DESIGN OF UNDERGROUND OPERATIONS COMPLEX FOR BLAST LOADS

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ABSTRACT:* Underground structures are an integral part of the infrastructure of modern society and are used for a wide range of applications, including subways and railways, highways, material storage, sewage and water transport. Underground structures built in areas subject to explosive attacks must withstand the blast loading and pressure coming on to the structure. Historically, underground structures have experienced a lower rate of damage than surface structures. The facility is deeply buried with a protective slab at top and a sand cushion between this protective slab and the roof slab of the facility so that it is safe from the top. But if the weapon penetrates through soil by the side of the protective slab at an angle and explodes, this will affect the side walls. For this condition we have to design the structure by providing sandwich RCC walls with sand filling in between or extending the top protective slab to a distance so that the distance between the final explosion of the weapon and the wall is increased thereby decreasing the design pressure. The structures subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of various structural elements.

***Key points*: Blast loading, Protective slab, Blast phenomena, Structural elements, Sand cusion.**

I. INTRODUCTION

The problem in the early twenty-first century is that deeply buried underground facilities are becoming an increasingly important part of the defence establishments in many states. These facilities allow states to conceal the personnel, equipment, and command and control functions that are essential to the successful prosecution of a war. In general, these facilities can protect a state's most critical governmental and military functions and contribute to victory during war, or at least make it more difficult for the adversary to destroy critical military capabilities.Deeply buried facilities have significant implications for national security, principally in terms of giving a state an effective sanctuary for protecting its weapons or command and control functions from attacks with modern precision guided weapons. At the same time, these facilities pose a difficult challenge for military forces, which will want to locate and destroy them in the event of a military confrontation. The development that is most worrisome to the defence establishment is the possibility that deeply buried facilities will contain nuclear, biological, or chemical agents, and that the destruction of these facilities may lead to the release of these agents with devastating environmental and political consequences.

The problem with using conventional weapons against targets is that the depth and hardness of the targets can exceed the physical ability of the weapon to survive passing through tens of meters of rock and rubble. Some experts estimate that new materials will need to be developed to penetrate modern concrete structures.

Underground structures have features that make their seismic behavior distinct from most surface structures, most notably 1) their complete enclosure in soil or rock, and 2) their significant length (i.e., tunnels) the design of underground facilities to withstand seismic loading thus has aspects that are very different from the seismic design of surface structures.

II. LITERATURE REVIEW

Youssef. M. A. Hashash, Jeffrey J. Hook, Birger Schmidt, John I-Chiang Yao studied The Seismic Design and Analysis of Underground Structures. Deterministic and probabilistic seismic hazard analysis approaches are required reviewed. The development of appropriate ground motion parameters, including peak accelerations and velocities target response spectra and ground motion time histories are discussed. Since the blast loads also produce ground motions, we can adopt the same techniques in analyzing our structure.

Joseph L. Giuliani, Daniel J. Hershey, David M. Mc Known studied on Complex Underground Facilities in which new technology development for the automated generation of underground structures to support correlated visual and constructive simulation.

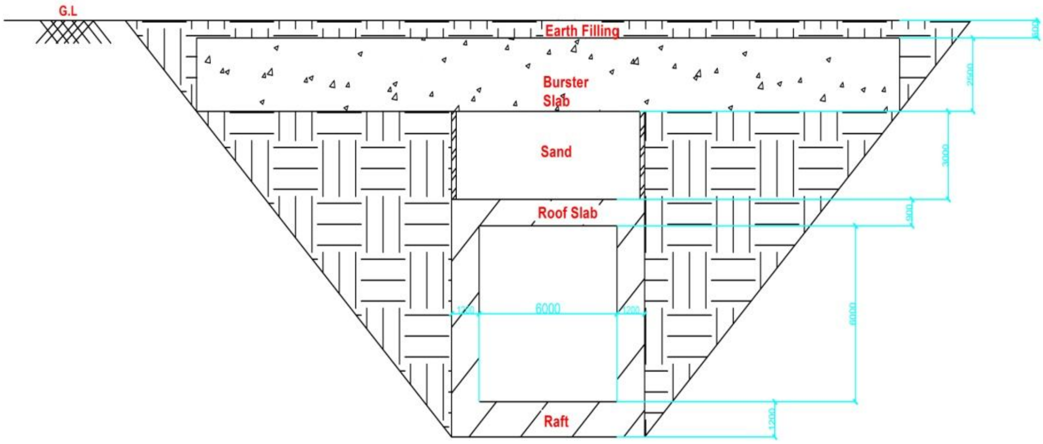
J. L.Merritt and N. M. New mark studied The Design of Underground Structures to Resist Nuclear Blast. In this project the experimental results from explosion a set of recommendations for the design of underground structures was prepared.

