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STEC PAMPHLET - 3

CONSTRUCTION OF BUILDINGS AND TRAVERSES FOR MILITAY EXPLOSIVES

2025

Issued by

Storage & Transport of Explosives Committee
Centre for Fire, Explosive & Environment Safety (CFEES)
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PREFACE

This pamphlet prescribes the technical requirements for the construction of buildings and traverses for military explosives. In the preparation of these regulations, provisions contained in STEC technical memoranda 1 and 2 have been merged and thus they stand superseded. The salient features of this publication are current international practices and section on the design principles for process and storage buildings and code of practice for explosives laboratories. To meet the storage requirement of services, regulations on storage of explosives in underground structures with tunnels was incorporated in year 2017.

Now, the guidelines on underground explosive storages was formulated by taking into account the extensive data generated through instrumented validation trials and a manual namely "Allied Ammunition Storage and Transport Publication AASTP-1 Edition-1 Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives, May 2010". The chapter on basic features of these underground explosive storages is covered in the Section-VI for better appreciation and understanding. In this revision the design of underground explosive storages with vertical shaft has been incorporated which was validated through instrumented field trials. Users can select the underground explosive storage in case option of above ground explosive storages is not viable, for optimum utilization of available land and financial resources without prejudicing safety.

A new design of blast containment structure for demolition of ammunition up to 8 kg HD 1.1 NEC has been incorporated. This structure requires minimal QDs hence will be useful in the establishments where sufficient quantity distances are not available. These regulations are applicable to the constructions of all new explosives facilities under the Ministry of Defence. They however do not apply to temporary storages in the field ammunition depots but any permanent buildings constructed in the field shall be governed by these regulations.

It is hoped that users will find this revised STEC Pamphlet 2025 simpler, easier to understand and implement, thereby promoting the safe storage and transportation of military explosive. This publication supersedes STEC Pamphlet, 2017 on the subject.

SECTION –I

INTRODUCTION

Scope

1. This pamphlet covers guidelines on the technical requirements for design and construction of explosives storehouses (which include magazines), process buildings (which include ammunition break-down workshops, laboratories, etc.) and traverses

2. While planning explosives facilities, the lay-out, orientation, design and construction of the buildings and traverses should be such so as to meet the following requirements:

   a) At an Exposed Site (ES) initiation of, and/or damage to the contents of an Explosives building, can be prevented/minimized by structural resistance to blast, high velocity projectiles and flame.

   b) At a Potential Explosion Site (PES) initiation of and damage to, the contents of adjacent buildings can be prevented by intercepting high velocity missiles and reducing blast.

   c) In process buildings, personnel can be protected from the effects of a nearby explosion.

3. The prescriptions contained herein reflect only the special features and therefore must be read in conjunction with the latest engineering practices along with the general specifications stated in these regulations.

4. Users are to interpret these regulations intelligently, bearing in mind that these regulations, although comprehensive and exacting cannot be expected to provide for every contingency or emergency that may arise, or to replace sound judgment, common sense, and efficient supervision. However, in case of any doubt, the matter can be referred to CFEES, Brig S.K. Mazumdar Marg, Timarpur, Delhi for clarification.

Definitions

5. Definitions of various terms used in this pamphlet are given in "Quantity Distances Regulations for Military Explosives –STEC Pamphlet-1". Meanings of a few other expressions occurring in this publication are given below:-

   (a) **Magazine**- A magazine is an explosives storage building where observance of clean conditions is necessary, construction of which embodies certain special features and

intended primarily for the storage of UN Hazard Division.1.1 explosives relatively more sensitive to spark and friction. Such special requirements are enumerated below:

(i) Floor must be gritless, even smooth and free from cracks.

(ii) The interior faces of the walls must be vertical, even, smooth and free from cracks. Ceiling, pillars, wooden fittings and interior wall surfaces must be painted with adequate coats of approved magazine paints conforming to relevant JSS/IS/IND/ME specifications. In all buildings, expense stores/transit buildings, magazines and process buildings where CE or nitro-phenolic bodies are handled/stored, the paints used as internal finish should be of lead-free type conforming to relevant IND/ME specifications and for other buildings, it should be of lead-restricted type conforming of IND/ME specifications.

(iii) All the internal corners of the floor, walls and roof must be rounded off to prevent accumulation of dust.

(iv) Exposed iron/steel must be avoided.

(v) There is no restriction on the use of aluminium or aluminium alloys containing more than 1% of magnesium for permanent fixtures like doors, etc.

(vi) Where wood has to be used for doors, windows, etc., it should be covered with asbestos cement sheet or other fire resisting materials, e.g., paints conforming to relevant JSS/IS/IND/ME specifications.

(b) **Explosives Storehouse-** A building used for storage of explosives other than those requiring magazine mentioned at sub para (a) above.

(c) **Underground Storage-**

Storages in chambers that are below surface level. In the case of an accidental explosion at such a site, the hazard of low angle, high velocity projections is reduced significantly. The other hazardous effects are similar to those in above ground storage, but are gradually reduced as the cover is increased.

i. Constriction

Constrictions are short lengths of tunnel whose cross-sectional areas are reduced to one half or less of the normal tunnel cross-section. Constrictions reduce the air blast effects

passing through them. To be effective constrictions should be placed within five tunnel diameters of the tunnel exit or the entrances of storage chambers.

ii. Portal Barricade

A barricade placed in front of an entrance of underground storage facility. Its functions is to reflect that portion of the shock wave moving directly outward from the entrance, thereby, reducing the pressure along with the extended tunnel axis and increasing the pressure in the opposite direction. The result is a more circular IBD area centered at the portal.

iii. Expansion chamber

It is protective construction feature in an underground storage facility designed to reduce the over pressure exiting the facility by increasing the total volume of the tunnel chamber complex. It may also function as an operating area within the underground facility or as debris trap.

iv. Quantity Distances for Underground Storage Facility

In case of underground storage of explosives, Quantity Distances (QDs) depend on the various variables i.e. ground shock, debris and air blast, including the local geology and site specific parameters. These parameters vary significantly from facility to facility.

The QD for ground shock is the same in all directions for homogeneous geological media, whereas QDs for other hazards (blast, thermal, impulse etc) vary markedly in different directions due to configuration specific features such as the locations of adits and ventilation shafts, hazard mitigation designs and terrain.

(d) **Above ground Storage-** Above ground storage building other than at sub para (a) below with its plinth level above the ground level.

(e) **Bunker type Storage-** An above ground type of storage building completely covered by earth (on all sides and roof) except at the cut-through passage.

(f) **Exposed Site (ES)** –A magazine, explosives storehouse, cell, stack, truck or trailer loaded with ammunition, explosives workshops, inhabited buildings, assembly place or public

traffic route which is exposed to the effect of an explosion (or fire) at the Potential Explosion Site (PES) under consideration.

(g) **Potential Explosion Site (PES)** –A building which contains or intended to contain ammunition and/or explosives under consideration.

(h) **Shaft:** A vertical passage that is constructed to provide access and material transport in deep underground structures.

Siting of Buildings

6. Selection of the site for the construction of explosives building must be done with due care taking into consideration the following:

(a) The site should not be susceptible to erosion.

(b) The site should be free from underwater courses.

(c) The site should be well drained and not prone to flooding.

(d) Site with continuous rock strata should not be elected because of the possible transmission of shock waves to excessive distances.

(e) The site should be within the easy reach of railways, main roads, public transportation, and sources of labour and supplies of water, fuel and electricity.

SECTION-II

CLASSIFICATION AND DESIGN CRITERIA FOR EXPLOSIVES STORE HOUSES

Types of Explosives Store Houses/Magazines

7. Depending on the type of explosives and other specific requirements, explosives storehouses/magazines can be divided into the following categories:

(a) Explosives storehouses/magazines for UN Hazard Division 1.1 explosives.

The building walls for this type of explosives storehouses/magazines shall be of 34 cm thick brick and provided with a natural angle traverse.

(b) Explosives storehouses for UN Hazard Division 1.2 explosives.

This type of storehouse shall have building walls of 68 cm brick or 45 cm RCC. Explosives storehouses with the above stipulation of wall thickness are considered to be effectively traversed against projectiles emanating from an explosion in an adjacent building or stack and therefore as an ES it does not normally require a receptor traverse as the walls fulfill this function. This type of building may trap some or all of the high velocity missiles, but however, it leads to increased amount of debris by the very nature of its construction.

(c) Explosives storehouses/magazines for UN Hazard Division 1.3 explosives.

Explosives storehouses/magazines for Hazard Division 1.3 explosives, i.e., explosives involving a mass fire risk shall be constructed with building walls of 68 cm brick. A special feature of this type of building is that it should incorporate a relatively weak section in the wall or roof to permit the rapid release of internal pressure built up in the event of a fire. The unit mass of this weak section should be as low as practicable, but in any case should not be much greater than 50 kg/m^2. Typical materials for an end or side wall of such a weak section could be glass reinforced plastic, asbestos sheeting, shatter proof glass or special type of light weight laminate materials. Weak section of two adjacent building should not be facing each other unless the separation distances are sufficient to prevent propagation of fire by directional projection of burning Hazard Division 1.3 explosives. The weak section will not be able to resist the high velocity debris emanating from untraversed PES containing Hazard Division 1.2 explosives. It is, therefore, essential that such a weak section should be protected with a 68 cm brick wall, located at 1 to 1.5 meter distance in front, to act as a good interceptor/receptor traverse. The length of the wall should be such

that it extends at least 1 m on either side of the weak section. No additional traversing is required.

(d) Explosives storehouses for UN Hazard Division 1.4 explosives.

Explosives storehouses meant for the storage of Hazard Division 1.4 explosives shall have 34 cm brick walls and need not be provided with a traverse.

(e) Bunker type storages

This category includes any above ground structure which has a minimum of 60 cm of earth on the roof, with walls backed with earth. This type of storehouse shall have an inner wall of RCC 22.5 cm thick and an outer wall of 22.5 cm brick with 1.25 cm water proofing material in between the two walls. This type of storage provided a good amount of protection as an ES as well as a PES and it is recommended for the storage of Hazard Division 1.1 and special category strategic explosives. Bunker type buildings should preferably be constructed near forward line for strategic reasons and in hot and dry climatic regions to provide a more uniform lower temperature inside.

(f) Igloo (Box type)

Igloo is an above ground, earth covered magazine made of reinforced concrete or steel. Igloo storage can provide considerable saving in land requirement and also ensures safety of explosive stocks in adjacent building due to special design features like directional attenuation of blast. LRC Igloo Inter separation distances between igloos with side to side or rear to rear orientation should be 0.5 $Q^{1/3}$ (for LRC Igloo) and 0.8 Q1/3 (for RCC Igloo) in place of 2.4 $Q^{1/3}$ and for constructional details, refer to E-in-C Branch drawing for RCC Igloo and to STEC pamphlet No.21for LRC Igloo. Due to this special design features it can withstand less seepage problems than bunker type magazines.

(g) Underground Storage Structure

A structure having top cover thickness more than 60cm & 0.1 $Q^{1/3}$ which may consist of a single chamber or a series of connected chambers, and other protective construction features. The chambers may be either excavated or natural geological cavities. Design of underground storage facilities must take into account site conditions, storage requirement and operational need. Special features (e.g debris trap, expansion chambers, portal barricade and constrictions) may be incorporated in the design of underground storage facilities to reduce the IBD for both debris and air – blast. Underground storage has many advantages e.g. a smaller total land area is required than aboveground storage, a high degree

of protection is afforded against bombing or terrorist attack, the area is easier to camouflage and to guard, in case of accident in an underground chamber, damage to ammunition in other chambers is preventable, the temperature in underground storage site is almost constant, no effects of snow, external fire and estate cost, as well as maintenance and operation may be less costly as for an above ground storage site.

(h) Rocket storage buildings

Where rockets are in a potentially propulsive state, the magazine should be of sufficient strength to resist their thrust. Alternatively, the rockets should be provided with devices to secure them and thereby eliminate the additional hazard arising from the flight of the rocket. Magazines which have not been designed to resist potentially propulsive rockets or which do not provide adequate anchorage points, should be surrounded with a suitable vertical inner faced traverse.

