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Explosion and Fire Resistance of Recycled Constituent Reinforced Concrete Structures

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Abstract

In the past few decades, the impact of explosions on buildings has been the area of research, mainly because buildings worldwide are increasingly facing the risk of deliberate explosion attacks, accidental explosions, and other forms of related explosion failure. The magnitude of the explosive load generated by most explosions is much higher than the design load of conventional structural engineering. As a result, with the intensification of global terrorist attacks, building owners, government departments, and design professionals have become more aware of the vulnerability and survivability of structures to explosive loads. Although much work on the impact of explosions on infrastructure continues, especially in India, numerical work to test explosives has been restricted. In addition, there are few computational tests for reinforced concrete beam-column joint to withstand explosive loads within a close range with a ruler spacing of less than as mentioned in IS: 1449. This may be due to the unreliable accuracy and relatively low survivability of most tools in this area.

Keywords: explosive loads; elevated temperature; explosive yield; Specific heat; Thermal conductivity.

1. Introduction

Because the uncertainty and difficulty of terrorist attacks and accidental explosions cannot be predicted, thereis little information on design recommendations and the performance of reinforced concrete structures exposed to explosives. Most of the results are not in the public domain. Civil engineers and others have been looking for solutions and developing inexpensive methods to protect lives and prevent a partial or complete collapse of the structure. Designed to prevent death and injury to residents and improve the survivability of buildings. Therefore, the solution includes improving physical security to increase and maintain clearances and strengthen the building's exterior walls. The preferred choice of materials for explosion-proof structures is based on their availability, relatively low cost, and their inherent ability to absorb the energy generated by explosions. Understanding how components behave in explosive situations is critical to improving the survivability of the structure. The explosion in Jaipur City made researchers aware of the importance of understanding the explosion-proof properties of concrete columns.[1-5]. Since such catastrophic events indicate that underground pillars may fail and lead to the gradual collapse of buildings, extensive research has been conducted to study the performance of reinforced concrete pillars under explosive loads, and the testing of live explosives is limited, especially considering the explosiveness Load test. Consider the influence of axial load on the bending performance of the column. This limit applies to reinforced concrete columns exposed to air loads in a narrow range of ratios. Builders and governments are increasingly interested in understanding the vulnerability of their structures to explosive devices and what measures can be taken to improve the survivability of buildings and the people in them. Other design professionals can understand the general characteristics of explosive loads and the expected behaviour of structures exposed to explosive charges and develop new methods and guidelines for buildings that can withstand explosive charges.T. Ngo, et al. (2007) [1] for their study on "Blast loading and Blast Effects on Structures" gives an overview on the analysis and design of structures subjected to blast loads phenomenon for understanding the blast loads and dynamic response of various structural elements.T. Ch. Madhavi et al. (2016) [2] the researchesimpact of precise temperature on concrete powerthrough the partial substitute of the first-class aggregate. Through Study they achieved to recognize the temperature outcomes on concrete throughout publicity of heat, hearth place, climatically modifications happen seasonal version has been investigated through reviewing a few global journals. To investigate the impact of extended temperatures of 100, two hundred, and 300°C with numerous publicity intervals of 4, 8, 12and 72 hours on trial blend specimen.[6-10].

2. Explosion Phenomena

Explosion can be described because of the unexpected launch of electricity within side a tiny proportion of second producing excessive stress and heat. Many blasts reassert can reasonharm to the structure, for example, chemical compounds that could react unexpectedly below positive situations and bring about the spontaneous launch of a massive quantity of electricity. Flammable substances shape smoke clouds within side the presence of air that generates an excellent quantity of electricity. Speedy launch of electricity generate through any reason produces a blast wave, for example, bursting of a stress vessel and unexpected segment transition from liquid to gas.

2.1. Features of Blast Waves

Fig.1 shows pressure-time history explosion wave.

