STRUCTURAL PERFORMANCE OF RCC BUILDING UNDER BLAST LOADING

Yerakala Karthik [1]
PG Scholar (Structural Engineering)

Mr. M Jugal Kishore[2]
Assistant Professor (Civil Department)

KALLAM HARANADHAREDDY INSTITUTE OF TECHNOLOGYGUNTUR-522019, A.P.

ABSTRACT:- The response and damage analysis of structure subordinated to the blast lading has entered considerable interest in recent times. There has been a number of studies on the damage analysis of structures due to air blast. Design guidelines for guarding structures against the air blast is available in several literatures. Despite the available knowledge on the subject, exploration is still continuing in this area, especially for assessing the damage caused due to the face blast. The thesis deals with the response and damage analysis of the corroborated concrete(RC) structures subordinated to the face blast.

The alternate part deals with the nonlinear time history analysis of the 3- D model of the four structures subordinated to the face blast. The analysis is performed with the help of SAP 2000 software. The dynamic ladings produced due to the air pressure and ground shock are dissembled using the procedure available in the literature. The parameters varied are the charge weight, standoff distance and height of the structure. The responses include the maximum top storey relegation, maximuminter-storey drift rate, number of plastic hinges formed and maximum base shear. The response geste of the structure under different parametric variations is critically examined in order to assess the damages caused due to the face blast. Further, the relative impact of the air pressure and ground shock on the total responses is delved .

Next, a completely coupled analysis of the 3- D model of a 6-storey structure is performed in which air- structure- soil commerce are completely included. The ABAQUS software is used to pretend the finite element(FE) modelling of the explosive, air medium, soil medium and structure in one single model. The nonlinear time history analysis is performed for two standoff distances, two different charge weights and two different types of soil(hard soil and medium soil). Results of the analysis are compared with those of the uncoupled analysis in which the soil- structure commerce(SSI) effect isn't considered.

INTRODUCTION:-

Analysis of the dynamic response of structures under blast lading is veritably complex, as it involves the effect of the high strain rate on the material geste , inelastic-nonlinear geste of the material and time-dependent distortion(Ngo etal., 2007). High strain rates(102to 104 s- 1) produced by blast loads alter the damage medium of structural rudiments by effecting their mechanical parcels. Strength of concrete and buttressing sword significantly increase due to the strain rate effect. Grote, Park and Zhou(2001) conducted trials and reported that for the concrete in contraction, the strength exaggeration factor is attained as high as 4 and in pressure, it's over to 6 for strain rates in the range 102 to 103 s- 1. Dowling and Harding(1967) conducted tensile trials on mild sword and concluded that the mild sword has a veritably high strain rate perceptivity. It was set up that the high stain rates doubled the lower yield strength of mild sword and increased the ultimate tensile strength by 50.

Blast cargo may produce both original and global responses of near structures. When an explosion takes place veritably near to a structural member, it causes localized flexural or shear failure of that member. The localized failure may be in the form of localized spalling and punching and, it's accompanied by fractions and debris.

Design guidelines for blast loading

The issue of structural safety from explosive blasts arose during World War II and now this concern has grown due to the increase in terrorist conditioning. A large body of literature for military operations has been developed which provides knowledge regarding the effect of the explosion on structures and design guidelines for the blast lading, which include(i) " Structures to repel the goods of accidental explosions ", TM 5- 1300(U.S. Departments of the Army, Navy, and Air Force, 1990);(ii) " A primer for the vaticination of blast and scrap ladings on structures ", DOE/ TIC- 11268(U.S. Department of Energy, 1992);(iii) " Defensive construction design Manual ", ESL- TR- 87- 57(Air Force Engineering and Services Center, 1989);(iv) " Fundamentals of defensive design for conventional munitions ", TM 5-855-1(U.S. Department of the Army, 1986);(v) " The design and analysis of toughened structures to conventional munitions goods "(DAHS CWE, 1998) etc. National Research Council in its report " guarding structures from lemon damage- Transfer of blast- goods mitigation technologies from military to mercenary operations ”(National Research Council, 1995) examined the operation of the construction and design methodologies developed for military structures to the mercenary structures. It was observed that the blast design principles developed for military purposes are generally applicable for mercenary design practice. TM5- 1300(1990) is extensively used by the service and mercenary association for blast resistant design of structures. It provides information about the blast lading, dynamic analysis principles and design of corroborated and sword structures. Guidance for the selection of security door, windows, and other factors are also handed in the primer. A report published by ASCE “ Design of Blast Resistant structures in Petrochemical installations ”(ASCE, 1997) provides general guidelines for blast resistant design of structures.