General Constructional Requirements

8. The main principles to be kept in view in the construction of explosives storehouses and magazines are given as under:-

(a) The use of flammable materials should be avoided as far as possible and non-combustible materials must be used for storehouses containing Hazard Division 1.1 and 1.3 explosives.

(b) There should be no exposed iron, steel, aluminium or any aluminium alloy in proximity to unpacked explosives compositions, which are sensitive to spark or friction.

(c) The orientation of the explosives store house should be carefully planned to avoid direct sun-light falling on any ammunition/explosives package. Advantage of the prevailing wind direction may also be taken into consideration to facilitate effective ventilation.

(d) The site should be protected from termite attack.

(e) The construction should be suitably water proofed to eliminate any possibility of seepage.

(f) The plinth level of the building should be well above the general flood level on the area and foundations should be strong enough to support the super structure. The drainage system in the area should be efficient.

(g) Materials like brick, concrete, reinforced concrete or any other pulverisable material is suitable for construction of explosives store houses. Stone may be used for the construction of walls of traversed storage only.

(h) The following restrictions are necessary in the use of materials like iron, steel and copper:

(i) Exposed iron/steel must be galvanized or painted with approved paint.

(ii) Steel overhead rails, if required, may be installed without galvanizing or painting provided the moving wheels are made of non-ferrous metal.

(iii) In buildings which may be used for storage of ammonium nitrate or ammonium nitrate based explosives, copper and copper alloys must not be used.

(iv) Untraversed explosive buildings shall be provided with minimum 5 meter wide concrete hard-standing to serve as fire-break.

Floor

9. The floor should be of well finished concrete free from cracks and crevices. It should be treated with sodium silicate and must be strong enough to support a load of 10 tonnes per square metre. Load bearing capacity for process buildings depend upon the type of stores handled and the requirements of users. These can be designed to withstand 2.5 t/m^2 and $5t/m^2$ respectively. When the floor is cast in panels, the joints must be carefully prepared to achieve a smooth finish and to avoid chipping. While casting floor panels, metal strips should be used in lieu of glass strips. The floors, for certain building when require, shall be surfaced with an approved composition, which is both spark-proof and capable of disseminating static electricity as per STEC Pamphlet-7.

Walls

10. The specifications of walls for different types of explosives store houses have been described in para 7. The interior surface of the wall should be finished off smoothly and free from cracks and crevices. Wall may be painted, glazed or treated with a good oil bound distemper of approved type. Plastering/grinding is acceptable for explosives store houses.

11. The height of the wall should be such that there will be a clearance of 60 cm between the top of the explosives stack (which may go up to 3.75m) and the roof height to facilitate handling of the explosives packages and for providing clearance from the roof. For this purpose, the reduction in the clearance at the soffits of the beams may be ignored.

12. In buildings storing air-craft bombs, sea-mines, heavy ammunition packages etc. where stack heights are low, the building height may be reduced as convenient.

13. In building storing missiles, etc. where crane and other lifting appliances have to be used, the building height may be increased if required.

Roof

14. The roof for the various types of explosives store houses mentioned in para 7 above shall be of well rendered RCC construction, minimum 15 cm thick with a suitable slope on either side and effectively water proofed.

Doors

15. The number of doors, their sizes and their position may be decided depending upon the size of the building and actual user requirements. Explosives buildings must however be provided with at least two doors for use as alternative exits in the event of a fire or explosion.

16. The doors should open outwards, be fire resistant and made to fit as close as possible. The doors shall be made of steel suitably painted over with an approved fire resistant paint and shall be minimum 12mm thick.

17. In case of bunker type storages, two sets of doors are provided with a lobby in between. The door at the outer end of the lobby is to be of grill/collapsible type.

18. Explosives/ammunition boxes are not to be opened inside the store house and hence to enable periodical sampling etc. a lobby of suitable size with earth plate for discharge of static charge may be provided for this purpose. A small room should be provided outside the building earmarked for drawing the sample and closing the same afterwards before depositing in the storage building.

Windows

19. Windows or skylights are not to be provided for explosives storages.

Ventilators

20. All explosives buildings shall be fitted with adequate number of ventilators to create effective ventilation when required. They should be well baffled and fitted with suitable wire-mesh net to prevent entry of rodents and reptiles. Provision of two sets of vents, one at about 0.3 m from the floor on one side of the wall and the other set at higher level near the roof on the opposite wall aid the creation of good draught and should be adopted. The ventilators should have "hit and miss type" Z vent

Loading Platforms

21. The design of the building should be such so as to meet requirements of rail or road service or both. Suitable covered loading platform should be provided.

Sizes of Buildings

22. The following general principles should serve as a guide while deciding the dimensions of storages/explosives houses:

    (a) A low or bunker type building is less likely to be affected by blast from an outside explosion.

    (b) Storage building of greater height normally maintains lower and more uniform temperature and facilitates taller stacks and use of mechanical lifting devices.

    (c) When rail service is to be provided, a long building will allow a number of wagons to be dealt with at one time.

    (d) Building with fewer pillars/columns would be most convenient for internal movement, use of fork-lift trucks and fire fighting and avoids wastage of space.

    (e) For working out the storage space requirements for stacking of explosives/ammunition, the floor area calculations should be based only on 50% of the available storage space to cater for the clearances from walls to stacks, stack to stack, passage ways for handling, etc.

23. The sizes of the buildings to be adopted are essentially governed by the requirements of the users and types of explosives/ammunition required to be stored. The sizes required may be selected from any one of the following, which have been adopted by the Services:

(i)	15m	x	6m	(with one internal partition)
(ii)	18m	x	10.5m	(without column)
(iii)	18m	x	12m	
(iv)	18m	x	24m	
(v)	18m	x	36m	
(vi)	30m	x	15m	
(vii)	38m	x	12m	

Record of Temperature

24. All storage building should be provided with thermometers for regular recording of minimum and maximum temperatures. Wet and dry bulb thermometers or hygrometers may also be provided, wherever required.

Electrical Installations

25. Electrical installation in explosives store-houses shall be in accordance with the provisions of STEC Pamphlet -7 on the subject.

Fire Fighting

26. Every building containing explosives must be provided with adequate first-aid fire fighting measures as stipulated in STEC Pamphlet -6 on the subject.

Lightning Protection

27. Lightning protection should be provided to all building containing explosives in accordance with the provision mentioned in STEC Pamphlet -7 and STEC Pamphlet -17.

Approach Road

28. Approaches to above ground explosives storages, served by roads should be by means of individual loop road leading from the main road. In case of rail served storages, subject to practical working considerations a number of storages may be served by one spur.

Line Plans

29 Line plans of a few typical aboveground explosives storehouses and bunker type magazines are given at Appendix 2. The standard drawings of various explosive facilities of various sizes and capacities may be used and may be obtained from CFEES. The list of standard drawings is given in Appendix 13.

SECTION-III

DESIGN PRINCIPLES FOR PROCESS BUILDINGS

Design Fundamentals

30 In general, process building is a building in which explosives are worked upon or manufactured. This category also includes facilities like ammunition workshops, pilot plants, development production units, explosives laboratories, preparation rooms, etc. The main aim of process building design should be to provide maximum possible protection to those working therein. When these buildings are to be positioned in or near a storage area, generally a minimum separation distance of 275 m should be kept.

While planning construction of process buildings, the following aspects should be kept in view:

(a) The process buildings shall normally be single storeyed unless necessitated by process requirements.

(b) Maintain minimum distances to inhabited buildings i.e. outside quantity distances and between process buildings i.e. Process Inside Quantity Distances, by careful site planning.

(c) Sub-divide process building into compartments by suitable partitioning walls so that a low NEC (unit risk) is obtained in each compartment. In such cases a reduced quantity distance can be used based on the quantity of explosives in each compartment of the building.

(d) Reduce missiles from the PES by smothering effect of the earth cover or by providing interceptor or container traversed. For this purpose, missiles should be stored in bunker type buildings or alternatively in buildings provided with Vertical Inner Faced Traverse.

Constructional Requirements for Explosives/ Ammunition Manufacturing plants

31. Although general requirements and other constructional details described in Section-II for explosives store-houses are also applicable to explosives process buildings, some of the specific requirements for these buildings are enumerated below:-

(a) In buildings where explosives belong to Hazard Division 1.1, are manufactured or handled, the building walls shall be 22.5 cm brick and invariably shielded by a vertical inner faced traverse. In buildings where up to 68 kg explosives are handled, RCC walls

of adequate thickness depending upon the quantity involved shall form the main building walls to perform the function of a container traverse (see Table 2, Section V).

(b) In buildings where explosives belonging to Hazard Divisions 1.2, 1.3, and 1,4 are manufactured or handled, the building walls shall be 34 cm brick. Where explosives belonging to Hazard Division 1.3 are handled, one of the walls should have a weak section (refer para 7(c) of Section II). Since these buildings are normally untraversed, care should be taken at the time of planning that they are sited in such a manner that the doors, windows and weak sections of one building are not facing those of another building. Alternatively, if it is practicable, traversed buildings should be interposed between them.

(c) The roof of all the process buildings shall be 15 cm RCC. However in explosives manufacturing units, specially the nitrating units, where chances of accidents during the process are relatively high the roof should be of light construction if the quantity involved is more than 50 kg.

(d) Process building shall be provided with adequate number of exits for quick escape of the personnel from the buildings in the event of a mishap. Minimum 2 doors are to be provided to each process room. The doors should be of wood painted with a suitable fire resistant paint and they should open outwards. In place of wooden doors for process buildings, following options may be selected as per required size:

i. Very large doors (Width > 20 ft X 30ft high)
   - Steel box, with electric motor operated (heavy)
   - Poly carbonate (conducting) door shutters with steel frame, manually operated
   - Light gauge steel reinforced sandwich composite door shutters.

ii. Medium size doors (6-7ft wide X 7-8 ft high)
   - HDF Veneer, HDF Sandwiched composite or glass fibre reinforced. Door shutters shall be tested in conformation to IS:4020-1994
   - Glass fibre reinforced with lamination of 0.5mm thick gal volume.
   - Polycarbonate (conductive type) double door shutters with steel frames

iii. Small size doors (3 ft wide X 7 ft high)
   - HDF Veneer, HDF Sandwiched composite or glass fibre reinforced when not exposed to sun
   - Rice husk/Jute/sisal/coir moulded doors
   - Doors should be painted with fire resistant paint
   - Hinges to be made up of brass except in process buildings where Ammonium per chlorate (AP) is processed due to its incompatibility

- All doors shutters should be tested in conformation to IS specification IS:4020-1994

(e) Untraversed explosive building shall be provided with 5 meter hard-standing to serve as fire-brake.

(f) The number and size of windows as well as ventilators should be decided depending upon the actual requirements. The window and ventilator frames may be of steel or wood painted with approved type of paint. The glass panes for the windows and ventilators should be of wired glass type.

(g) Process buildings should be provided with conductive or anti-static flooring where ever required. The epoxy based floorings may be used in process buildings where the explosives are not exposed and do not give rise to flammable vapours or explosives dust e.g. Missile integration, Missile check-out facility, Missile Maintenance and Preparation Unit. Epoxy based floorings should not be used in explosive process buildings (e.g. filling, mixing, pressing, grinding etc.) where the explosives are exposed and likely to give rise to flammable vapours or explosives dust.

Dividing / Partition Walls within Buildings

32. When a process/storage building intended for Hazard Division 1.1 explosives comprises of several individual rooms/compartments, the partitioning walls should be such so as to delay substantially, transmission of explosion between explosives on opposite sides of the wall thereby preventing simultaneous detonation. The main advantage of such partitioning walls is that quantity distances can then be based on Net Explosive Content in one compartment (unit-risk) instead of the aggregate quantity in the building. A second advantage is that an accidental explosion is less likely to render unserviceable all the stocks in the building. The specification of such a wall depends upon quantity, proximity and type of ammunition or explosives on each side. The thickness of RCC partition walls for different quantities of explosives are given in Table 1.