P_O = Pressure of surrounding
P_{SO} = positive side-on overpressureof blast wave
$P^{-}{}_{SO}$ = negative side-on overpressureof blast wave
P_r = Reflected overpressureof wave
i_S = positive phase-specific impulse
$i_S{}^{-}$ = negative phase-specific impulse
t_a = stretching timeof wave
t_o = positive phase duration of wave
$t_o{}^{-}$= negative phasedurationof wave

Overpressure described as because of the growth in the strain of the environment regarding ambient strain. Free-area loads are the loads produced via an explosion that strikes immediately over the item with no mirrored image and puts off all the gadgets of their route. Free-area load is likewise defined as side-on while the explosion wave contemplated over a wall or different item parallel to its path. [4].

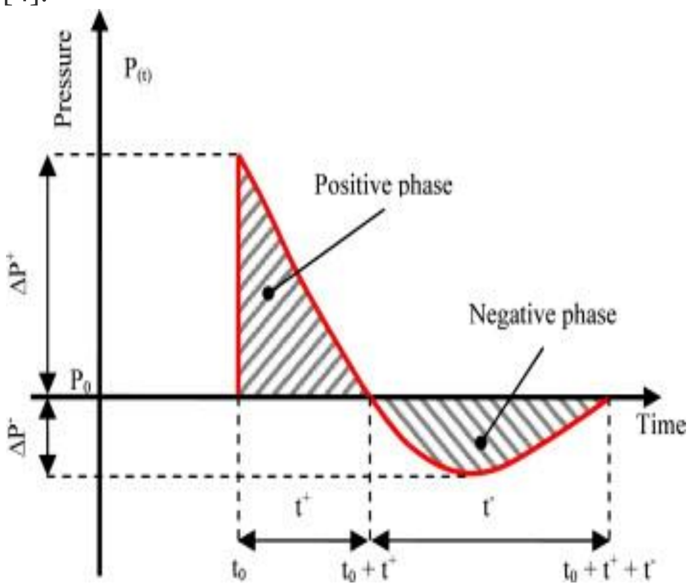

Fig. 1 Blast wave

2.2. Scaling of factors

Explosion parameters are generally provided in a scaled shape like pressures, velocity, impulse, times, and lots other. Previous lyit has proven that scaling legal guidelines may be carried out to explosions with comparable geometry within side the identical ambient conditions, same explosive and specific size. Scaling may benefit blast predictions, numerical modelling facts for any explosion, and variant standoff distance patterns.

Scaling may be executed in step with IS: 4991 [3]:

$$\text{Scaled distance x} = \frac{\text{Actual distance}}{W^{1/3}}$$

$$\text{Scaled time } t_o = \frac{\text{Actual time}}{w^{1/3}}$$

Where

W = yield of explosion

3. Fire phenomenon

According to the 'National Building Code of India' (Part four Fire and Life Safety-2005), hearth place resistance is an asset of both a detail and fabric of constructing creation. A hearth place can most effectively beginwhile3factors are gift simultaneously: oxygen, flammable substances, and a warmth source. Together, they make up what has usually known as the hearthplace triangle. The first factor will most effectively begin combustion while the irritation temperature is reached [4]. Building substances utilized in creation are of types: Combustible substances will integrate exothermically with oxygen, provide upward push to flame, and unfold the hearth place. Such substances, whether shape a part of the shape or contents of the construction, burn themselves and grow the depth and boom of the hearth place, i.e., it acts as a gas for the hearth place. Examples of such substances are timber and all timber merchandise, synthetic merchandise, fibreboard, strawboard, etc.[11-15]. Non-Combustible substances these substances do now no longer make contributions to the boom of a hearthplace. Still, they will get broken while the temperature reaches an excessive degree wherein fusion occurs, ensuing within side the construction's lack of energy. If such substances are used within side the shape, it could keep the shape's integrity for an extended period and subsequently collapse. Examples of such substances are metal, stone, glass, concrete, clay merchandise, gypsum merchandise, and asbestos merchandise. [16-20].