Soil structure interaction effect due to the blast loading

In recent times, the SSI effect on the structural response caused due to the blast- convinced vibration has been delved using different approaches like, the modal superposition system, pressure- impulse illustration and using empirical equations. Ma, Quek and Ang(2004) studied the soil- structure commerce(SSI) effect on the response of a five- storey aeroplane frame caused due to an underground explosion and set up that when the SSI effect is considered the structural response gets reduced and an increase in the shear haste of the soil causes a reduction in the SSI effect. Huang, He and Ma(2011a) represented that structural damage with due consideration of the SSI effect due to the blast can be fluently and directly estimated with the help of P- I plates. It was shown that the exponential air- pressure surge palpitation, when simplified as a triangular palpitation, overrated the structural response and for conniving P- I illustration, the exponential palpitation shape is largely recommended. Mahmoud(2014) delved the effect of base soil inflexibility on the dynamic response and damage of erecting under air pressure due to the blast by working governing equations of stir. It was set up that the flexible base structure was more susceptible to damage due to the blast than the fixed base structure and for a correct estimate of the structural response and damage, soil inflexibility should be considered. Liu(2009) delved the goods of burial depth, stiffness of ground medium and weight of explosive on the response of shelter coverts under internal blast conditions by using unequivocal dynamic finite element system.

Progressive collapse analysis of buildings

An explosion at a close distance to the structure causes severe damage to the nearest crucial factors of the structure. This original failure spreads from element to element due to the redivision of loads, which causes the collapse of an entire structure. This type of collapse of the structure is nominated as ‘ progressive collapse ’(NISTIR, 2007). General Services Administration guidelines(GSA, 2003) recommend four procedures of the progressive collapse analysis, videlicet, direct static, nonlinear static, direct dynamic and nonlinear dynamic. The selection of the analysis procedure depends upon the structural configuration(irregular or regular), size and significance of the structure. Among these four procedures, the nonlinear dynamic analysis is considered as the most complex yet dependable approach. The guidelines on progressive collapse resistance of structures promote proper connection detailing(ray- column, ray- ray) and redundancy of the structure in order to insure vacuity of the alternate cargo path if the loss of any crucial member occurs.

Scope and objectives of the work

Keeping in view the above-mentioned areas of investigation, this study is performed to investigate the behaviour of seismically designed multi-storey buildings under the surface blast scenario, focusing mainly on the nonlinear characteristics of the building including failure. A preliminary estimate of the relative contributions of the ground shock and air pressure on the responses produced due to the surface blast is attempted using equivalent SDOF models of building frames having different heights (3 storey, 6 storey, 9 storey and 12 storey).

- Estimation of the relative effects of surface blast generated ground shocks as compared to air pressure on RC buildings using an equivalent SDOF model.

- To study the nonlinear response of earthquake-resistant multi-storey buildings under different intensities of the simulated surface blast using 3D models of the building; the parameters varied in the study include the building height, charge weight and standoff distance.

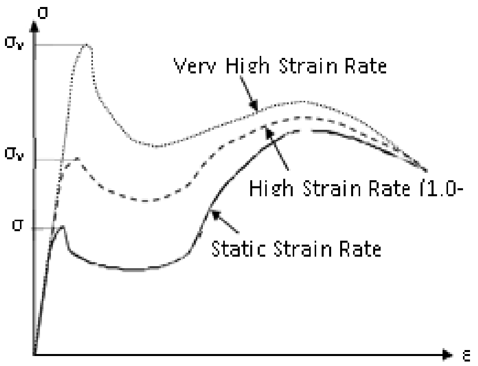

Fig 1: Effect of high strain rates on steel properties

Surface blast

The surface blast is different from the airblast in respect of producing the dynamic loading on structures supported on the ground, due to both air pressure and ground vibration caused by the blast. Air pressure produces the load on the surface of the structure exposed to air pressure, which in turn causes the vibration in the frames or other elements of the structure. The ground shock provides the dynamic forces, as caused due to the earthquake, but with higher magnitude and shorter duration than earthquake. The dynamic loadings caused by the surface blast are simulated by generating the pressure-time history for the air pressure and acceleration time history for the ground vibration using the procedure.

Equivalent SDOF model of the building frame for the linear analysis

While the normal mode theory can be conveniently used to develop an SDOF model of the multi-storey building vibrating only in one mode, the quantification of the effects of the total air pressure and ground shock in the SDOF model is not straight forward. For obtaining an equivalent SDOF system for the multi-storey building frame subjected to the surface blast, only the first mode response is considered. The reason for choosing only the fundamental mode of vibration for developing the SDOF model is that for very short duration impulse, the maximum response occurs in the free vibration phase of the structure after the end of the pulse (Chopra, 2007). Since the free vibration of any structure takes place in the fundamental mode, the equivalent SDOF models for the building frames are developed using only the fundamental mode of vibration.