TABLE- 1

Wt of Explosives in kg		**Thickness of the wall in cm for percentage of reinforcement by volume**		
Over	**Up to**	**0.2%**	**0.5%**	**0.7%**
0	50	10	10	10
50	75	10	10	10
75	100	15	15	10
100	150	20	20	15
150	200	25	25	20
200	250	30	25	25
250	300	30	30	25
30	350	35	35	30
350	400	-	-	30
400	450	-	-	35
450	500	-	-	35

Notes: (a) The explosives will be kept at a minimum distance of 1 m from the wall

(b) The thicknesses given above do not ensure the protection of machinery and other equipment.

(c) The wall if made of brick should be twice thickness of RCC wall with 0.2% reinforcement.

(d) In case of Hazard Division 1.2 and 1.4 explosives, the partition wall, carried from floor to roof without any gap, should be constructed of 23 cm thick brick.

(e) In case of HD 1.3 explosives, design of multiple compartment storage building up to 10 tons per cubicle capacity, should have the following design parameters:-

(i) Side, rear and partition walls should be of 30 cm thick RCC

(ii) Front wall should be of 20 cm thick brick.

(iii) Door should of 6mm thick MS sheet welded in angle iron same of dimensions 60mm x 60mm x 6mm thick.

(iv) All bays should have independent 10 cm thick RCC roof.

(v) For calculating of size of the cubicle, a criteria of $10m^3$/t of propellant should be used.

(vi) Since the front portion of such a propellant storage magazine acts as a pressure release and flame, siting with front to front orientation of building should be avoided.

(vii) From such a potential explosives site, the quantity distances to exposed site should be used in maximum quantity of propellant stored in any of the cubicle.

Design for HD 1.3 multiple-compartment explosive storage building up to 50 ton per cubicles based on Unit Risk Principle (URP), should have the following design parameters.

(i) All the walls should be 45cm thick RCC (0.4 % reinforcement by volume).

(ii) Inner side of the walls of the structure, ordinary brick lining should be provided.

(iii) All compartments should have independent roof with minimum 20cm thick RCC (0.4% reinforcement by volume).

(iv) Vent area to be provided at the roof should not be less than 1.2 m^2/T of propellant.

(v) Vents of the roof should open at less than 1 bar overpressure.

(vi) Doors to be provided on opposite sides, except where user requires doors on the same side for facilitating loading/unloading.

(vii) 30 cm RCC (0.2% reinforcement by volume) blast wall should be provided in front of the compartments.

(viii) For calculating the size of the compartment, criterion of minimum 10m^3/T of propellant should be used.

(f) In case of Hazard Division 1.1 design of URP based multiple compartment explosives storage building for capacity more than 1100 kg NEC per compartment and up to 2000kg NEC should have following design parameters:-

(i) Multi-compartment explosives storage building should have composite sandwiched side walls having 900mm X 900mm sand pockets retained by 300mm LRC walls.

(ii) Intentionally left blank.

(iii) Intentionally left blank.

(iv) The front and rear walls of the compartments should be 300mm thick LRC.

(v) The roof of the compartment should be 300mm thick LRC.

(vi) The width of the compartment should not be less than 6000mm.

(vii) M 30 grade of concrete should be used for construction.

(viii) Interceptor should have lean reinforcement beyond 2400mm from ground level.

g) Another type of storage building (for prevention of sympathetic detonation and possible occurrence of delayed detonation) for storage of HD 1.1 explosive up to 5.0

ton capacity per compartments named as High Performance Magazine (HPM) should have following design parameters.

(i) Partition wall between adjacent compartments to be made of sand-air-sand composite structure.
(ii) Sandwich walls comprising of two 30cm LRC walls with 3m sand fill in between, should be provided on extreme ends of the compartments of the HPM.
(iii) Doors of all compartments of HPM to be on opposite sides. However, it can be placed on same side if required by user.

Ammunition Workshops, Pilot Plants, Development Production Units, etc

33. The constructional and other special features mentioned in paras 31 and 32 above for explosive / ammunition manufacturing plants are also applicable in the design and construction of ammunition workshop, pilot plant, and development & production unit and ammunition preparation room. Depending on the actual user requirement, these prescriptions may be suitably altered, particularly for specialized buildings like missile test rooms.

SECTION-IV

CODE OF PRACTICE FOR EXPLOSIVES LABORATORIES

General Principles

34. Explosives laboratories under R&D and DGQA Organisations handle explosives in small quantities. These laboratories may sometime handle and deal with such type of explosives whose properties are not fully known or established. Utmost care and all possible safety precautions must be taken for safeguarding personnel and property while planning and setting up of explosives laboratories

35. The main principles to be kept in view while deciding the lay out, design and construction of new facilities are:-

    (a) Explosives laboratories should be a single storey construction as far as possible.

    (b) These laboratories should be sited preferably outside the enclosed explosives area; however, if due to functional requirements this is impracticable then they must be located beyond process inside quantity distance or 45 m from an explosives building, whichever is more.

    (c) Construction should be such as to preclude the communication of effects of explosion of fire in case of a mishap, to the adjoining laboratory/rooms.

    (d) Reduction of explosion and fire risk to the minimum this necessitates the elimination of as far as possible, flammable materials from the structures.

    (e) Provision of adequate entrances and exits so that in the event of an accident the operators quickly escape from the building without any hindrance.

    (f) Provision of efficient working conditions- There must be no overcrowding by men or plant, machinery, stores or apparatus in explosives rooms.

    (g) The area shall be enclosed by proper perimeter fencing for security reasons.

36. The prescriptions contained herein are to be followed in the planning of new explosives laboratories. It is not intended that extensive alterations be made to the existing laboratories to make them conform to these regulations. However, if it is practicable and economically feasible, necessary modifications may be made to bring them up to the desired safety standards.

Salient Constructional Features of Laboratories

37. The main laboratory building should comprise of several laboratory room to permit process activities of compatible explosives only to be carried out in each laboratory room. Users may suitably alter this set up depending on their actual functional requirements.

38. The building plinth should be sufficiently raised so as to prevent any water entering it. The apron around it should be sloping outward to drain the surface water.

39. The construction of laboratories should be of most economical materials consistent with stability and climatic conditions. Brick, concrete and stone are the most suitable. Wood and flammable material generally should be avoided. As far as possible doors, windows and ventilators should be of steel.

40. The floor should be non-slippery and of well finished concrete free from cracks and crevices. In laboratory room/s where highly sensitive compositions are handled, the floors shall be surfaced with an approved composition/material which is both spark proof and capable of disseminating static electricity.

41. The main building walls including the partitioning walls of individual laboratory rooms shall be 34 cm thick brick. Inside surface of walls shall be finished off smoothly and free from cracks and crevices. Walls may be painted, glazed or treated with a good oil-bound distemper.

42. The roof shall be of well-rendered RCC construction of minimum 12.5 cm thickness to give protection against penetration by debris, low velocity fragments and lobbed ammunition.

43. Adequate number of windows, doors and ventilators shall be provided in the laboratories. It is desirable to have minimum number of two doors per laboratory room. Windows and ventilators shall be fitted with wired glass panes.

Explosives Limits

44. **(a) Laboratory Rooms**

Maximum permissible explosives limits of different laboratory rooms shall be as under:

High Explosives/Ammunition Laboratory : 2.5 kg
Propellant Laboratory : 5.0 kg
Initiatory Laboratory : 0.1 kg
Pyrotechnic Laboratory : 1.0 kg

It is desirable that an initiatory laboratory be provided with a cubicle having pigeon holes properly earthed for the storage of initiatory samples up to a maximum limit of 0.25 kg.

(b) **Sub-Storage/sample cubicles**

To cater for daily requirements/supply of explosives to the various laboratories, a separate building having several cubicles for storage of small quantities of explosives shall be constructed at a minimum of 5 m distance from the main explosives laboratory building. Construction details as mentioned above will be followed. Maximum permissible explosives limits i.e. Net Explosive Content (NEC) of the various cubicles shall be as under:-

High Explosives	Hazard Division 1.1	5.0 kg
Gun Powder and Pyrotechnics	Hazard Division 1.1	5.0 kg
Propellants	Hazard Division 1.1	5.0 kg
Propellants	Hazard Division 1.3	25.0 kg
Ammunition	Hazard Division 1.1	5.0 kg
Ammunition	Hazard Division 1.2	25.0 kg

(c) **Laboratories for chemical warfare ammunition, phosphorous and inflammable liquids/gels.**

Laboratories handling chemical warfare ammunition, WP/PWP or WP/ PWP ammunition, inflammable liquids or gels should be located separately at least 10 m away from the main laboratory buildings. These laboratories require special first aid precautions and should be planned accordingly.

(d) **Isolation magazines**

Waste explosives awaiting disposal should be kept in a separate isolation magazine constructed at an appropriate distance from the burning ground. Waste explosives should be kept under oil/water during storage. The isolation magazine should be constructed at a remote location from the main storage location and quantity distance permitted as per STEC regulations should be provided.

(e) **Burning/Demolition Ground**

For disposal of waste explosives by burning, a suitable platform made of fire bricks should be constructed and for disposal of waste ammunition / explosives by demolition, suitable demolition pits, as stipulated in AMI Pamphlet OP-IV series should be provided. The burning / demolition ground should be sited at appropriate distances, as given in the above mentioned AMI Pamphlet.

(f) Blast Containment Structure for demolition of Ammunition up to 8 kg HD 1.1 NEC

The disposal of unserviceable and life expired ammunition has always been a matter for a great concern with the armed forces. With the induction of more quantum of explosives, the quantum of unserviceable/life expired ammunition has also increased. In order to dispose off such ammunition, local demolition grounds are developed in depots which require large safety distances for safe operations and prevention of any collateral damage to existing infrastructure. The conventional approach for disposal of ammunition involves open detonation/demolition that requires large safety distances, with a minimum of being 275 m (radial). Sandbags are placed over the round to reduce the blast pressure and capture fragment munitions which is a cumbersome job that requires a lot of logistics still has associated risk of severe injury or fatalities. The containment structure is fully enclosed container type structure which is capable to withstand repeated explosions with predefined quantity of explosives for safe & secure disposal. The design of blast containment structure can repeatedly contain blast and fragmentation effect of ammunition having Net Explosive Content of 8 kg HD 1.1. The structure has RCC inner wall and outer wall to withstand internal pressure loading of 3 bar. Sand layers as blast mitigating material for reducing the transmitted blast/shock loads on the structure. The super structure has been covered with the sacrificial layer of aluminium sheet to protect the structure from fragment impact damage. The structure consists of blast door to withstand load due to internal explosion and ventilation system for exhaust of sand dust post explosion. The structure consists of automated sand filtration system to pump out the sand and pump it back after separation from debris present.

(g) Magazines

For the purpose of storing still larger quantities of explosives/ammunition, magazines shall be constructed as per the requirements of STEC regulations. Such magazines shall be sited at appropriate distances based on quantity of explosives stores.

(h) Sample room to ESH

A small sample room should be provided outside the building earmarked for drawing the sample and closing the same afterwards, before depositing in the storage building.

45. In an explosives laboratory room or a cubicle meant for storage of explosives/samples, only explosives which are compatible with each other shall be handled or stored. However in exceptional circumstances and with the approval of competent authority i.e. Head of the Establishment, explosives of different compatibility groups can be stored in a cubicle provided the NEC per cubicle does not exceed 5 kg. Even in such a case, principle of separating high explosives from primary explosives shall be observed.

46. Explosives of doubtful stability shall not be stored in cubicles. Arrangements must be made to have them shifted in isolated magazines and kept under special observation.

Electrical Installations

47. Electrical lighting, heating and power supply in explosives laboratories/ storage cubicles shall comply with the regulations given in STEC Pamphlet -7 on the subject. In short, the following points shall be borne in mind:

(a) An electrical wiring system within an explosives building must be enclosed entirely in solid drawn/ERW steel screwed conduits. Alternatively lead-covered twin-cored steel wire armoured cables or mineral insulated metal sheathed cables of approved type should be used in lieu of conduit system.