4. Thermal properties of concrete

Experiments have demonstrated that when a material is subjected to various temperatures, its structural qualities can alter. These changes can have a big impact on the outcome of a fire-damaged structural investigation. In the event of a fire, structure members can reach temperatures of up to 1000 °C for an extended length of time.[21-23].

4.1. Specific heat (J/Kg K)[6]

$C_c(T) = 900$ for 20°C ≤ T≤ 100 °C

$C_c(T) = 900 + (T - 100)$ for 100°C < T≤ 200°C

$C_c(T) = 1000 + (T - 200)/2$ for 200°C < T≤ 400°C

$C_c(T) = 1100$ for 400°C < T≤ 1200°C

4.2. Thermal conductivity (W/m K)for 20°C ≤ T≤ 1200 °C [6]

Lower limit:

$$k(T) = 1.36 - 0.136\left(\frac{T}{100}\right) + 0.0057\left(\frac{T}{100}\right)^2$$

Upper limit:

$$k(T) = 2 - 0.2451\left(\frac{T}{100}\right) + 0.0107\left(\frac{T}{100}\right)^2$$

5. Pressure on closed rectangular structures

5.1. Front face

When the shock wave strikes a structure's vertical face, it reflects, and the pressure quicklyrises to the reflected overpressure(p_{ro}) [3].

$$p_{ro} = p_{so}\left(2 + \frac{6p_{so}}{p_{so} + 7p_a}\right)$$

Where

p_a = the surrounding pressure (1kg/cm^2)

at time t, the pressure applied on the opposite face to the loading direction is called reflection overpressure p_r or $(p_s + C_d q)$, whichever is greater [3].

C_d = drag coefficient

t_c = clearance time given by: t_c = least of $\frac{3S}{U}$ or t_d

S = H or B/2, whatever is the smallest

U = velocity of shock front = M × a

a = sound velocity in air which may be taken as 344m/s

M = incident pulse's Mach number given by$\sqrt{1 + 6p_{so}/7p_a}$[3]

5.2. Rear face

The standard loading on back face is calculated as shown in Fig.2. (a) The time has been measured from the time the shock wave first struck the structure's front face[3].

The time intervals that are of interest as follows: -

$\frac{L}{U}$ =from the front to back face, a shock wave travels through time

$\frac{4S}{U}$ =when the pressure on the back facerises [3]

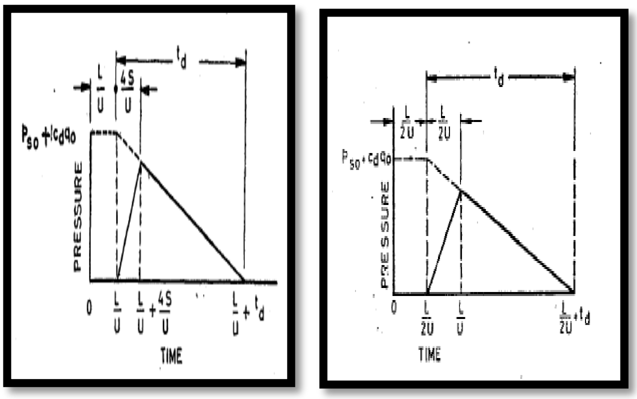

Fig.2. (a): For the back face, Pressure vs. time (b): When $t_d > t_t$, the average pressure curve

5.3. Roof and sidewalls

The variation in average pressure and time for roof and sidesis shows inFig.2. (b). When t_d is greater than t_d, the transit time is takenas$t_t = \frac{L}{U}$, and when t_t is greater than t_d, the load on the roof and sides can be modelled as a moving triangle pulse with peak overpressure and time $(p_{so} + C_d q_o)$ and t_d[3].

