# Design of Armored Room for High Pressure Pneumatic Actuation System

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**ABSTRACT**

***The paper describes the process of determining the blast load on structures and provides a numerical example of a fictive structure exposed to this load. The aim was to become familiar of using methods for calculating the dynamic response of structural elements including reinforced concrete and procedure to calculate the strength required resisting the applied blast loads. The blast load was analytically determined as a pressure and numerical model of the structure was created in STRAP. The analysis and design of structures subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of structural elements. This gives a comprehensive overview of the effects of explosion on structures.***

***Keywords: blast load, conventional software, pressure calculation***

## 1. INTRODUCTION

In the past few decades considerable emphasis has been given to problems of blast and earthquake. The earthquake problem is rather old, but most of the knowledge on this subject has been accumulated during the past fifty years. The blast problem is rather new; information about the development in this field is made available mostly through publication of the Army Corps of Engineers, Department of Defense, U.S. Air Force and other governmental office and public institutes. Much of the work is done by the Massachusetts Institute of Technology, The University of Illinois, and other leading educational institutions and engineering firms.

Due to different accidental or intentional events, the behavior of structural components subjected to blast loading has been the subject of considerable research effort in recent years. Conventional structures, particularly that above grade, normally are not designed to resist blast loads; and because the magnitudes of design loads are significantly lower than those produced by most explosions, conventional structures are susceptible to damage from explosions. With this in mind, developers, architects and engineers increasingly are seeking solutions for potential blast situations, to protect building occupants and the structures.

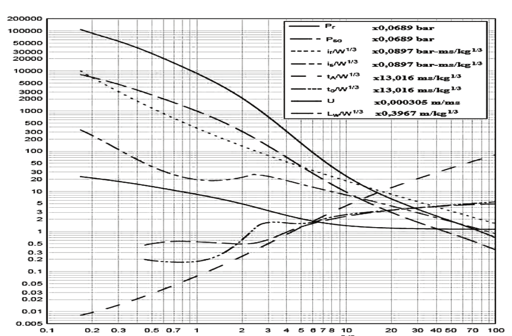
## 2. EXPLOSIONS

Explosive is widely used for demolition purposes in military applications, construction or development works, demolitions, etc In order to be able to use explosives they have to be inert and stable, which means that the explosion is a triggered, rather than a spontaneous reaction. The explosion is a phenomenon of rapid and abrupt release of energy. Speed of the reaction determines the usefulness of explosive materials that can be condensed, solid or liquid. When they detonate they disintegrate emitting the heat and producing gas. Most of the explosives detonate by a sufficient excitation and convert into a very hot, dense gas under high pressure that presents a source of strong explosive wave. Only about one third of the total chemical energy is released by detonation. The remaining two thirds are released slowly in the blasts as the explosive products mix with the surrounding air and burn. The explosion effects are presented in a wave of high intensity that spreads outward from the source to the surrounding air.

### *Explosion as a loading*

In most instances simplifications lead to conservative constructions. However, unknown factors may lead to the overestimation of the structural capacity to blast loadings. Unexpected shock wave refraction, design methods, quality of construction and materials, interaction with ground, are different for each particular structure. In order to overcome these uncertainties it is recommended that the mass of TNT equivalent is increased by 20 %. This increased value of the charge weight is called the "effective charge weight".

If the charge is located very close to the ground or on the ground the explosion is termed near the ground. Refracted wave arises as the initial blast wave is refracted and increased by reflection of the ground. For an explosion near the ground, the load acting on the structure is calculated as for the explosion in the air, except that the initial pressure and other parameters for the positive phase are determined as explained in Fig. 1 and the theoretical parameters of the negative phase as in fig2



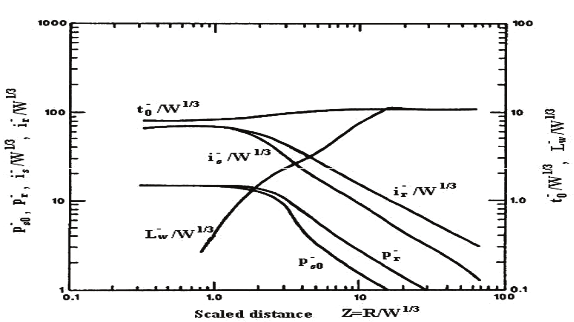




**Figure 1 Parameters of the positive phase blast wave near the ground Figure .2 Parameters of the negative phase blast wave near the ground**

