# DYNAMIC ANALYSIS OF MILITARY BUNKER SUBJECTED TO BLAST LOAD

**DipikaKhandelwal[1], D.H. Tupe[2], G. R. Gandhe[3]**

*[1]PG Student, Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad 431005, India*
*[2]Assistant Professor, Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India.*
*[3]Professor, Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India*

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**Abstract -** *This study includes the analysis and design of a bunker constructed on three different soil types. Though each and every bunker has mostly similar components and machines but the analysis and design of civil structures in a plant are always done with different ideas and optimized techniques. Hence this paper is based on some new and different considerations in analysis and design aspects and optimization. One of the objective is to study the difference between analysis and design of conventional structures and important structures or special structures. There are huge different machines in Military bunker which are subjected to axial thrust as well as vibrations. The structure results are found by means of 'ANSYS'. Optimum analysis results in optimum design. As earthquake ground shaking affects all structures below ground in case of an Military bunker and since some of them must sustain or withstand the strongest earthquake ground motion, they have to be designed and checked for different types of design earthquakes.*

***Key Words*: Dynamic analysis, military bunker, blast loading, explosion, time history, ANSYS-16.0**

## 1. INTRODUCTION

A bunker is a military fortification that is designed with the aim of protecting people or valuable goods from bombs or any types of attacks. Bunkers were extensively used during the First World War, Second World War, and also during the Cold War. They have also been used as command centers, stores for weapons, and distribution points.

The effect of blast loads on buildings is to be considered in the design process. Although these attacks are exceptional cases, man-made disasters (terrorist attacks), blast loads are dynamic loads that should be taken into consideration while designing of the structure just like earthquake and wind loads.

The main aim of this study is to give protection to the military bunkers against the explosions. In this paper, the method for mitigating the effects of detonations, thus providing protection for human being, structure and the important equipment inside. In this study literature on blast loads, the possibility of vulnerability evaluation, risk easing, also the main objective of this study is to examine the behavior of a military Bunker structure in different soil conditions during seismic excitation

### 1.1. Uses of Bunkers

1. Bunkers majorly protect people and valuable resources from damage that can be occasioned by enemy bombs.
2. It prevents ear and internal damage by the dropping bombs by deflecting the blast wave from close detonations.
3. Moreover, the bunkers protect people from harmful radiation by blocking its entry into the sheltering places. The main function of Bunker is that it must be built in a manner that can withstand a nuclear attack and its under-pressure aftermath that persist for many seconds after the shock waves.
4. The bunkers' doors should be equally strong just like their walls and have ventilation if they will be inhabited for many days. Also, bunkers play a role in securing the artillery installations from destruction.
5. The protection of weapons helps the fighting soldiers access enough armaments to facilitate the success of the battles. Apart from the military use, bunkers can be useful during tornadoes.

### 1.2 Objectives of study

1. Understand the concept of behavior of structures on blasting and its impact
2. The main objective of this study is to examine the behavior of a military Bunker structure in different soil conditions during seismic excitation
3. To study soil structure interaction of Military bunker is studied using FEA tool ANSYS 16.
4. Modelling and analysis of military bunker for external (air blast) explosion.
5. Study optimum design, ultimate impact load capacity under blast loads

## 2. LITERATURE REVIEW

**T. P. Nguyen Et. al. 2011**[1],in this paper studies include the dynamic response of vertical wall structures under blast loading. Blast loading is simulated by the form of dynamic excitation in time based on the assumptions to assure physical nature of dynamic problems.

The vertical wall structure is modelled by plates restrained in an edge and fixed in four edges is surveyed both linear as well as nonlinear response under explosion. The nonlinear dynamic analysis is considered along with the cracked behavior of the plate. The governing equation of motion of the structure is established by Finite Element Method with quadrilateral four nodes elements and integrated by constant acceleration method of New-mark's family. BLASTSHELL program which analyses the behaviour of shell under blast loading is built on MATLAB software.

The problem of vertical wall structures with various boundary conditions due to blast loading simulated by negative exponential function and elasto-plastic model of material has been analysed. The BLASTSHELL program is helpful for the needs of design work. The results show that the effect of location of explosive as stand-off distance, high and volume of TNT is sensitive to dynamic responses of wall structures

**Ashish Kumar Tiwari, Et. al. 2018[2],** this study presents a comprehensive study of concrete wall against this dynamic loading. Concrete wall subjected to blast loading is modeled in Finite Element package using Ansys and then analysed in Autodyne with and without steel plate to study the impact of blast loading.