(b) Protected electrical lighting fittings in an explosives laboratory shall be in accordance with the type of explosives handled in that room. Totally enclosed lighting fittings may be installed in the storage cubicles.

(c) Where necessary, explosives laboratories should be centrally air-conditioned to comply with the requirements of STEC Pamphlet-8. In exceptional cases, ceiling fans may be permitted with suitable safety precautions. Use of pedestal and table fans is prohibited.

(d) Exhaust fans, if installed in explosives laboratories shall be provided with approved type of electrical motors.

(e) The following heating system may be used in the laboratories:
   i) Hot Water,
   ii) Low pressure steam not exceeding 1 kg/cm^2, and
   iii) Thermally-designed electric heaters conforming to flame and explosion proof standards with a surface temperature not exceeding 85ºC.When steam or hot water is installed, the temperature of steam pipes or radiator panels must not exceed 109ºC.

(f) Installation of lightning protection system is not a must.

48. Fire Fighting and Medical Facility

Adequate fire-fighting measures shall be provided as per STEC Pamphlet-6. Explosives laboratories should also be provided with medical first aid facilities including shower bath for immediate decontamination due to spillage of corrosive liquids, etc.

SECTION-V

TRAVERSES THEIR FUNCTIONS AND CONSTRUCTION

Functions

49. A traverse is a solid mass of earth, and, concrete or brick built around a building or stack containing explosives and its main functions are as under :-

(a) To intercept low-angle high velocity missiles generated by explosion and stop them from causing direct propagation if explosion/fire to explosives in adjacent buildings or stacks.

(b) To protect the personnel in nearby buildings/open from low angle high velocity missiles generated by an explosion.

(c) To protect explosives/ personnel from direct missile attack in the event of an explosion in an adjacent building containing explosives.

In addition to the above, a traverse also deflects blast/radiant heat even though to a limited extent.

A traverse, however, provides no protection from high angle missiles fragments of roof, wall or lobbed ammunition projected upwards. Such missiles/debris, which escape over the traverses may get scattered over a large area and cause injuries to the personnel in the vicinity. However, propagation of explosion to the adjacent buildings at Storage Inside Quantity Distance is unlikely due to comparatively lower velocity of the missiles falling under gravity, more so if the adjacent buildings have RCC roofs.

Classification of Traverses

50. Traditionally traverses have been classified into three functional types depending on the nature of protection they afford. It is not always possible to distinguish clearly between them as they tend to merge according to their position relative to the PES and ES. However, it is considered that this classification by function is still useful because a measure of the traverse strength required is indicated. The three types of traverses are as given below:-

(a) Receptor Traverse –Its function is to protect the explosives within the building it surrounds from direct attack by low angle high velocity missiles from a nearby explosion. Normally a building wall of 68 cm brick or 45 cm RCC will serve the purpose of a receptor traverse.

(b) Interceptor Traverse –It is to protect explosives outside such a traverse from direct attack by low angle high velocity missiles from an explosion in a building or stack within its confines. It can be undermined by the crater and destroyed by the blast but it must remain

standing long enough to intercept the missiles. It must be massive to be effective and hence may be uneconomic for large quantities of explosives.

(c) Container Traverse –Its function is primarily to protect personnel elsewhere from an explosion within its confines. It must remain substantially intact after an explosion. This is practicable only for small quantities of explosives up to 1100 kg and may be used for certain process buildings.

Design of Traverses

51. Depending upon the constructional design, there are six different types of traverses. They are shown with their explosive limits in Appendix 1. These are as follows:-

(a) Natural Angle Traverse, NAT

(b) Vertical Inner Faced Traverse, VIFT (or Semi Vertical Inner Faced Traverses).

(c) Chi worth type traverse

(d) Bunker type building (or Igloo)

(e) Wall traverse: Brick, reinforced concrete, earth/sand sandwiched between concrete/steel.

(f) Natural features of site, for example, hillocks, etc.

Geometry of Traverses

52. Proper traverse geometry is necessary to reduce the risk of high velocity projections escaping above or around the ends of the traverse and so producing an explosion in an adjacent site. Since such projections do not move along perfectly linear trajectories, reasonable margins in traverse height and length must be provided beyond the minimum dimensions, which block the line of sight.

53. In general a traverse should be placed as close as possible to the explosives stack it protects in order to give maximum shielding from high velocity missiles and also to restrict its height and length to a minimum. The traverse toe or face should be positioned about 1 to 1.5 m from the stack of explosives/store house wall. However, it is essential to make the distance greater to provide passage for vehicles, etc.

54. Earth traverses with a minimum cross-section of 2.4 m at the level of the top of the explosive stack are considered to be effective in providing protection. Traverse should be at least 0.6 m higher than the maximum stacking height of the explosive and, in the case of a building the traverse should normally be up to eave's height. As an alternative to this, the limiting

dimensions for the earth traverses can be controlled by a 2^0 rule where the stack height can be fixed. The procedure is to establish a reference point at the top of the far edge of a stack under consideration (see Appendix 3). The crest width should be 1 m minimum for NAT and 1.5 m for VIFT. The length of the traverses can be determined by extending the traverse exclusive of the end slope to 1 m beyond lines between the extremes of the two stacks of explosives under consideration. These lines must pass through at least 2.4 m of traverse material (Appendix 3).

55. Where a traverse may be under-mined by the crater or NEC exceeds 70,000 kg, the traverse should be moved outwards or alternatively the cross section area of the traverse should be increased in direct proportion to the weight of explosives so that an increase is made in that part which is normally 2.4 m in cross-section. The stipulation is necessary to ensure that at least two-third of the traverse base is excluded from the crater. The crater diameter (D) in meters is determined by $D=Q^{1/3}$ (Q is NEC in kg) and is measured from the centre of explosives.

56. For explosive process building where the explosive are handled/ processed at a height not more than 1.5 m from the ground level, the traverse may be 0.3m above the doors/windows height whichever is more.

57. The entrances/passage ways for traversed buildings should be suitably designed to provide the maximum convenience for mode of service i.e. rail and road. These must also be so located as to facilitate quick escape in an emergency. This could be achieved by providing curved /doglegged entrances or blast walls in front. The optimum angle which doglegged entrance should make at its centre is related with its length (L) and the width of opening (D) by the formula i.e. $2\tan^{-1}(L/2D)$. A sketch of the doglegged entrance is given at the Appendix-5. The orientation of entrances should be such that fragments from inside the building arising from an explosion are contained and entry of external fragments is precluded.

Materials and Precautions for Construction of Traverses

58. Earth for traverse and for cover of building should be made of material as prescribed below:

(a) When concrete or brick is used in conjunction with earth, either of these materials may be taken as equivalent to 4 times its thickness of earth with regard to ability to stop fragments. Concrete or brick may be used to support the earth or it may be those parts of the roof and walls of a building, which intercept the high velocity projections.

(b) There are two types of precautions, which are necessary in the construction of earth traverses or the earth cover for buildings used for storage and process of explosives and ammunition. One type relates to the potential hazards to the other ammunition and to personnel in the event that the material is dispersed by an accidental explosion in the contained building. The other type relates to the precautions necessary to ensure the structural integrity of the earth traverse or cover.

(c) There is no need to consider the first type precaution if it can be predicted that the material would not be dispersed by the postulated explosion. This will be the case if the traverse is sited beyond the crater radius.

(d) Where it is possible that the material would be dispersed by an explosion, precautions should be taken to reduce the hazard of large stones causing initiation by impact upon ammunition or explosives in adjacent sites The selection of material and its use should be governed by the following prescriptions which represent a reasonable compromise between undue hazards and excessive cost of construction:

(i) Do not deliberately use rubble from demolished buildings.
(ii) Ensure that stones larger than 75 mm diameter (about the size of man's clenched fist) are removed during construction. Other deleterious matter should also be eliminated.
(iii) The design slope for a well compacted traverse material should be between 1:1.3 to 1:2 (37º to 26º) depending on the proportion of fineness in the earth used.

(e) Regarding the second type of precaution relating to structural integrity, this is applicable for all types of traverse. For this purpose, the material should be reasonably cohesive and free from excessive amounts of trash and deleterious organic matter. Compaction and surface compaction should be provided as necessary to maintain structural integrity and avoid erosion. Where it is impossible to use a cohesive material, for example, at a site in sandy desert, the earth work should be finished with a layer of cohesive soil or an artificial skin. On the other hand, one should avoid solid, wet clay during construction since this is too cohesive and would result in an excessive debris hazard.

(f) To prevent the erosion of earth from the traverse mounds, toe wall of brick or concrete of 1 m height, should be provided on both sides of the natural angle traverse and on the outer side of vertical inner-faced traverse. Additionally to bind the earth on traverse, suitable turfing should be provided.

Wall Traverses

59. **(a) External Wall of Buildings :**

(i) A 68 cm brick or 45 cm RCC wall of a building can be considered to act as an adequate traverse at an ES.

(ii) Where stocks are to be preserved, or personnel protected, the walls of the building can be designed to resist collapse. Appendix-4 gives approximate thickness of simply supported or cantilever RCC walls to resist various charge weight exploding in an adjacent storehouse.

(b) Internal Walls of Building Traverses:

(i) The merit of reducing the overall effect of the contents of an explosives building by providing walled compartments containing small quantities of explosives has already been discussed in Para 32 of Section-III. This is especially important for process buildings where the walls may be required to act as container traverses and protect personnel. Suitable RCC walls for this purpose may be obtained by using Appendix 4.

(ii) For relatively small charges often used in process buildings, the following canti-lever container traverse of 3 m maximum height and 1 m from the charge may be used as given below in Table 2.

TABLE –2

Charge Weight kg	Preferred choice: RCC wall thickness (Buttressed at 3m centers,0.2% tension reinforcement) mm	Second Choice: Brick wall thickness mm
2.5	225	340
5	225	340
7	225	450
12	225	570
18	300	-
35	450	-
50	600	-
68	750	-

(c) Sandwich / Composite Walls

As an alternative to a vertical inner-faced traverse, Sandwich/Composite walls comprising of two 20 cm RCC walls with 3m sand fill in between can also be used for process buildings handling up to 1100 kg of UN Haz. Div. 1.1 explosives/ ammunition. Such walls are also recommended as partitioning walls for bin type buildings for unit risk of above quantity. Besides offering advantages like very little recurring maintenance cost, better clean area conditions around the process buildings and security, sandwich type of construction is well suited for situations where availability of land is a major constraint. However, the initial cost of sandwich wall is likely to be marginally higher than a vertical inner-faced traverse.

60. **Additional design parameters for storage of WP ammunition**

(i) Wall: 2.5 m high, 34 cm thick brick

(ii) Roof: 3m high and 15cm thick RCC with sufficient projections outwards to protect the stores from direct sunrays and rain.

(iii) Door: The ESH should have at least two doors and they should open outward. The height of the doors may be same as the height of wall i.e. 2.5 m.

(iv) Water Tank: Water tank of size 1.5 m x 1.5 m x 1.0 m close to each door outside the building.

(v) Floor: PCC: Suitable wire net for WP shed is to be provided after 2.5 m height of wall to protect the stores against entry of birds. The sketch of WP shed is given at Appendix 6.

61. **Partition wall for segregation of explosive of different compatibility groups**

Storage of ammunition of same hazard division but different compatibility groups (except compatibility group A & L together) is permitted in the same building subject to the following conditions:

i. Provision of partition wall of at least 23 cm thick bricks or equivalent PCC up to the ceiling for buildings of height up to 3.5 m.

ii. For buildings of height greater than 3.5m thickness of partition wall of bricks/PCC may be increased to ensure stability of the wall.

iii. Ammunitions /explosives of one compatibility groups should be stored in the same bay.

SECTION-VI

BASIC DESIGN PARAMETERS FOR UNDERGROUND FACILITIES
INTRODUCTION

Scope

62. The section covers basic design parameters for underground facilities for storage of explosives / ammunition of Hazard Division 1.1

(a) This chapter covers guidelines on the basic requirements for siting and design of underground explosives storehouses.