***Design calculations***

Computation of dynamic loading on closed rectangular structure, Let it be assumed that it is required to determine the average net horizontal pressure $p_{net}$ that acts on the rectangular aboveground building shown in fig. and the dimensions of the armed room are also shown in fig room specifications are

Length of room (L) =6.0m

Breadth of room (B) =4.0m

Height of Room (H) =3.0m

Weight of charge (W) =3 lbs

Concrete=M25

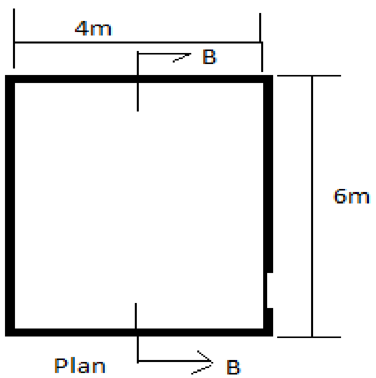



**Figure .3 Plan of armed room**

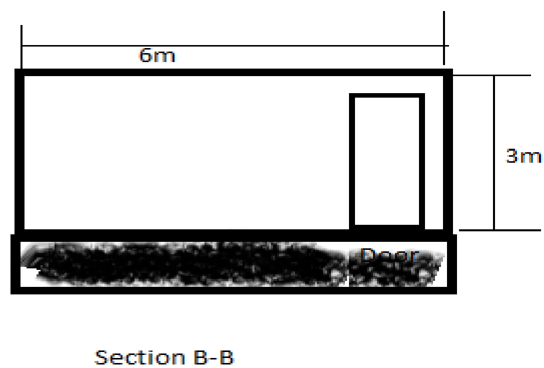



**Figure .4 Section view of armed room**

***Calculation of the blast loading***

Step1. Select point of interest on the ground relative to the charge. Determine the charge weight, and ground distance $R_G$.

Step2. Apply a 20% safety factor to the charge weight.

Step3. Calculate scaled ground distance $Z_G$:

$$Zc = \frac{Rc}{W^{1/3}}$$

Step 4. Determine free-field blast wave parameters from Figure for corresponding scaled ground distance $Z_G$

***Read***

Peak positive incident pressure *Pso*

Shock front velocity *Uo*

Scaled unit positive incident impulse $i_s/W^{1/3}$
Scaled positive phrase duration $t_o/W^{1/3}$
Scaled arrival time $t_a/W^{1/3}$
Multiply scaled values by $W^{1/3}$ to obtain absolute values.

**Table.1. Loading details of different walls**

| | Wall W1 | Wall W2 | Wall W3 | Wall W4 |
|---|---|---|---|---|
| Scaled charge distance Za (ft/lb$^{1/3}$) | 4.03 | 6.10 | 15.5 | 4.83 |
| Peak positive incident pressure *Pso* (mpa) | 0.20 | 1.03 | 3.8 | 2.25 |
| Scaled unit positive incident impulse $i_s/W^{1/3}$ (mpa-ms) | 22.22 | 0.82 | 0.47 | 0.103 |
| Scaled arrival time $t_a/W^{1/3}$ (ms) | 2 | 2.75 | 3.86 | 2.7 |
| Scaled positive phrase duration $t_o/W^{1/3}$ (ms) | 1.8 | 2.9 | 4.6 | 3.06 |

***Design pressure impulse for closed rectangular structure (here considering a critical case i.e wall W1)***

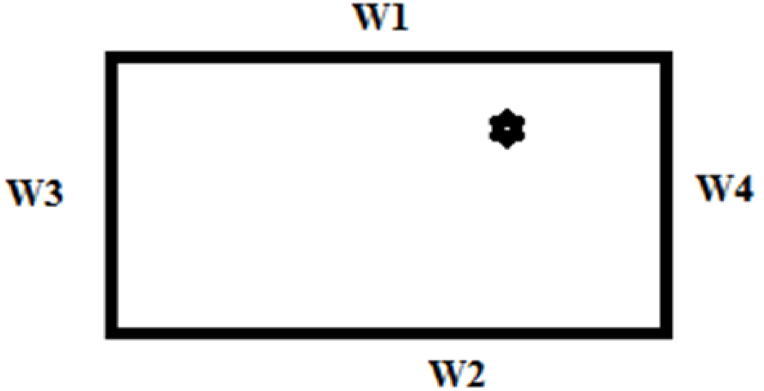



**Figure. 5. Applied charge in critical case**

Number of Reflecting faces adjacent to the surface of wall W1
N=4, h=1.64ft, H=9.84ft, L=13.12ft
Distance between charge point and wall w1