It can be stated from literature survey that for the estimation of blast load or pressure the empirical approach (Kinney and Graham's) proves to be ideal as blast phenomenon is complex in nature. Complexity arises due to unpredictability of charge weight and standoff distance as well as the behavior of material under different loading conditions and post blast triggering events. Ansys Autodyn is an efficient and user friendly software tool for simulating explosives and impact loading linking it with workbench environment. The blast simulation was carried out using JWL as equation of state for explosive materials.

**Akhila Ramanujan, Et. al. 2018[3]**, has studied the bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads, of many structures. Studies were conducted on the behaviour of structural concrete subjected to blast loads. This analysis investigates the behaviour of reinforced concrete blast wall subjected to air blast loading.

From the comparison of analysis results such as deflection and stress, the blast wall wrapped with GFRP showed better performance in preventing damages due to explosion. The degree of resistance to explosion of GFRP wrapped blast wall is greater in higher TNT values. Hence the GFRP panels can be recommended for various blast resistance.

**C. M. Deshmukh, Et. al. 2016[4],** in the present study, the RCC frame was analyzed by using conventional code for gravity loads using moment resisting frame. The blast load was calculated using UFC-340-02 (2008) or IS 4991-1968 for 500 kg and 100 Kg TNT at standoff distance of 10m and 30m from face of column at first floor level. The triangular impulse was applied as nodal time history at all front face joints. The analysis was performed using Computer aided software. The response of structure of will be evaluated under various blast scenarios. The response will be checked for safety of the structure on many parameters like displacement, acceleration and velocity.

Blast load varies with time and distance. The behavior of structure greatly depends on charge of explosive and its standoff distance. Due to sudden released explosive energy causes failure of structure such as collapse the structure, damage of structural elements and crack formation in structure.

**M. Meghanadh,, Et. al. 2016[5]**, in this study the effect of blast loads on 5 storey R.C.C building. Effect of 100kg Tri nitro toluene (TNT) blast source which is at 40m away from the building is considered for analysis and designed. Blast loads are calculated manually as per IS: 4991-1968 and force time history analysis is performed in STAAD Pro. The influence of blast loads on structure is compared to that of same structure in static condition, The parameters like peak displacements, velocity, acceleration are studied.

Blast resistant design refers to improving structural integrity of structure instead of complete collapse of building ,The present study on G+5 Residential building proves that Increase in stiffness of structural members by increasing in size proving better results which also resist the uplift force on footings by increasing in dead weights.

**Sajal Verma., Et. al. 2015[6],** The Indian code does not have enough provisions for dealing with blast load, so it is important to study the properties of blast loading as dynamic loading. The various methods discussed are FRP retrofit technique in masonr walls, unidirectional passive dampers in steel structures, varying core density in sandwich structures and composites materials. it is observed that FRP retrofit technique in blast protection and steel structure with passive dampers are effective as blast resistance technique since no visible damage, crack, or de-bonding occurred in any of the walls and steel structure as the internal energy is mainly dissipated by the dampers.

Blast loading and blast resistance techniques used in structures are discussed in this paper. The important parameters of blast loadings like Strain Rate Effect, Natural Period, and Dynamic Load Factor of Vibration were studied. Different blast resistant techniques used in masonry, concrete and steel structures were studied and following conclusions can be drawn from the studies: FRP used in masonry walls were found to be effective in resisting blast, polyuria and GFRP retrofits were found to be successful in preventing wall fragmentation, polyuria sprays has the capability of channelizing the load to the frame.

**Mr. Chandrashekhar., Et. al. 2017[7]** the effect of blast load on building is a serious matter that should be taken into consideration in the design, Even though designing the structure to be fully blast resistant is not a realistic and economical option.

We can even improve the new and existing building to ease the effect of a blast. In this study we have analysed the effects caused by the blast loads and to find ways to reduce the effects using Etab-2013 software. From these studies we conclude that the variation could be analysed on unsymmetrical structures.

By increasing column and beam size in a structure will improve the resistance but it is not practical in most cases due to serviceability problems because huge cross section of beam and column needed to resist blast loads. Additio of shear wall and bracing helps to resist the blast loads effectively. The addition of steel bracings gives good results but shear wall more desirable results than steel bracings and it is economical too compared to other methods.

## 3. METHODOLOGY WORK STUDY

To know the effects of blast loadings on buildings or structures, use of FINITE ELEMENT ALALYSIS (FEA) to calculate response of structure due to stresses produced. Finite element analyses safety of structure when exposed to critical conditions, to justify its design.

The ANSYS philosophy can be summarized as one that aims to simulate the complete real-life engineering problem. The simulation usually begins by using a three dimensional CAD model to construct a finite element mesh followed by imposing loads and boundary conditions in the pre-processor.