Linear and nonlinear analyses of the SDOF

Both the linear and nonlinear analyses of the equivalent SDOF systems are performed using equations . The reason for carrying out both types of analysis is that the building frame can undergo both the elastic and inelastic excursions depending upon the charge weight, fundamental period of the building and standoff distance. Further, the initial stiffness of the idealized pushover curve utilized for the nonlinear time history analysis differs to some extent from the linear spring stiffness used for the linear time history analysis. This is the case because the linear time history analysis uses the fundamental frequencies of the buildings The response is obtained as the top floor displacement of the structure. For the linear analysis, top floor displacement is x1 = 11 z1. Since 11 is set to unity x1 = z1 .

For the nonlinear analysis, equations 3.26 and 3.27 are solved using the Newmark's Average Acceleration method for solving the incremental equation of motion (Chopra, 2007). The algorithm duly takes into account the different loading and unloading paths. Further, it takes into account the transition points during incremental analysis by monitoring the displacement and velocity after each increment of time.

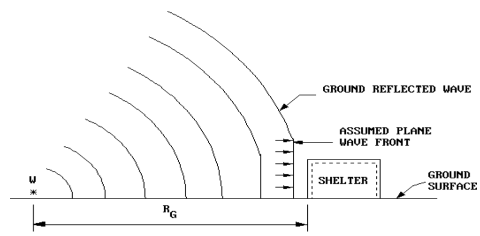

Fig.2 Surface Burst Blast Waves.

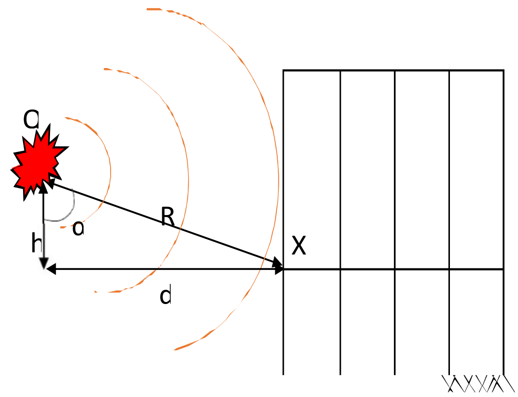

Fig 3: Free air blast

Effect of Surface Blast On Multi-Storey Buildings:

Surface blast:- A surface blast causes both air pressure and ground shock effect on a nearby structure. In order to simulate the effect of the surface blast, time histories of the reflected air pressure on the exposed surface of the building, and ground acceleration are generated using the equations given by Wu and Hao (2005).

Modelling and analysis of the building:-

The structure is modelled as a 3D frame. The arbor action is properly included in the model. shafts and columns are modelled as ray rudiments, while the arbor is modelled using shell rudiments. The base of the structure is assumed to be fixed. The simulated time histories of the ground shock are applied at the base of the columns and those of the air pressure are applied on the ray- column joint bumps of the structure. The time history records are dissembled with the time pause effect, which is incorporated by the appearance times of the ground shock surge and air pressure surge. For carrying out the nonlinear time history analysis, the dereliction plastic hinge parcels of the SAP 2000 are used at all sections where plastic hinges are anticipated to form(near the ray and column ends) so that all possible types of failure modes including the pure storey sway failure mode caused by the conformation of hinges can develop. Force- distortion and moment-gyration geste of the dereliction plastic hinges is shown in Figure4.1. As shown in the wind, point A shows the origin. A-B shows direct distortion of the element. This direct distortion occurs in the element, not in the hinge and beyond the yield point(B) the element goes into the plastic range. Beyond the point B, plastic distortion occurs in the hinge in addition to the elastic distortion being in the element. Points C, D and E represent ultimate capacity, residual strength and total failure independently.

For simulation, Rayleigh commensurable damping is espoused for the first two vibration modes by considering critical damping as 5 and Hilber- Hughes-Taylor direct time integration approach is used for nonlinear time history analysis with portions Gamma = 0.5 and Beta = 0.25.

