     | 74.037   | 1905.724 | Safe   |
| C28     | 100.889  | 2596.875 | Safe   |
| C29     | 100.47   | 2586.088 | Safe   |
| C30     | 100.264  | 2580.801 | Safe   |
| C31     | 98.866   | 2544.823 | Safe   |
| C32     | 89.549   | 2304.995 | Safe   |
| C33     | 88.445   | 2324.178 | Safe   |
| C34     | 89.549   | 2304.995 | Safe   |
| C35     | 98.866   | 2544.823 | Safe   |
| C36     | 100.264  | 2580.801 | Safe   |
| C37     | 100.47   | 2586.088 | Safe   |
| C38     | 100.889  | 2596.875 | Safe   |
| C39     | 74.037   | 1905.724 | Safe   |

Table 6. Results analysis of the 3rd floor
Table 7. Analysis Results Columns

|       | Average of M3 (KNmm) | Percentage (%) |
|-------|----------------------|----------------|
| 1st FLOOR | 11644.635            | 4.27%          |
| 2nd FLOOR | 7051.535             | 2.99%          |
| 3rd FLOOR | 2412.523             | 0%             |

Table 8. Results analysis of the 1st floor

|       | P (KNmm) | M (KNmm) | Status |
|-------|----------|----------|--------|
| C1    | 242.68   | 9311.848 | Safe   |
| C2    | 414.689  | 10674.084| Safe   |
| C3    | 475.74   | 12245.517| Safe   |
| C4    | 476.805  | 12272.965| Safe   |
| C5    | 475.105  | 12229.213| Safe   |
| C6    | 441.854  | 11373.315| Safe   |
| C7    | 440.83   | 12637.128| Safe   |
| C8    | 441.854  | 11373.315| Safe   |
| C9    | 475.105  | 12229.213| Safe   |
| C10   | 476.805  | 12272.965| Safe   |
| C11   | 475.74   | 12245.517| Safe   |
| C12   | 414.689  | 10674.084| Safe   |
| C13   | 242.68   | 9311.848  | Safe   |

Table 9. Results analysis of the 2nd floor

|       | P (KNmm) | M (KNmm) | Status |
|-------|----------|----------|--------|
| K14   | 153.641  | 11073.564| Safe   |
| K15   | 261.929  | 7000.843 | Safe   |
| K16   | 292.459  | 7527.892 | Safe   |
| K17   | 292.635  | 7860.935 | Safe   |
| K18   | 290.731  | 7483.418 | Safe   |
Based on the results of checking the capacity of the column structure, it can be shown that the moments obtained on each floor have different results. The resulting moment is smaller than the structure due to the explosion at a distance of 10 meters, and the column structure on each portal is safe and able to withstand loading due to explosion load, that the column structure on each portal is safe due to explosion and there is no damage to the structure of the building.

The difference distance of explosion source on the structure has a significant impact on the structure's effects and decides whether the structure is safe or not. So that the structure's ratio due to the blast load can be seen at a distance between 10 meters and 15 meters, and the structure of this building has a safe distance from the explosion load at a distance of 15 meters.

### Table 10. Results analysis of the 3rd floor

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| K27     | 88.412   | 2275.712 | Safe   |
| K28     | 103.062  | 2652.825 | Safe   |
| K29     | 102.794  | 2645.924 | Safe   |
| K30     | 102.739  | 2644.507 | Safe   |
| K31     | 101.74   | 2618.8   | Safe   |
| K32     | 94.704   | 2437.683 | Safe   |
| K33     | 93.957   | 2472.24  | Safe   |
| K34     | 94.704   | 2437.683 | Safe   |
| K35     | 101.74   | 2618.8   | Safe   |
| K36     | 102.739  | 2644.507 | Safe   |
| K37     | 102.794  | 2645.924 | Safe   |
| K38     | 103.062  | 2652.825 | Safe   |
| K39     | 88.412   | 2275.712 | Safe   |
Table 11. Results analysis of the 1st floor

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C1      | 261.021  | 19744    | Safe   |
| C2      | 402.308  | 12165.779| Safe   |
| C3      | 372.886  | 11276.087| Safe   |
| C4      | 362.357  | 10957.685| Safe   |
| C5      | 462.47   | 13985.106| Safe   |
| C6      | 357.51   | 10811    | Safe   |

Table 12. Results analysis of the 2nd floor

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C14     | 163.928  | 10310.376| Safe   |
| C15     | 249.385  | 10362.73 | Safe   |
| C16     | 225.681  | 10490.624| Safe   |
| C17     | 221.578  | 10954.73 | Safe   |
| C18     | 277.836  | 10630.597| Safe   |
| C19     | 215.941  | 9590.138 | Safe   |

Table 13. Results analysis of the 3rd floor

| Columns | P (KNmm) | M (KNmm) | Status |
|---------|----------|----------|--------|
| C27     | 61.325   | 11194.655| Safe   |
| C28     | 95.372   | 10437.183| Safe   |
| C29     | 73.888   | 9706.022 | Safe   |
| C30     | 70.685   | 9413.66  | Safe   |
| C31     | 94.387   | 9345.319 | Safe   |
| C32     | 68.998   | 8391.816 | Safe   |

The structure of the building due to the blast load beside the structure with a distance of 15 meters is analysed to prove that the structure of this building has a safe distance to the explosion load at a distance of 15 meters.
The results of the analysis indicate that the column structure does not collapse and is safe to receive a 500 kg TNT explosive wave load. So that it can prove that the building structures' safe distance from the blast wave is 15 meters.

4. Conclusion
Based on the data of wave analysis generated by explosion load which was positioned perpendicular to the side of the building structure by Y coordinate and Z coordinate with different explosion load distances and getting common explosion load mass, it could be concluded as:
1. The resultant moment force that is too large causes structural damage to the building column with an explosion load distance of 10 meters in front of the structure, with a moment of magnitude 15098.843 Knm.
2. The structure can withstand waves generated by an explosive load of 500 kg of TNT at a distance of 15 meters.
3. The structure has a safe distance from the blast wave, which is 15 meters from the structure.

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