6. Result & Discussions

The reinforced concrete structure is both stable and long lasting. It has elevated resistance to pressure and tension. It is economical. RCCis almost impervious to warping and rust. It is resistant to fireand other climate conditions. RCC may work with ordinary skilled employees on a worldwide scale and does not require experienced professionals. The following conditions are observed:

Case 1: 10-meter distance from the structure with 400 kg yield of explosion

Case 2: 20-meter distance from the structure with 400 kg yield of explosion

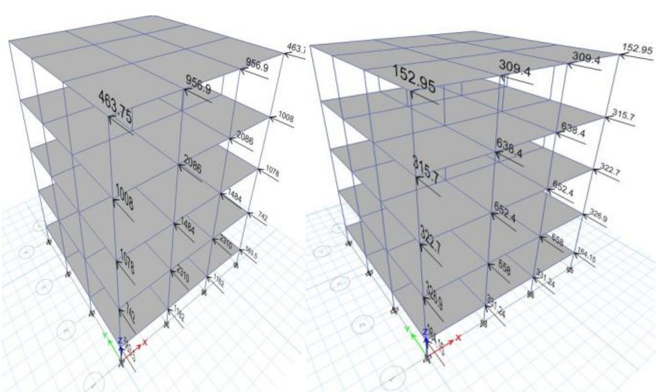

Fig.3. Blast load applied over the structure for case 1 and 2

Case 3: 10-meter distance from structure with 200 kg yield of explosion

Case 4: 10-meter distance with 400 kg yield of explosion for 4 bay X 4 bay structure

Case 5: 10-meter distance with 400 kg yield of explosion for 6 bay X 6 bay structure

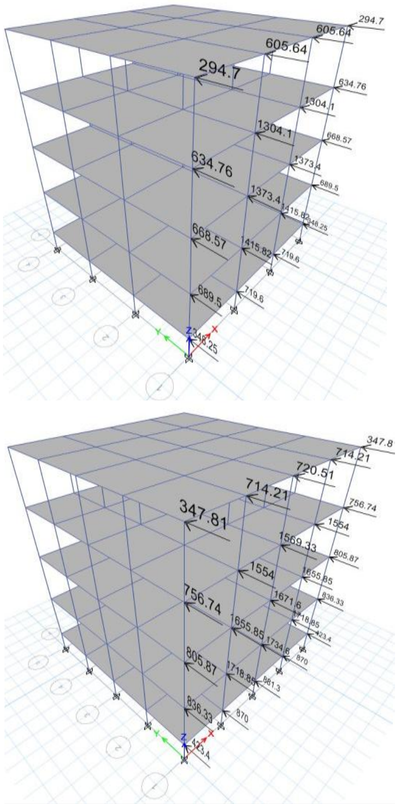

Fig.4. Blast load applied over the structure for case 3 and 4

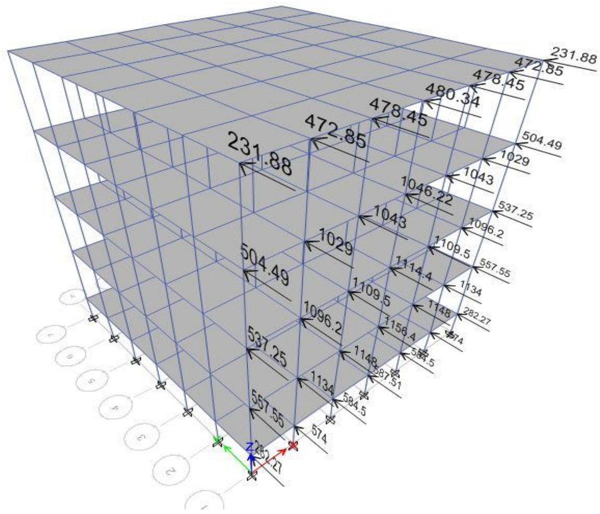

Fig.5.: Blast load applied over the structure for case 5

6.1. Load and displacement curves

Blast load is applied over the structure and after the analysis the structure deform, and the displacement values as shown below