Ra=5.74ft, L/Ra=13.12/5.74=2.286

Scaled normal distance from the wall W1

$ZA=RA/W^{1/3}$

$=4.03ft/lb^{1/3}$

Average Value of peck reflected pressure pr=100.08psi

Scaled unit reflected impulse = $ir/W^{1/3}$

=122.82 psi-ms

To account for secondary shocks pressure is increased by factor of 1.75

214.95psi-ms

Duration of load on Wall T = 2.43m-s
Providing the wall slab thickness =350mm
Coefficient for movement of inertia of cracked sections with equal reinforcement on opposite sides
For reinforcement ratio =0.0046
Modular ration=8
From fig 3-36 TM 5-1300
Equivalent elastic deflection
Xep=0.361cm
Equivalent elastic stiffness Ke=146.39N/$Cm^2$
From table 3-13 TM-5 1300
Elastic rang (All supports fixed) KLM=0.77

Effective unit mass of element =609.2N-ms2/cm3

Calculation of natural period of vibration $Tn = 2 * \pi \sqrt{Me / Ke}$

=12.82

For Maximum response of elasto- plastic from fig 3-64(a) TM5-1300

Xm/Xe=1.4

Tm/To=2.91

The above value is in between 0.1< Tm/To >3

The following procedure is correct.

The ultimate shear stress $V_{UH}$

$$V_{UH} = \frac{3ru(1-de/x)^2}{de/x(5-4de/x)}$$

$V_{UH}$=1.18 N/mm2

$$V_{UV} = \frac{3ru(0.5-de/H)(1-x/L-2dex/HL)}{de/H(3-X/L-8deX/HL)}$$

$V_{UV}$ =1.82 N/mm2

Allowable shear stress

Ve=[1.9 (fdc)$^{1/2}$ +2500*p]

Allowable shear stress in vertical direction

$V_{EV}$=119.56psi

=0.40 N/mm2

Allowable shear stress < shear force at vertical direction

Vertical lacing bar A $v_{Lacing}$=142.58mm2

Horizontal lacing bar $A_{H\ lacing}$=93mm2

Design of diagonal bars

The required area of diagonal bars is determined from

Ad=(VSV –VEV)bd/fds sin a

=850.32mm2

Provide 12 mm dia bars at 150mm c/c.

***Model and Analysis***

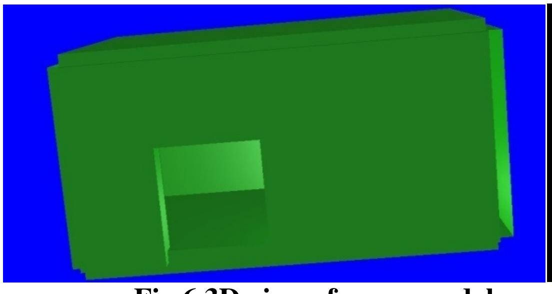


**Fig.6 3D view of room model**

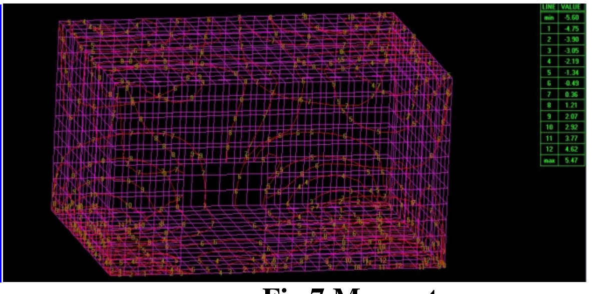


**Fig.7 Moments**

The armed room model was done in STRAP the above calculated loads (Table.1) are applied to the model, after the analysis get a moments and stress values are shown in below table Table.2.

**Table.2 Moment and Stress Values**

| | Moment | Stress | Von misses Stress |
|---|---|---|---|
| Min | -5.60 | -272 | 7 |
| Max | 5.47 | 263 | 578 |

## 3. CONCLUSION

The above discussion shows that the blast load was calculated as per TM 5-1300. Blast load for close explosion was determined and simulated on a model building using STRAP. Since the model structure was close to the source of detonation, it was not necessary to determine the loading on the structural surfaces. The aim of the analysis of the structure elements exposed to blast load is to check their demanded ductility and compare it to the available ones. This means that non-liner analysis is necessary and simple plastic hinge behavior is satisfactory. In elements exposed to distant explosions, conventional reinforcement provides sufficient ductility, while for close explosions additional reinforcement is needed.

## REFERENCE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