Darina Fiseerova, Numerical Analysis Of Buried Mine Explosions With Emphasis On Effects Of Soil Properties On Loading. This paper describes a numerical modelling approach for studying soil blast interaction in landmine explosions. The numerical analysis is carried out using the non-linear dynamic analysis software, AUTODYN. The research progressed from: 1) the explosion of hemispherical charge laid on a rigid surface, through 2) the study of explosion of mine deployed in dry sand, to 3) the validation of mine explosion in cohesive soil for different setups.

P. S. Bulson, Explosive Loading Of Engineering Standards, this book gives us a short review of developments over the years in methods of calculation, measurements and prediction of dynamic loading on structures from explosions. It endeavors to trace the history of the subject and to summaries some of the latest published thinking, and considers finally a range of structures from buildings and bridges to ships and aircraft. The work and achievements of major contributors to the subject over the past century are discussed.

III. DESIGN PROCEDURE

Crater Design: Choosing GP2000 characteristics of typical generic High-Explosive Bombs.
Charge Weight, W = Total weight x Charge weight
Charge Weight after increasing 20%



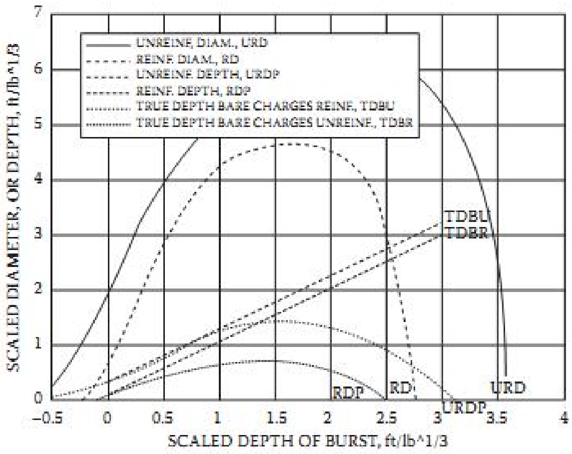
SECTIONAL PLAN OF AN UNDERGROUND STRUCTURE

Depth of burst (considered as zero for impact burst) = 0 ft

Scaled depth of burst, $Z = \frac{Depth\ of\ burst}{W^{1/3}}$

Scaled Depth of Crater, d (from graph)

Depth of crater, D $= d \times W^{1/3}$



CALCULATION OF LOAD ON ROOF:

Considering the GP2000 from UFC, by analysis the load on the roof using following formulae:
Following equations,

Peak pressure, $P_o = f.(r_c).\ 160Z_g^{-n}$

Peak particle velocity, $V_o = f.160.\ Z_g^{-n}$

Peak acceleration, $a_o = \frac{f.(50).c\ .Z_g^{n-1}}{W^{1/3}}$

Peak displacement, $d_o = \frac{f.\left(\frac{500}{c}\right).Z_g^{-n+1}}{W^{1/3}}$

Impulse, $i_o = f.\ r_o.\ (1.1).\ Z_g^{-n+1}.\ W^{1/3}$

Where: f –coupling factor; r_c – Acoustic impedance; r – Mass density of soil; c – seismic velocity $=(\frac{M}{r})^{0.5}$; M - Modulus of soil ; n – Attenuation coefficient; r_o – mass density; $Z_g = \frac{R}{W^{1/3}}$.

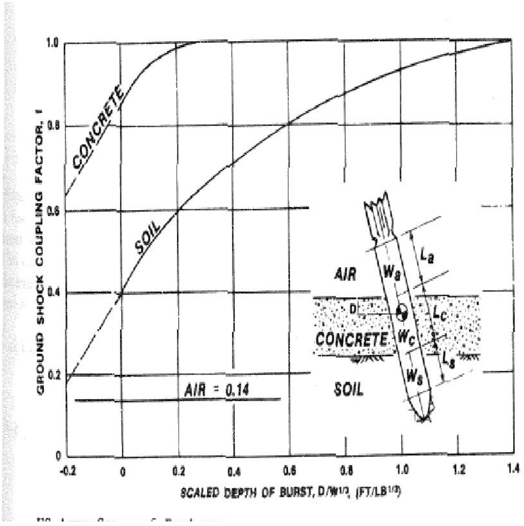
From the UFC calculations we can get the values of the pressure in 73 Psi.

Through these pressure calculations we can proceed to design the roof slab as per UFC.