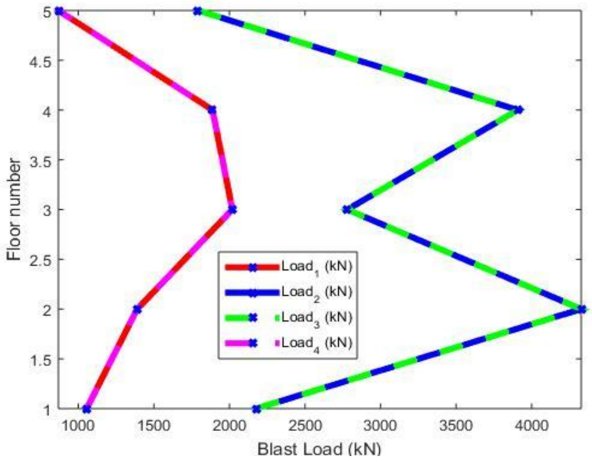

Fig.6. (a) Load vs floor number for case 1

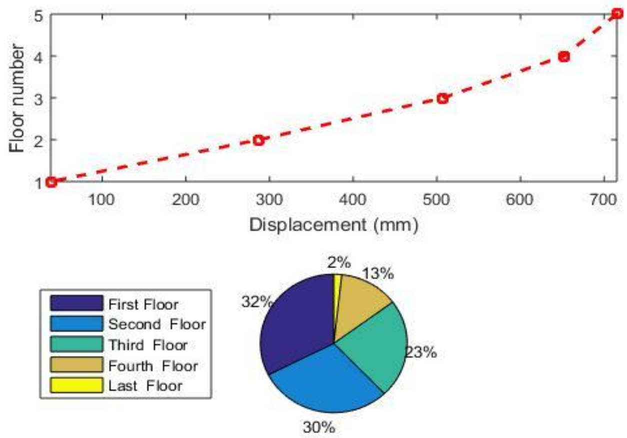

Fig.6. (b) Displacement vs floor for case 1

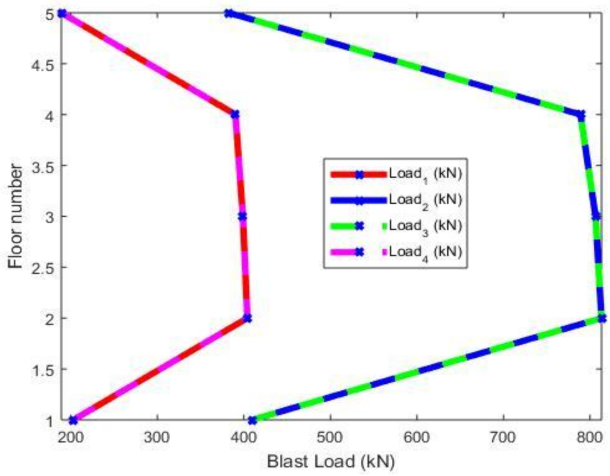

Fig.7. (a) Load vs floor number for case 2

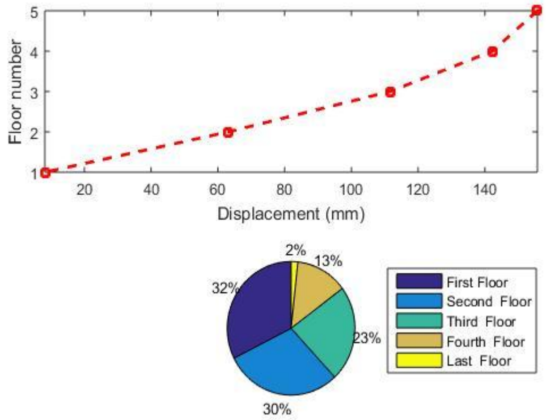

Fig. 7. (b)Displacement vs floor for case 2

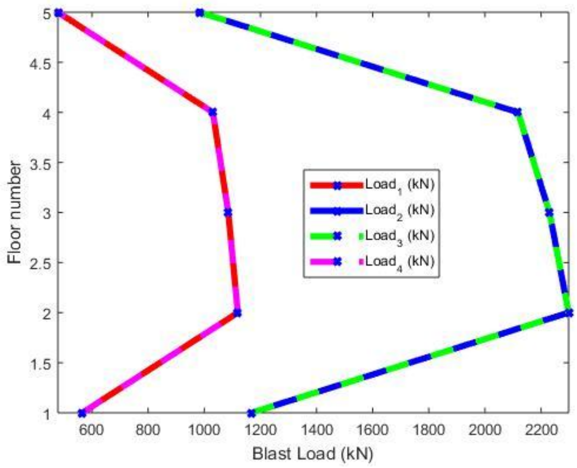

Fig.8. (a)Load vs floor number for case 3

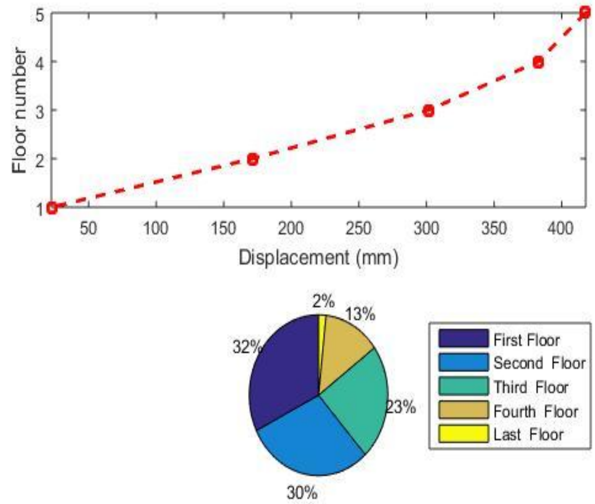

Fig.8. (b) Displacement vs floor for case 3

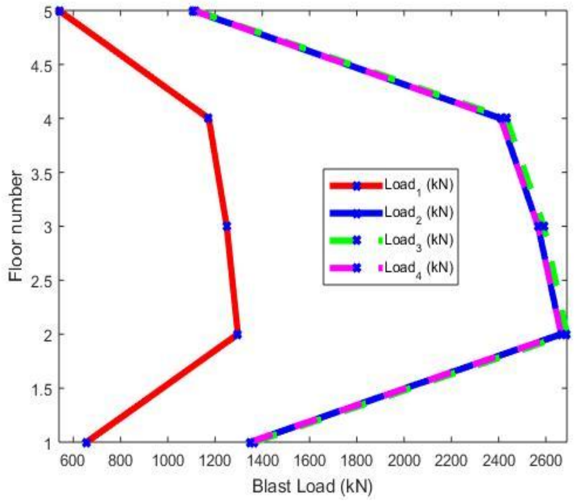

Fig.9. (a)Load vs floor number for case 4

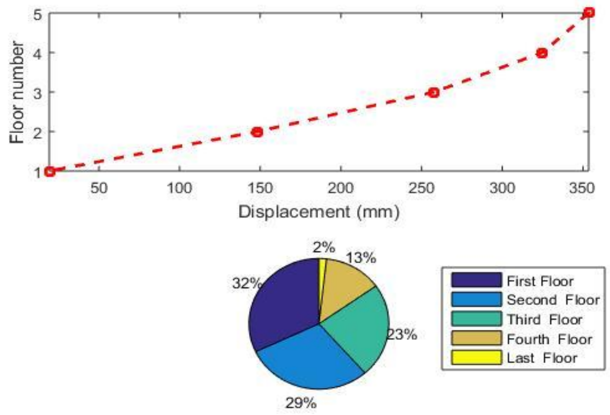

Fig.9. (b) Displacement vs floor for case 4

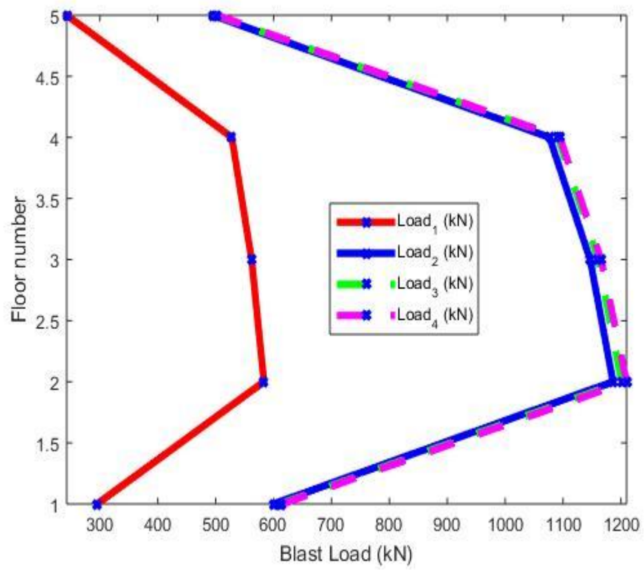

Fig.10. (a) Load vs floor number for case 5

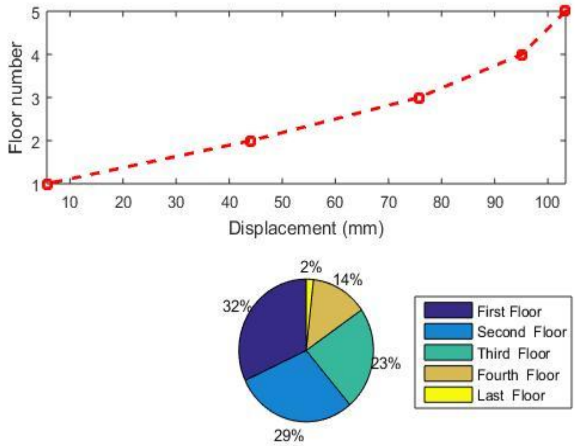

Fig.10. (b) Displacement vs floor for case 5

Maximum storey displacement can be seen in case 1 that is when the distance of explosion is 10 meters from the yield of the explosion is 400 kg but when the standoff distance is double by making the yield of explosion constant then the maximum