The main processor generates the element matrices, computes displacements strains and stresses and stores the result in the files.

The obtained results are displayed in tabular and graphical form by post-processor.

Type of analysis - in this case structural analysis includes,
1. Geometric model
2. Material properties
3. Loadings and boundary conditions

## 4. PROBLEM STATEMENT

In this chapter Military tunnel with soil structure interaction with clay, silty and sandy soil including material properties given in chapter 3 and Finite element models are analysed for static loading as well as dynamic loading (time history analysis). A Military bunker having three main parts namely, Access tunnel, Bunker cavern unit and a Transformer cavern is analysed. The dimensions of the tunnel are as follows:

| | Width | Side Wall Height (m) | Arch Height (m) | Length (m) |
|---|---|---|---|---|
| **Bunker Cavern** | 20 | 24 | 5 | 47 |
| **Transformer cavern** | 10 | 10 | 3 | 14 |
| **Access Tunnel** | 6 | 4 | 3 | 43 |

A Military bunker project is carried out in a fractured soil mass. It consists of a series of Military structures. Three main parts of the bunkers are analyzed in this study: the bunker cavern, transformer cavern and access tunnel. The domain of rock mass with dimensions 130 m X 114 m X 110 m is considered. Three joint sets are identified based on the analysis of the collected data from field survey, and the detailed information is shown in Table 3. Three types of surrounding soils are considered in this paper, clayey, silty and sandy soil conditions. The effect of earthquake waves on each of the soil types and the ultimate effect on the bunker structure is analyzed with the help of ANSYS. Specified earthquake motion El Centro is considered for 31sec and implemented in ANSYS

## 5. MESHING

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multi physics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation

## 6. LOADING CONDITIONS

The design loads considered for the study primarily include the loads acting on the elements of building structure (dead and live loads). The loads primarily include the Dead Loads (DL), Imposed Dead Loads (IDL) and Live Loads (LL). DL includes the self-weight of building elements, i.e. loads from slab, beams and columns. IDL denote the dead load on the structure after slab and beams have been casted. This includes loads of Percentage of Imposed Load to be considered in Seismic Weight Calculation. LL are referred to probabilistic loads which include all the forces that are variable within the structure normal operation cycle not including construction or environmental loads.

### 6.1 Design Consideration:-

As the impulse of the negative zone is less than the impulse of the positive zone, the negative face is usually not taken into account for the design purpose.

### 6.2 Determining Factors for Blast Parameter:-

1. Explosive charge weight
2. Stand-off distance

### 6.2.1. Explosive Charge Weight (W):

W is expressed in weight or mass of TNT. The equivalent W of any other explosive material is based on experimentally determined factors or the ratio of its heat of detonation to that of TNT.

### 6.2.3. Stand-off Distance (R):

R measures how close to the building a bomb could explode and is therefore a function of the physical characteristics of the surrounding site.This is the distance from the source of explosion at which the blast effect caused by standard charge weight is just equivalent to as caused by 'W' charge at distance 'R' is called Scaled distance

### 6.3 IS Code Provision:-

As per IS 4991 – 1968, the value of the Pso, qs, Pr computed from Table 1 for 1 tonne detonation amount. The pressure time relationship in the positive phase are idealized by using a straight line starting with the maximum pressure value but terminating at a time td or tq.

### 6.4 Material Properties

Materials used in ANSYS for analysis consists of RCC roofs and walls, in order to account for the non-linear behaviour of RCC, use of tangent modulus is made. Other general properties of RCC are considered for determining behaviour of structure under blast loading conditions.

The FEA model is constructed with following particulars

1. Programme controlled meshing is chosen with medium size mesh option.
2. All contacts in model are considered as bonded contact.

The table shows the concrete and steel bar properties, which are used for modelling of the reinforced concrete Military structures in ANSYS Concrete and steel bar properties as per IS 456

| Concrete Properties | | Steel Bar Properties | |
|---|---|---|---|
| Unit weight ($\gamma cc$) | 25 (kN/m3) | Unit weight ($\gamma ss$) | 76.9729 (kN/m3) |
| Modulus of elasticity ($EEcc$) | 22360.68 (MPa) | Modulus of elasticity ($EEss$) | 2x105 (MPa) |
| Poisson ratio ($\nu cc$) | 0.2 | Poisson ratio ($\nu ss$) | 0.3 |
| Thermal coefficient ($\alpha\alpha cc$) | 5.5x10-6 | Thermal coefficient ($\alpha\alpha ss$) | 1.170x10-6 |
| Shear modulus ($GGcc$) | 9316.95 (MPa) | Shear modulus ($GGss$) | 76923.08 (MPa) |
| Damping ratio ($\varsigma cc$) | 5 (%) | Yield strength ($FFyy$) | 415 (MPa) |
| Compressive strength ($FFcc$) | 30 (MPa) | Tensile strength ($FFuu$) | 485 (MPa) |