(b) While planning underground explosives facilities, the lay-out, orientation, design and construction of the underground explosive facility and traverses should be such so as to meet the following requirements:

(i) At an Exposed Site (ES) initiation of, and/or damage to the contents of an Explosives building, can be prevented/minimized by structural resistance to blast, high velocity projectiles and flame.

(ii) At a Potential Explosion Site (PES) initiation of and damage to, the contents of adjacent buildings can be prevented by intercepting high velocity projectiles and reducing blast.

(iii) In process buildings, personnel can be protected from the effects of a nearby explosion.

(c) The prescriptions contained herein reflect only the basic features and therefore must be read in conjunction with the geotechnical investigation of the selected site, latest engineering practices along with the general specifications stated in these regulations.

(d) Users are to interpret these regulations intelligently, bearing in mind that these regulations, although comprehensive and exacting cannot be expected to provide for every contingency or emergency that may arise, or to replace sound judgment, common sense, and efficient supervision. However, in case of any doubt, the matter can be referred to CFEES, Brig S.K. Mazumdar Marg, Timarpur, Delhi for clarification.

Design Criteria

63. Before actual construction of any underground explosive /Ammunition storage, various requirements have to be defined. The Underground Explosive storage should be designed based on tolerable levels of blast effects. The Inhabited Building Distances (IBDs) for underground explosive storages should be based on tolerable levels of damage expected from

a side-on Air blast overpressure of 5 kPa. At IBDs, the fragments and debris produced in an accidental explosion should not exceed one lethal fragment (energy > 79 J) per 56 m^2.

64. Before actual construction of the underground explosive facility geotechnical investigation of the site should be carried to confirm the type rock/ soil at the proposed site. The requirements for foundation may vary depending upon the seismic zone of the site.

65. For brick or RCC structures having foundation in different soil/rock, the criteria for allowable ground shock peak particle velocity (PPV) as accepted by Indian Bureau of Mines should be taken into consideration. The structure should withstand an internal pressure of 5 bar and ground shock of 10 ‘g’ for 30 ms duration

Storage Requirement

66. Storage requirement should be established based on quantity of explosives/ ammunition that has to be stored i.e. Net Explosive Content (NEC) and package dimensions.

(a) **Capacity**

Underground storages may have a capacity up to 40,000 kg (Net Explosive Content) of explosives per chamber. Size and shape of the chamber will be based on the required NEC per chamber, the bulk volume of the ammunitions, and the engineering properties of the rock in which storage chamber will be excavated. For ammunitions such as rockets and missiles, required volume may be many times greater than those of ammunitions with large explosive quantities. The required floor area will also depend on the size of the packaged ammunitions and the operating space required by the MHE that stacks them.

(e) **Size**

Size of the chamber may vary with NEC to be stored. Chamber width should be so as to accommodate stocking space and operation of MHE. Maximum chamber width may not exceed structural limit of excavated space depending upon the rock properties. Chamber width of 20 to 30m can be constructed in very strong rock types. Large storage capacity can be achieved by increasing the lengths up to six or eight times the chamber width, maintaining a stable chamber. Preferably the width-to-length ratio of the chamber should be 1:2 or 1:4.

Chamber loading density should be less than 10 kg/m^3. This may be increased up to 40 kg/m^3 after case-specific study by CFEES.

67. **Siting of Underground Storages for Explosives/ Ammunition**

(a) **Accessibility of the site:** Site should be within the easy reach of railways, main roads, public transportation, and supplies of water, fuel and electricity.

(b) **Geotechnical investigation of the site:** Geotechnical investigation of the site should be carried out to determine the physical properties of the material (soil/ rock) that has to be excavated, ground water conditions and presence of cracks and fissures in the rocks.

(c) The site should not have permeable rock with a high water table.

(d) The site should be well drained and not prone to flooding.

(e) The site should not be susceptible to erosion.

(f) Rocks with cracks and fissures should be avoided to locate the underground storage. These should be sited preferably in sound rock.

Types of Underground Facility Layouts

68.The layout of the entrance/exit tunnels (and the engineering properties of the rock in which a chamber is excavated, for any secondary access passages) and the storage chambers will be determined by the minimum tunnel length, required chamber cover thickness, additional length needed to accommodate loading/unloading chambers, expansion chambers, etc or to reduce the explosion hazard levels. Layout of the underground explosive storage facility may be straight / 'U' shaped, depending upon the piece of land available.

(a) Single chamber:

A small facility may consist of a single chamber and a coaxial entrance tunnel (Appendix-8, Figure a). It may also consist of a storage chamber that is located at an angle to the entrance tunnel (Appendix-8, Figure-b).

(b) Multi-chamber

A large facility may have several storage chambers and more than one portal and may consist of single large chamber or series of storage chambers connected to main passageway with access tunnel {Appendix-8 Figure-(a) and Figure-(b)}. Lay out and configuration of the underground facility is such that it provides maximum reduction in exit pressures and minimum hazards in case of an accidental explosion.The number of chambers depends upon topographical, geological conditions and total quantity of explosives to be stored.

70. **Tunnels**

(a) Main Entrance Tunnel

Chambers will be connected to outside by means of tunnels, the length of which, will depend on cover thickness and height of the chamber. The tunnel width must accommodate the width of the largest vehicle, a separation distance for any two-way traffic and maneuverability room. Multi-chamber underground facility should have at least two exits. Minimum separation distance between two exits should be equal to chamber interval that depends on quantity of explosive. The rock thickness between the chamber and passageway should be at least equal to or greater than the chamber separation distance. The height of the tunnel should accommodate lighting fixtures and ventilation ducts above the required clearance height of the largest vehicles. Exits from underground storage sites should emerge away from other entrances, buildings, or traffic routes etc. to avoid hazards due to blast, flame and debris. The tunnel should withstand internal pressure of 10 bars, where cover thickness is less than 1m.

(b) Length of the Tunnel

If the ratio of the length of the main passageway to its diameter is greater than or equal to 11 then maximum angle of dispersion should be taken as ±10 degrees. If the ratio of the length of the main passageway to its diameter is less than 11, the dispersal angle should be taken as ± 20 degrees. For inhabited building falling outside the maximum angle of dispersion, debris from the adit need not be considered.

(c) Chamber Access Tunnel

Chamber entrance tunnel will be used only by hand trucks or forklifts for moving ammunitions from the main tunnel or from the loading/unloading chamber to the individual storage chambers. The widths of these tunnels should be based on the width of the MHE and /or large ammunition container plus a separation distances for two-way traffic, plus maneuverability room. The height of this tunnel must be based on the height of the MHE, forklift in the raised and transporting position. The distance between chamber access tunnel and the main tunnel should be at least equal to chamber interval.

(d) Slope of the tunnel

The length of the tunnel will depend on earth cover and slope of the tunnel. Slope of the tunnel should be convenient for vehicle access. The slope of approx. 1:14 or so as per user's requirement should be maintained for the main entrance tunnel leading to the chamber. Landings should also be provided in the tunnel to facilitate manual loading-unloading or for repairs/ maintenance of vehicle if required during loading–unloading operation.

(e) Inclination of the Tunnel

Chamber access tunnel should be inclined to main entrance tunnel, at an angle between 40º to 70º preferably at 60º for facilitating the access of MHEs to the chamber.

71. **Rock / earth cover required for Underground Storage Facility**

Thickness of the cover will depend on both; the quantity of explosive to be stored and the structural strength of the rock at the site. It may vary with the required protection level. If the cover is part soil and part rock, the effective thickness of the cover will be determined based on mass by considering soil as having one half of the mass of rock. The rock-cover/ thickness surrounding an underground storage site should be such that crater blast-hazards in case of an accidental explosion are excluded. Minimum scaled cover thickness {Actual Thickness/ $(NEC)^{1/3}$} of 0.35 kg/m^3 should be provided. The roof lining should be strong enough to withstand minor rock-falls.

72. **Provision of Quantity Distances**

(a) Chamber interval:

Minimum separation distance should be provided between two chambers to prevent major damage by spall, propagation through passageways, blast, flame and hot gases, cracks and fissures.

(b) Outside Quantity Distances:

For provision of QDs, following effects due to accidental explosion should be considered:

i. Blast effects from tunnel adits
ii. Blast effect from craters, if the rock cover is insufficient
iii. Ground Shock
iv. Debris from tunnel adits
v. Debris from cratering
vi. Flame and gases

The QD for tolerable ground shock is the same in all directions for homogeneous, geological media, whereas QDs for other hazards (blast thermal and impulse, etc.) vary markedly in different directions. IBD in a given direction must be the largest of the distances determined for protection against blast, debris and ground shock.

Minimum Inhabited building Distance (IBD) should be provided so that in case of cover rupture due to accidental explosion, there is negligible airblast hazard due to crater blast.

Minimum IBD should be provided along the extended centerline axis of an opening/adit to prevent from hazard due to overpressure higher than 5 kPa.

Quantity distances for multi chambered underground ammunition storage facility should be determined as follows:

i. Scaled cover thickness = Earth cover (m) / $Q^{1/3}$ …….(Equation-1)
   Where earth cover = Actual thickness of earth over the underground chamber
   Minimum scaled earth cover of 0.35 should be provided.

ii. Chamber interval $=1.4Q^{1/3}$ (for soft rock or soil) .....(Equation-2)

$= 2.0Q^{1/3}$ (for hard rock)…….(Equation-3)

iii. OQD around chamber (Crater debris) $= 6.0Q^{1/3}$.....…….(Equation-4)

The quantity distances required for underground ammunition storage facility of 40 MT NEC capacity per chamber and having a loading density of less than $10kg/m^3$ can be illustrated as given below:

1.	Earth Cover	= 12m
2.	Scaled cover thickness	= 0.35 m/ $kg^{1/3}$
3.	Chamber interval	=48 m (for soft rock or soil) = 69 m (for hard rock)
4.	OQD around chamber (Crater debris)	= 205 m
5.	OQD around Adit	= 465 m (without barricade) = 200m (With barricade)

These distances are depicted as shown in Appendix-9

73. **Hazards mitigation features**

Hazard mitigation features may be provided to contain or mitigate the hazardous effects of an explosion, such as airblast, debris (fragments), and thermal effects. Following hazard mitigation features (Appendix-10) may be incorporated in underground storages:

(a) Expansion chambers

Large rooms located between the storage chambers(s) and the tunnel entrance(s) having cross sectional area at least three times that of the largest tunnel intersecting the expansion chamber and length equal to expansion chamber width should be provided. Expansion chamber helps in reducing the adit blast. Expansion chamber can entrap debris also, if the tunnels entering and exiting the expansion chamber are offset in axial alignment by at least two times the tunnel width. Expansion chamber should preferably be located nearer the portal rather than the nearer to the storage chamber for achieving considerable reduction in quantity distances.

(b) Debris Traps

Debris Traps are pockets excavated in the rock/soil at or beyond the end of access tunnel sections, and designed to entrap debris blown through the tunnel from an explosion. These

should be at least 20% wider and 10% taller than the tunnel leading to the trap with a depth of at least 1.5 times the tunnel diameter.

(c) Portal Barricade/ Traverse

Properly designed and located portal barricade can reduce the IBD for adit-blast up to 50%. A barricade shall be located in front of a portal and centered on the extended axis of the tunnel. The barricade shall be located at a distance of not less than the width of the tunnel and not more than three times the width of the tunnel from the portal. The actual distance should not be greater than that required to allow passage of any vehicle or material handling equipment (MHE). The distance shall be based on the turning radius and operation width required for the vehicle or MHE.