displacement is reduced to 160 mm from maximum displacement. When the yield of the explosion is half that is 200 kg by making the standoff distance same (10m) then the maximum displacement is around 425mm. Without altering the column and beam dimension, increasing the stiffness of the structure by increasing the bays from three bay of four-meter to four bays of three-meter and three bays of four-meter to six bays of two-meter in both directions then the maximum displacement is 350 mm and 105 mm, respectively.

Conclusions

The purpose of developing this program is to study the effect of explosive loads on reinforced concrete columns. The test procedure included reinforced concrete columns with various transverse steel components that were subjected to open-air explosion tests at the Indian Forces Base and equipped with pressure gauges, tendon potentiometers and strain gauges. The pressure time and movement time of the column are recorded and displayed. The shear force enhances the part effect, the proportional distance effect, and the axial load effect. This relationship is analysed by comparing the failure and failure modes and displacement characteristics of traditional cylinders, RCC cylinders and cylinders designed as part of the shear load system structure. Regardless of the type of column is ordinary, seismic or RCC, the response of concrete columns cannot withstand the 0.22m/kg1/3 scale distance. The larger the scale distance, the smaller the degree of damage. When the maximum lifting height is 0.86 m/kg1/3, the responses of all columns are relatively the same. In the test with a scale distance of z = 0.22 m/kg1, the influence of cross-sectional details and seam overlap is obvious. Strip the concrete of the traditional column and cut the column into two parts. In the seismic column, only the concrete cover is crushed and split. The concrete core has been well restrained; the tightly spaced sections of the transverse steel bars increase the impact resistance of the pillars, especially at smaller distances. Therefore, pillars with seismic components have higher explosion resistance than pillars with conventional components.

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