## 7. RESULT AND DISCUSSION

### 7.1 Modelling and Analysis

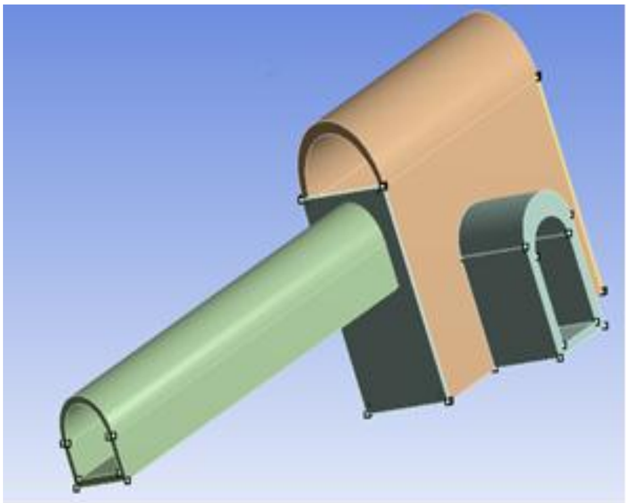

**Fig 1.** Model of bunker in ANSYS

**Table 1:** Total Deformation for static (m)

| TOTAL DEFORMATION | | |
|---|---|---|
| CLAY | SILTY | SANDY |
| 0.0012647 | 0.0015176 | 0.00189705 |

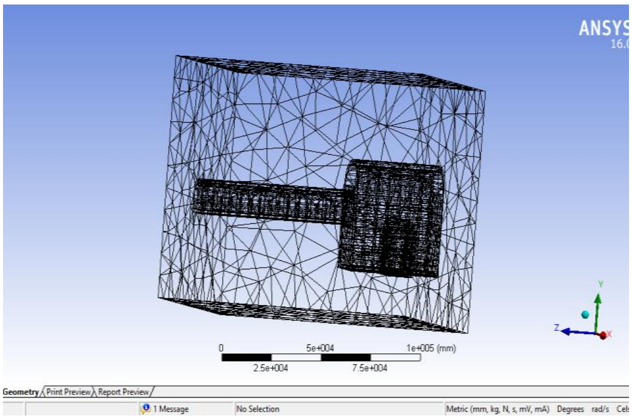


**Fig 2.** Meshing in Design Modular

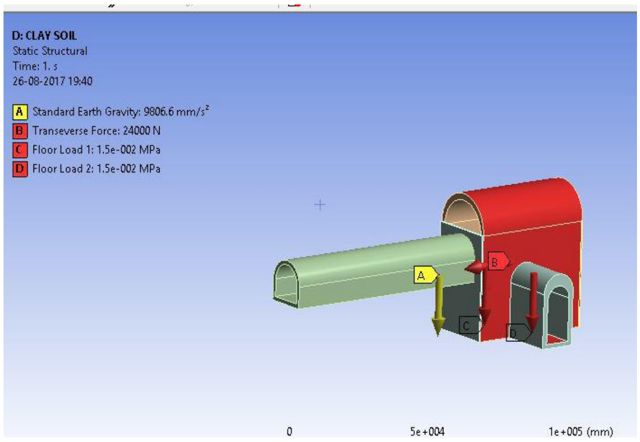


**Fig 3:** Loading on MODEL

The main objective of this study is to examine the behavior of a military Bunker structure in different soil conditions during seismic excitation.
The soil types considered are

1. Silty Soil
2. Sandy Soil
3. Clayey Soil

The Military structure is analysed for all the three soil types mentioned above and values for parameters like Total Deformation, Normal Elastic Strain, Shear Stress and Equivalent Stress are compared and the most suitable soil type is finalized.