The face of the barricade toward the portal shall be vertical and concave in plan and oriented perpendicular to the tunnel axis, with wing walls on either side of the face that are angled at 30 to 60 degrees towards the portal. The width of the barricade face (excluding wing walls) shall intercept an angle of at least ten degrees to the right and left of the extended tunnel width. The height of the barricade along its entire width shall intercept an angle of at least ten degrees above the extended height of the tunnel. The front face of the barricade (excluding wing walls) shall be constructed of reinforced concrete, with a minimum thickness of 0.305 meters or a thickness equal to the 10 percent of the barricade height, whichever is greater. The concrete wall shall have a spread footing of sufficient width to prevent significant settlement, and the central wall, wing walls, and footing must be structurally tied together to provide stability. The backfill behind the concrete wall may be composed of any fill material, including rock rubble from the tunnel excavation with a maximum particle size of 75mm within the area extending out to 1m from the rear face of the wall. Refer Appendix-11 Figure-(a) and (b) for details.

74. **Operation Support Systems**

(a) Temperature and Humidity Control

Air conditioning temperature and relative humidity should be maintained as per user's requirement. The chamber may be lined with concrete or coated fabric to control humidity. These facilities should be well designed to provide environmental control needed for storage of the ammunition and this should be available under all circumstances.

(b) Electrical Fittings

All wiring and electrical equipment in underground facilities should be of moisture and corrosion resistant materials and should comply with STEC regulations. Facilities should have emergency lighting systems to provide minimum illumination in the event of a power failure. Emergency power generator should also be provided.

(c) Lightning Protection

Underground storage will not normally require lightning protection.

(d) Transportation and Material Handling Equipments

Underground facilities may have provision of various means for transport of the explosive. Various type of transportation equipments will be used that may govern ventilation requirements. Underground facilities should also have provision for material handling equipments like mobile lifting or stacking appliances and cranes of the fixed gantry type operated electrically. Electrical installations and equipments have to be installed similar to above ground installations.

(e) Fire Fighting Equipments

Automatic heat and smoke-detecting and fire-extinguishing system may be installed in the tunnels. Fire Alarm system may be provided to operate throughout the whole area, both above and below ground near the portal. In air conditioned sites or in its sites provided with forced ventilation, shut down of these on an outbreak of fire may be

provided. Fire-fighting equipment retained underground should be positioned for accessibility and potential use.

(f) Parking Area

Provision for parking of explosive vehicles, fire tenders, and recess for electric generator set should be made beyond the portal.

(g) Ground Water Control

Based on ground water and surface hydrology survey and investigations, proper drainage/pumping system should be provided in the underground storage facility.

(h) Seepage Control

A water proofing system should be provided in storage chambers and tunnels.

(i) Ventilation System

Vehicles will be permitted in underground installations, therefore natural ventilation and mechanical ventilation system should be provided based on overall facility layout, types of loading and unloading equipments and transportation vehicles that will operate in the facility. As ventilation shafts will open to the exterior, design should be such that trespass and sabotage can be prevented.

75. **Underground explosive storage structures with vertical shaft**

Conventional Underground Explosive Storage Structure has very long inclined tunnels on either ends which provide access to underground chambers. The design of underground explosive storage structures with vertical shaft further reduces the required safety distances and reduced construction cost and land footprint. This blast escape shaft provides the directional path to the tunnel blast overpressure to release in the upward direction in atmosphere which will reduce the blast overpressure to the surroundings and thereby reduce the safety release in the upward direction in atmosphere which will reduce the blast overpressure to the surroundings and thereby reduce the safety distance requirements. Automation system for transportation of explosive inside the tunnel has also been incorporated in the design along with goods lift facility.

Design Features

The underground ammunition storage with vertical shaft consists of storage chambers, access tunnel connecting storage chambers to the main tunnel, debris traps, expansion chambers for mitigation of the shock front pressure, goods lift and staircase for entry/exit of personnel and goods. The structure has following features:

a. Vertical blast escape shaft to release blast pressure in vertical upward direction in the atmosphere.
b. Blast doors to safeguard explosives kept in acceptor compartment and to isolate lift and blast escape shaft from effects of explosion.

Advantage

The blast escape shafts provide the directional path to the tunnel blast overpressure to release in the upward direction in atmosphere which reduce the blast overpressure to the surroundings and thereby reducing the safety distance. The specific design feature of vertical shafts has reduced the foot print area requirement approximately to 40% and land area requirement for OQDs has been reduced to approximately to 20% for full scale of twin compartment 40 MT NEC HD 1.1 capacity as compared to conventional underground storage structures.

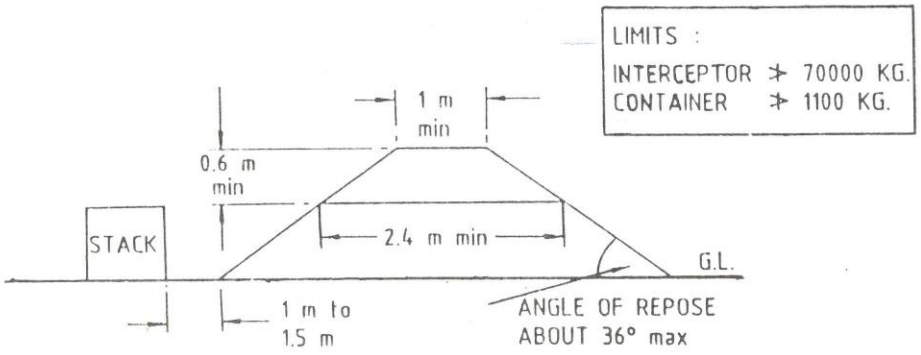
76. **Vetting of design**

CFEES will analyze the request from the user and generate the necessary specifications for conceptual design which will be input for development of detailed structural design. The structural design drawings for underground storage facility peculiar to site/ location as per zonal specification will be prepared by E-in-C Branch (MES) or consultant identified by them or user. The design will then be reviewed and approved by standing committee of experts.

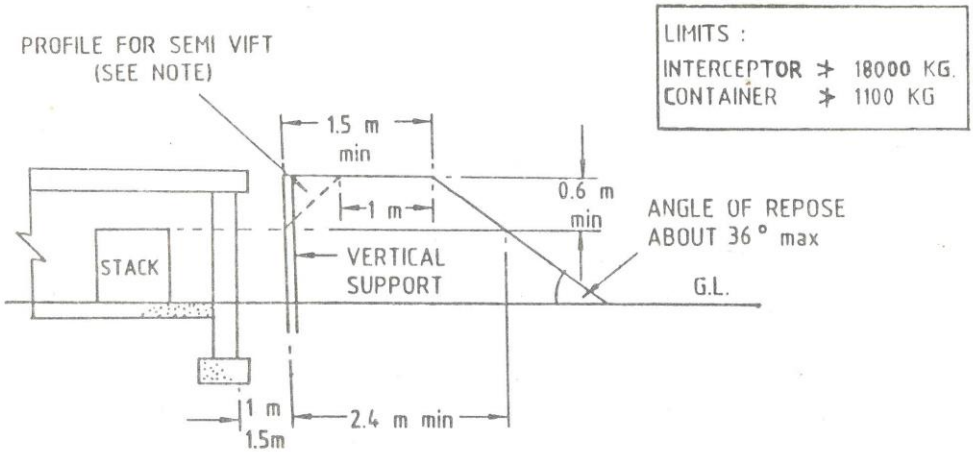
APPENDIX 1

DIAGRAMMATIC SKETCHES OF DIFFERENT TYPES OF TRAVERSES

TYPE I NATURAL ANGLE TRAVERSE (NAT)



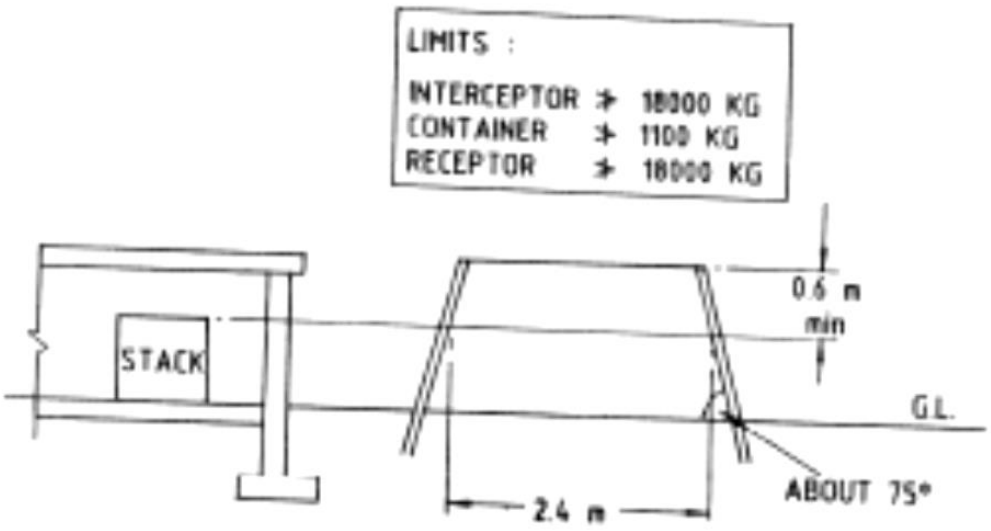
TYPE II VERTICAL INNER FACE TRAVERSE (VIFT)



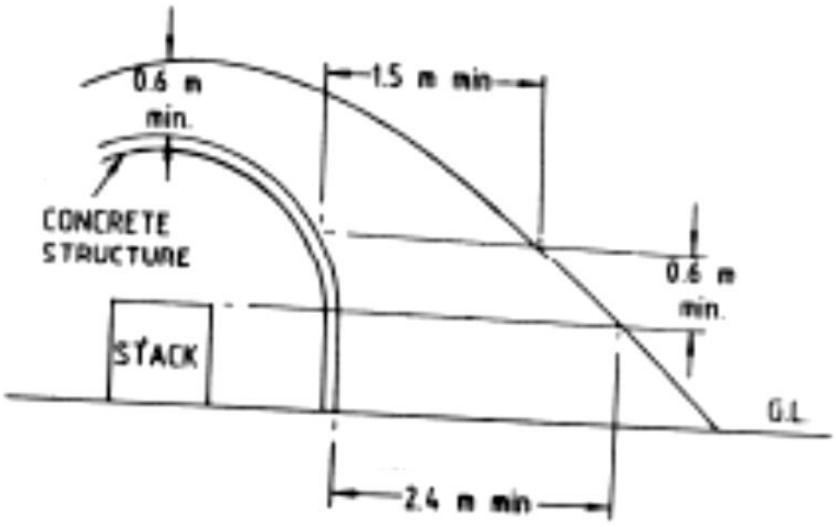
NOTE:- SEMI VERTICAL INNER FACE TYPE
THIS TYPE IS SIMILAR TO TYPE II EXCEPT THAT THE VERTICAL SUPPORT STOPS AT THE TOP LEVEL OF STACK AND TRAVERSE IS SLOPPED OFF TO GIVE A MIN. WIDTH OF 1m AT THE CROWN.