TABLE 3.12
Soil Properties for Calculating Ground Shock Parameters

Material Description	Seismic Velocity c (fps)	Acoustic Impedance c (psi/fps)	Attenuation Coefficient (n)
Loose, dry sands and gravels with low relative density	600	12	3–3.25
Sandy loam, loess, dry sands, and backfill	1,000	22	2.75
Dense sand with high relative density	1,600	44	2.5
Wet sandy clay with air voids (less than 1%)	1,800	48	2.5
Saturated sandy clays and sands with small number of air voids (less than 1%)	5,000	130	2.25–2.5
Heavy saturated clays and clay shales	>5,000	150–180	1.5

Source: TM 5-855-1, 1986.



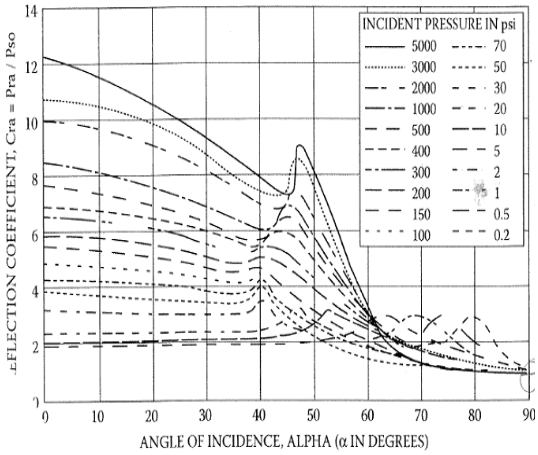


Table 2-10 Mass Density for Typical Soils and Rocks

Material	Mass Density, ρ (lb-sec²)/in⁴
Loose, dry sand	1.42 E-04
Loose, saturated sand	1.79 E-04
Dense, dry sand	1.65 E-04
Dense, saturated sand	2.02 E-04
Dry clay	1.12 E-04
Saturated clay	1.65 E-04
Dry, sandy silt	1.57 E-04
Saturated, sandy silt	1.95 E-04
Basalt	2.56 E-04
Granite	2.47 E-04
Limestone	2.25 E-04
Sandstone	2.10 E-04
Shale	2.17 E-04
Concrete	2.25 E-04

DESIGN OF ROOF AS ONE WAY SLAB AS PER UFC:

SUMMARY:

Thickness of slab =900mm; Grade of concrete = M40; Grade of steel = Fe500; Clear cover = 50mm. Main reinforcement: Provide 25 mm diameter @ 170 c/c top straight, 25 mm diameter @ 170c/c bottom straight. Distribution reinforcement: Provide 20 mm diameter @ 170c/c top straight, 20 mm diameter @ 170c/c bottom straight. Shear reinforcement: Provide 12mm diameter single leg stirrups @ 340 c/c.

DESIGN OF BURSTER SLAB: The principal function of reinforcement in concrete protective structure are to carry tensile stresses and to inhibit cracking splintering, scabbing and spalling which result from a direct hit or explosion. In general steel reinforcement will consist of the following component, each of which contributes its share towards inhibiting cracking and breaching of the concrete slabs, wall or roof subjected to direct hits:

i) *Front force mat:- tends to reduce the spall area around the point of impact and to hold some of the shattered front crater material in place. This action on the whole increases the resistance of the slab to repeated shots in the same general area.*
ii) *Back face mat:- tends to reduce back scabbing and raise the scabbing limit velocity. The back face mat gives resistance to inward bending.*
iii) *Shear steel:- ties both mats to each other and to the body of the concrete slab.*

When a structure is covered with soil and burster slab is then placed on the soil structure, anti-scabbing plates are not required.
Provide minimum steel as per UFC.
The mini reinforcement is 0.1 percent in each face, in each direction or a total of 0.4%
Thickness of burster slab considered, D=2500 mm (from load roof)

$$_{P}H = 0.1$$
$$A_{Sh}=10 \times {}_{P}H \times D$$

Diameter of bar =20mm
Spacing of bars (Top and bottom) =120mm.
P_V =0.1

$$A_{SV} =10 \times {}_{P}V \times D$$

Diameter of bar =20 mm
Spacing of bar (Top and bottom) = 120mm.

IV. CONCLUSION

In this paper we studied the effect of the blast loads on the structure which have been taken. For this load, the design reinforcement to be made to the structure so that, it can with stand the blast load. In that the pressure has been calculated according to the UFC standards. In this design consideration the pressure as 73 Psi. For this pressure the protective slab and burster slab are designed. As per UFC standards the designed structure is safe for that pressure.

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