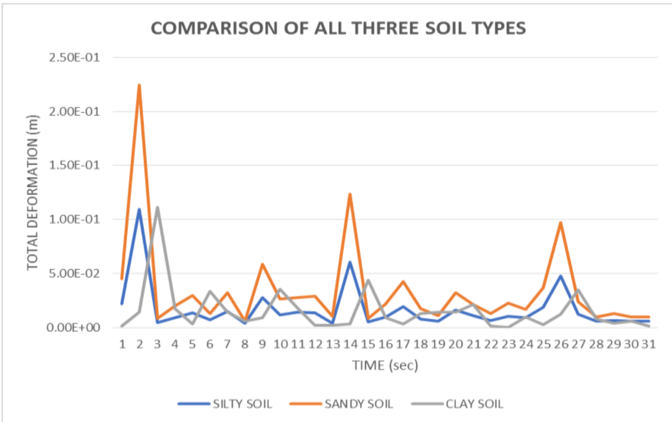


**Chart -1:** Graph of Time vs Deformation for different soil types.

| SHEAR STRESS (MPa) | | |
|---|---|---|
| CLAY | SILTY | SANDY |
| 2.1293 | 2.55516 | 3.19395 |

**Table 2:** Maximum Normal Stress for static

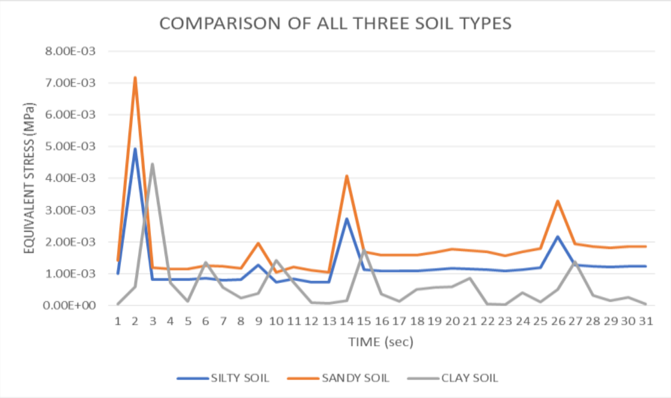


**Chart -2:** Graph of Time vs Maximum Equivalent Stress for Different Soil Types

**Table 3:** Maximum Shear Stress for static

| NORMAL STRESS (MPa) | | |
|---|---|---|
| CLAY | SILTY | SANDY |
| 8.85E+05 | 1061508 | 1326885 |

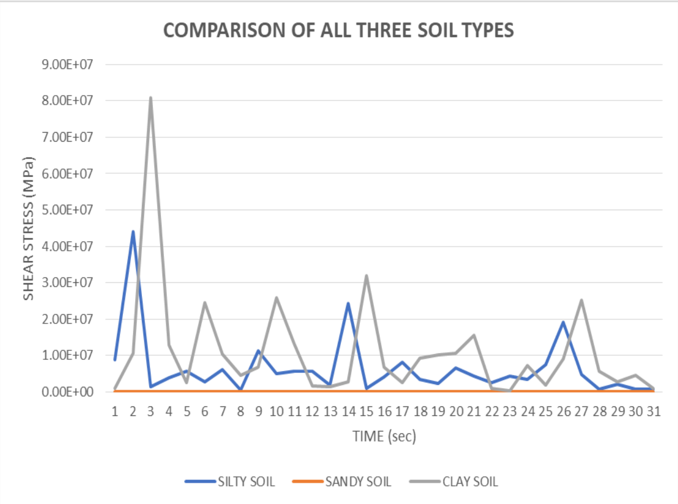


Chart -3: Graph of Time vs Maximum Shear Stress for Different Soil Types

## 8. CONCLUSION

1) In this study soil structure interaction of Military bunker is studied using FEA tool ANSYS 16. After applying El-Centro data it is observed that the total deformation, normal stress, shear stress and equivalent (von misses) stress are less in clayey soil as compared to Silty soil and Sandy soil.
2) Hence, as far as construction of a Military bunker is concerned clayey soil is best suited. However, no abrupt change is observed in the natural frequency and time of structure.
3) All Military structures have to be checked and designed against earthquakes. In many cases the earthquake load combination will not be the governing one for the design.
4) Earthquakes are multiple hazards and all relevant ones have to be considered in Military structures.
5) Conceptual and structural measures are often more effective than sophisticated dynamic analysis.
6) Equipment's and components in caverns have to be designed against earthquakes similar to surface structures.
7) Tunnels for spillways and bottom outlets (including intakes, outlets and valve chambers) must be functional after the safety evaluation earthquake. Therefore, these Military structures have to be designed for higher seismic hazard labels than any other Military structures.
8) Active fault zones in pressure tunnels need special attention especially when leakage can cause hydro-fracturing of the rock. Earthquake design of Military structures for is still in its infancy. Even ten years ago hardly any engineer would have considered earthquake action in Military structures in rock. However, for tunnels in soil seismic action had been considered much earlier.

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