TYPE III CHILWORTH TRAVERSE

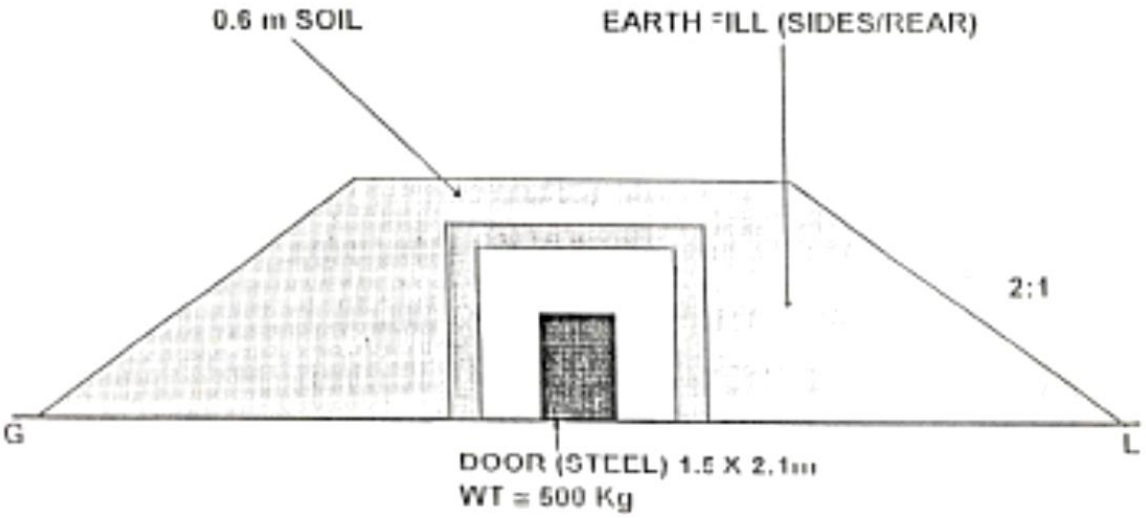
APPENDIX 1 (CONTD)



TYPE IV BUNKER TYPE BUILDING (ABOVE GROUND)



TYPE V IGLOO (BOX TYPE)



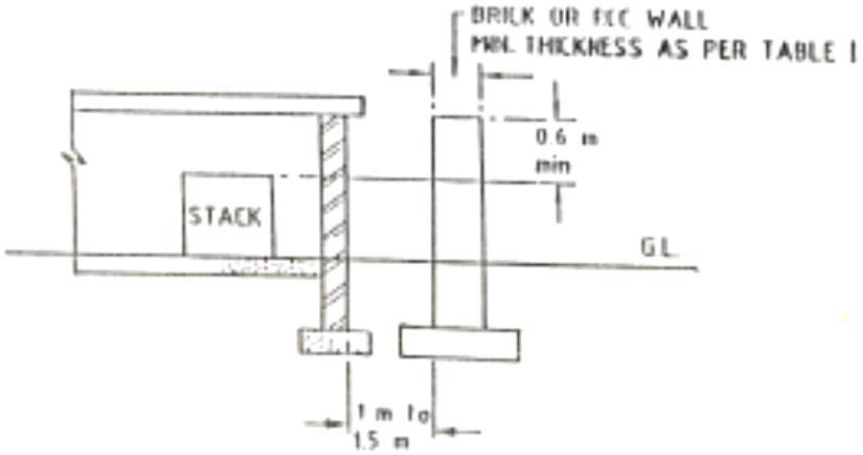
DIMENSIONS : 3.6 X 4.5 X 3.6 m (CLEAR)

THICKNESS = 300 mm (LRC)

CAPACITY: 5000 Kg TNT

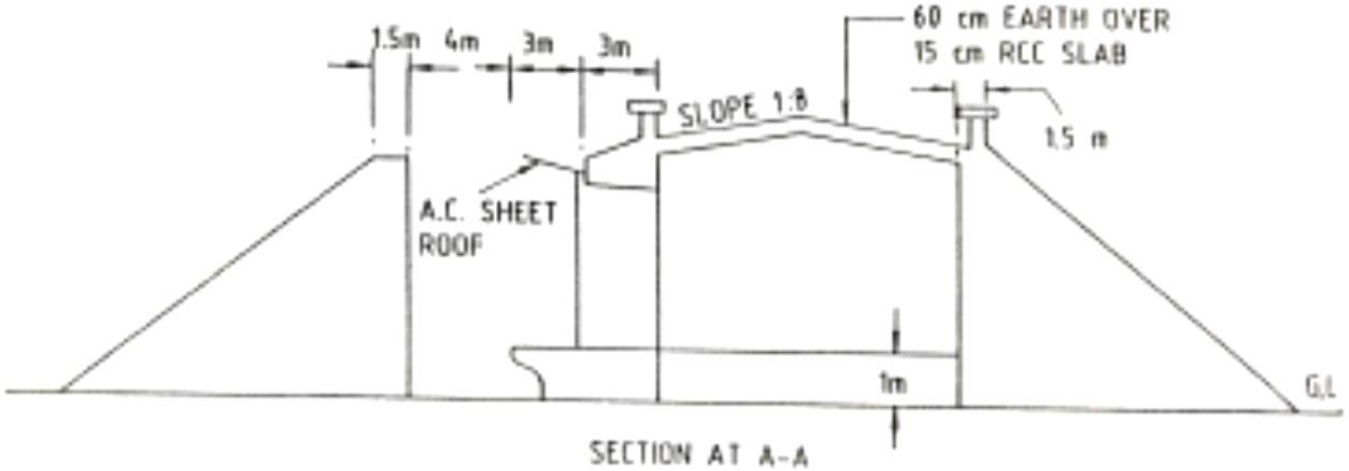
INTER MAGAZINE DISTANCE : 10 m

TYPE VI BLAST WALL

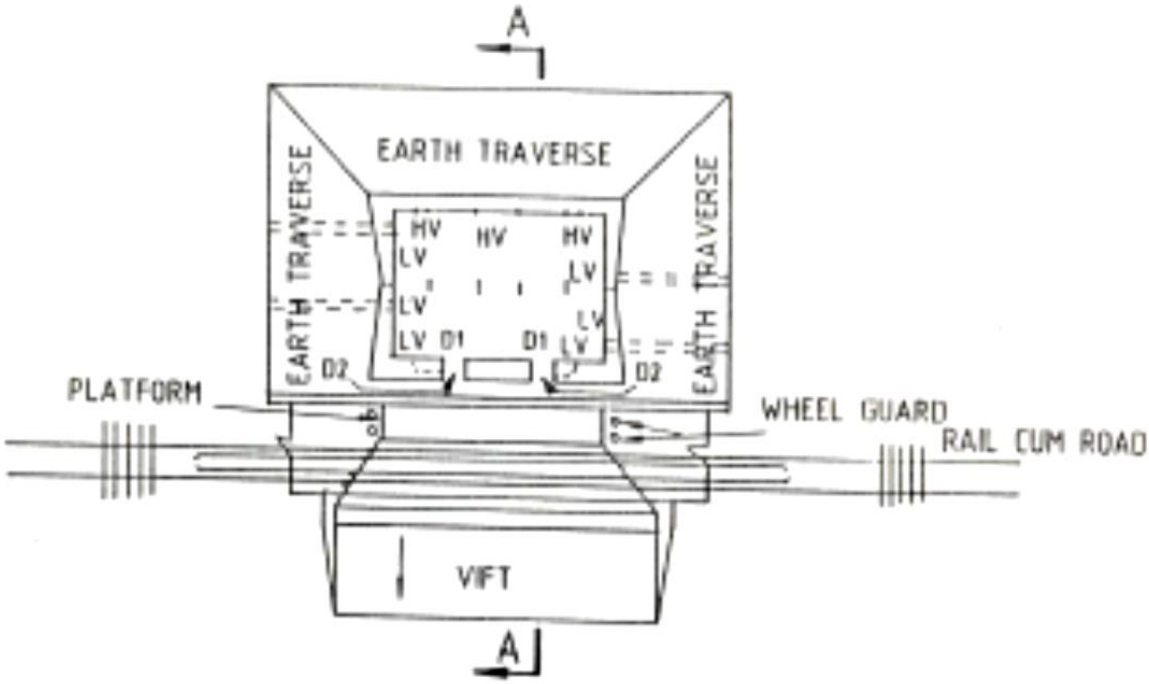


APPENDIX 2

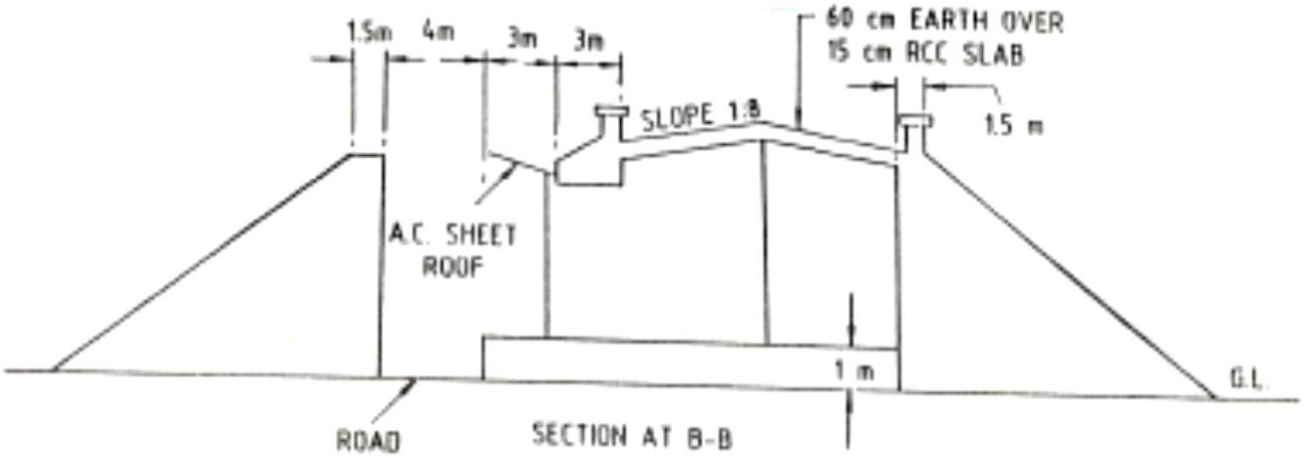
ABOVE GROUND BUNKER MAGAZINE (RAIL CUM ROAD SERVED)

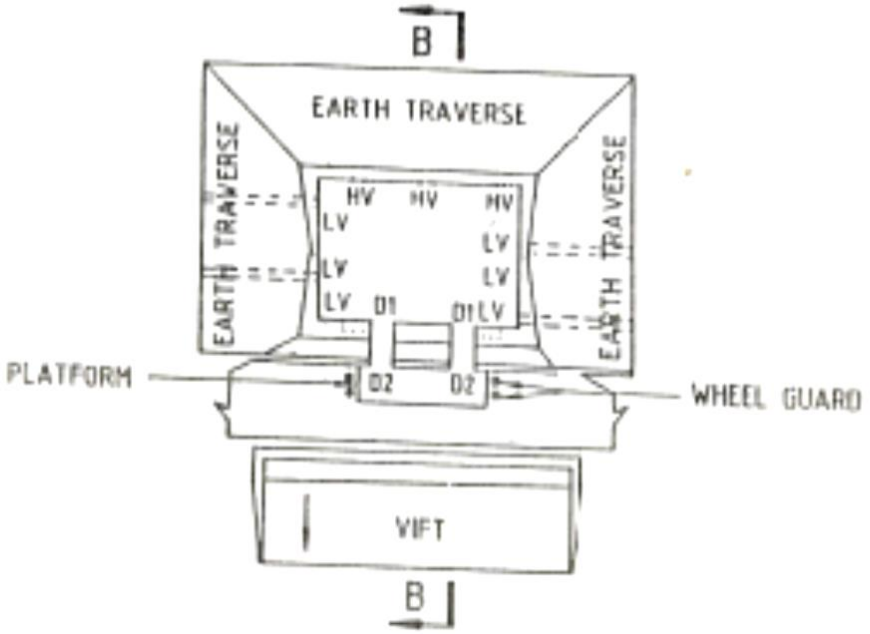


SECTION AT A-A

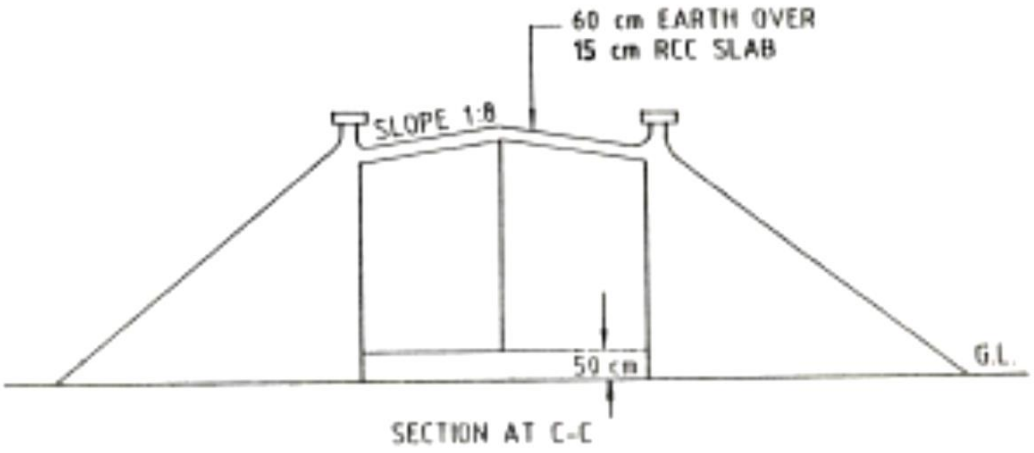


ABOVE GROUND BUNKER MAGAZINE
(ROAD SERVED)