Numerical study:-

Four RC buildings having the same plan dimensions with different number of storeys, namely, 3, 6, 9 and 12 storeys are considered for the investigation. Figure 4.2 shows the plan of the four buildings and 3-D view of the 6 storey building. Plan dimensions of all the four buildings are 16m x 16m with four equal spans in each direction and all storey heights are 3m. Grades of concrete and steel reinforcement bars are M30 (compressive strength 30 MPa) and Fe 415 (yield strength 415 MPa) respectively. The buildings are designed for the gravity loads and earthquake load for zone V (peak ground acceleration 0.36g with a probability of 10% exceedance in 50 years) in accordance with IS 1893 –Part 1 (Bureau of Indian Standards, 2002). First three time periods (T1, T2, T3) of the buildings, sizes of the members and reinforcements (R/F) of structural components

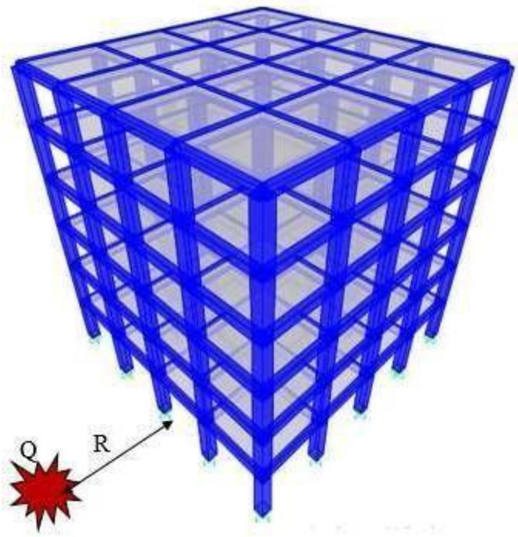

Figure 4: 3D view of 6 storey building

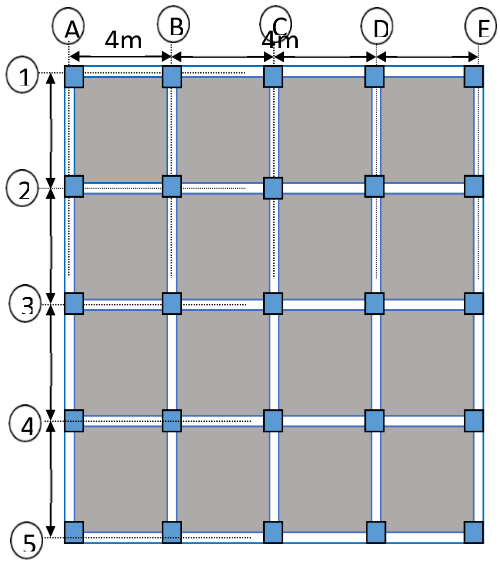

Figure 5 Plan of the four buildings

Discussion of results:-

For the building frames, four response quantities of interest are evaluated, namely, the top floor displacement, inter-storey drift ratio, base shear and number of plastic hinges formed. The effects of the variation of the standoff distance, charge weight, and building height on these response quantities are evaluated in order to investigate the effect of the surface blast on the buildings.

Conclusions

The responses of RC buildings of different heights produced by the surface blast are investigated. For this purpose, four RC buildings with the same plan dimensions and different heights, designed for gravity and earthquake loads are considered. For the analysis, charge weights of 1000kg and 500kg of TNT and standoff distances of 5m to 60m are considered. Responses of the buildings include the peak top floor displacement, maximum inter-storey drift ratio and maximum base shear. The extent of damage in the buildings is evaluated in terms of the number of plastic hinges formed. From the numerical study, the following conclusions can be drawn:

- Forlow rise buildings (3 and 6 storey), at small to medium standoff distances, the maximum top storey displacement and maximum inter-storey drift ratio are more for the air pressure than the ground shock produced by the surface blast. At large standoff distances, the effect of ground shock becomes predominant.

- For high-rise buildings (9 and 12 storeys), at smaller standoff distances (R ≤ 10m), the effect of the ground shock on the displacement and drift responses is more than that of the air pressure. For standoff distances R > 10m, the two effectson the responses are nearly the same.

- For both low and high rise buildings, the base shears produced by the ground shock is more than that produced by the air pressure for all standoff distances.

- With the increase in the charge weight, the effect of the ground shock increases more significantly than the air pressure.

From the above conclusions, it is apparent that the response of a building produced by the surface blast is a complex phenomenon arising out of both the air pressure and ground shock acting on the building. These two effects are significantly influenced by the standoff distance, charge weight and building height. For low rise buildings, the surface blast may be critical as compared to the free airblast at greater standoff distances (15m ≤ R ≤ 60m). For smaller standoff distances (R ≤ 15m), the surface blast may produce less responses in buildings as compared to the free air blast because of the opposing nature of oscillations produced by the ground shock and air pressure.

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