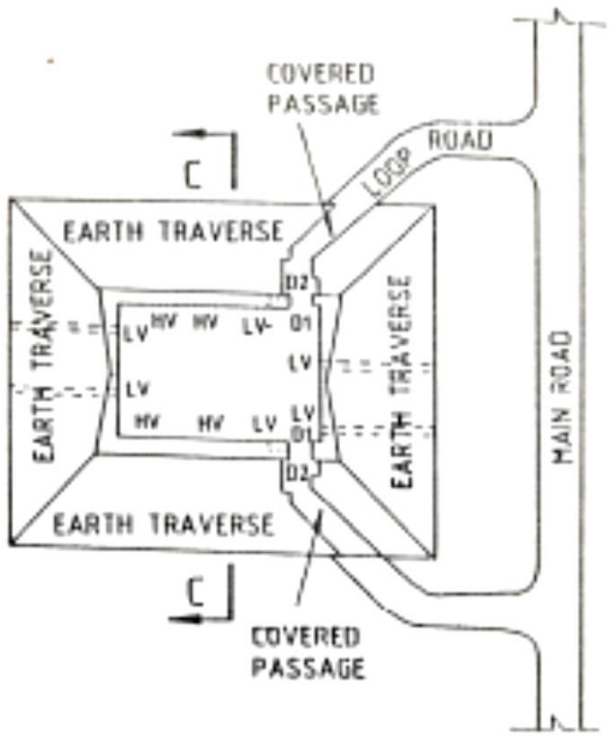




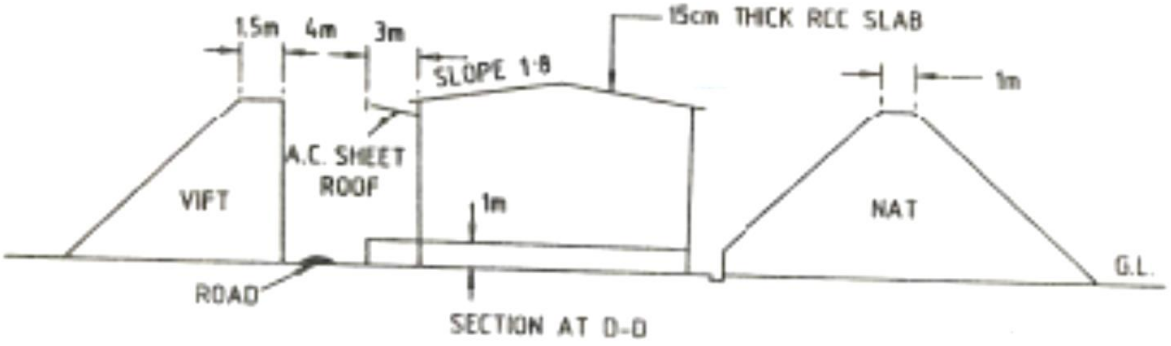
ABOVE GROUND BUNKER MAGAZINE (TRAILER SERVED)



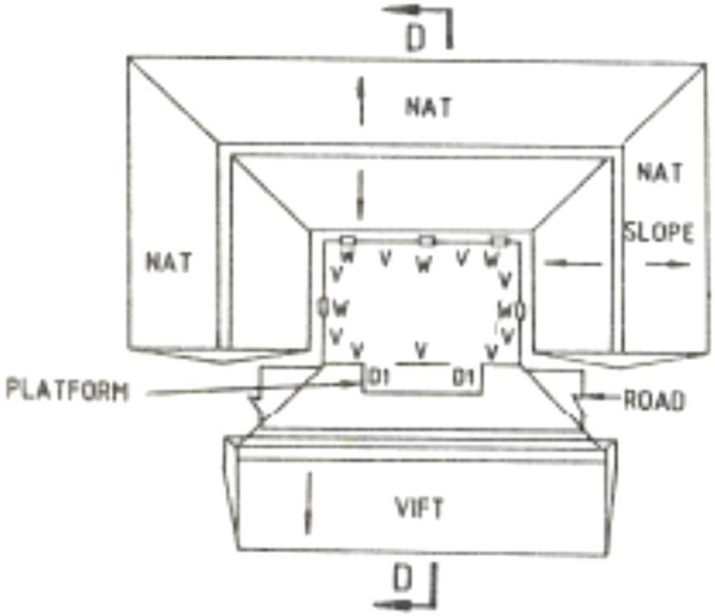
SECTION AT C-C



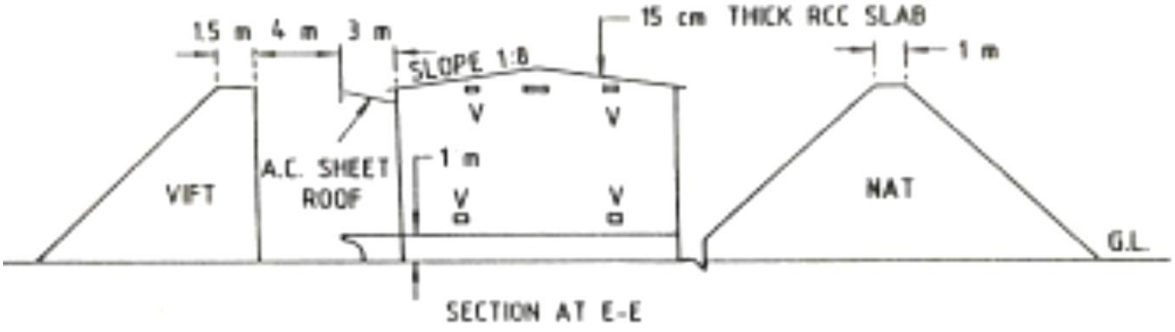
ABOVE GROUND SURFACE MAGAZINE (ROAD SERVED)



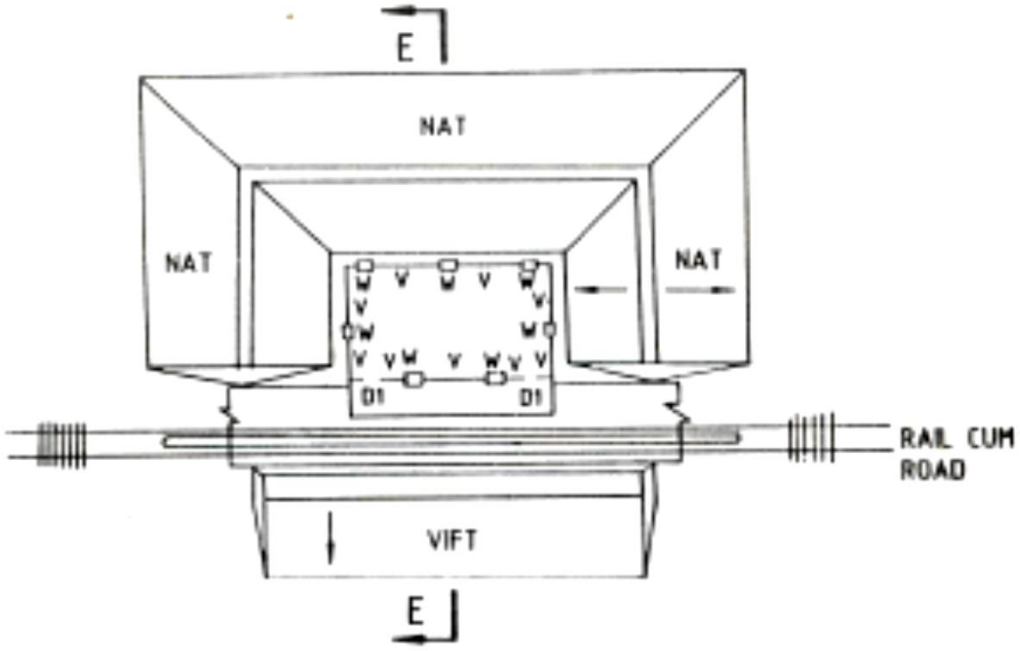
SECTION AT D-D



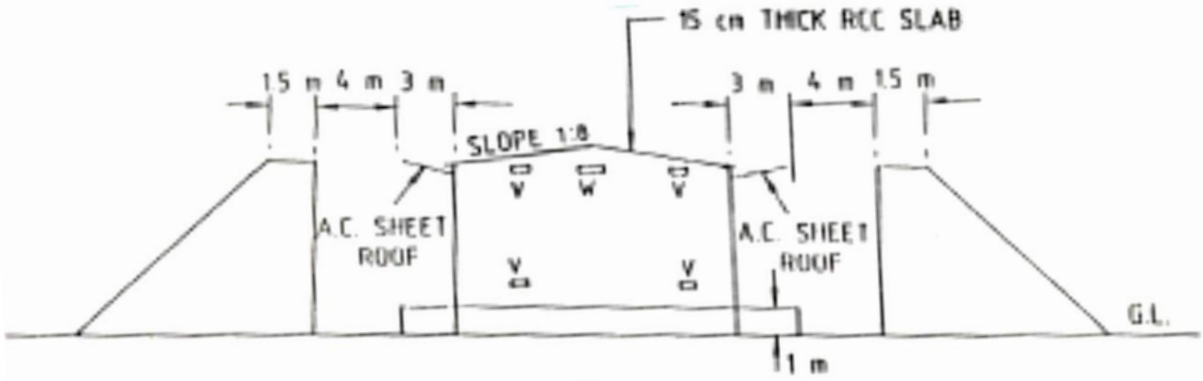
ABOVE GROUND SURFACE MAGAZINE (RAIL CUM ROAD SERVED)



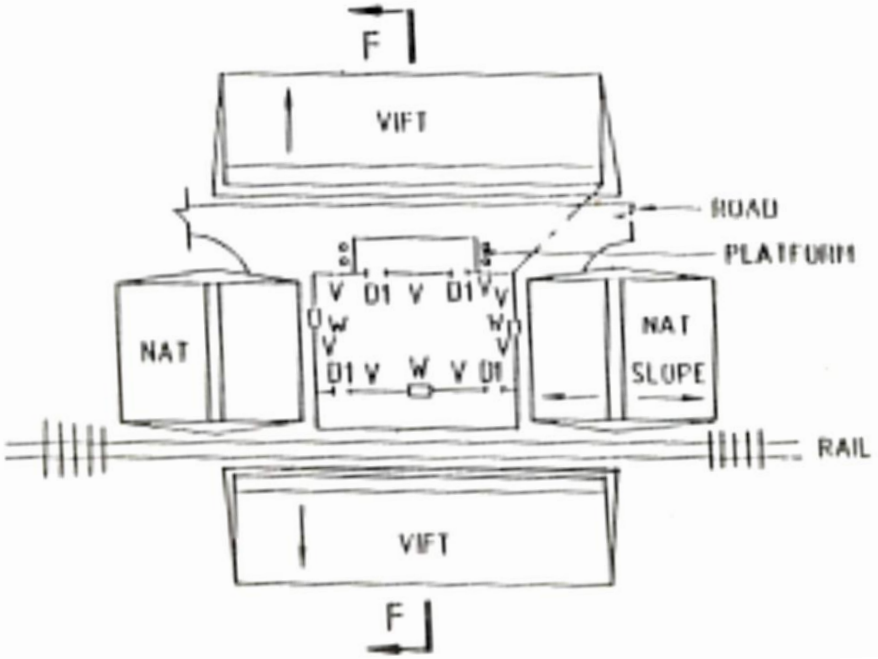
SECTION AT E-E



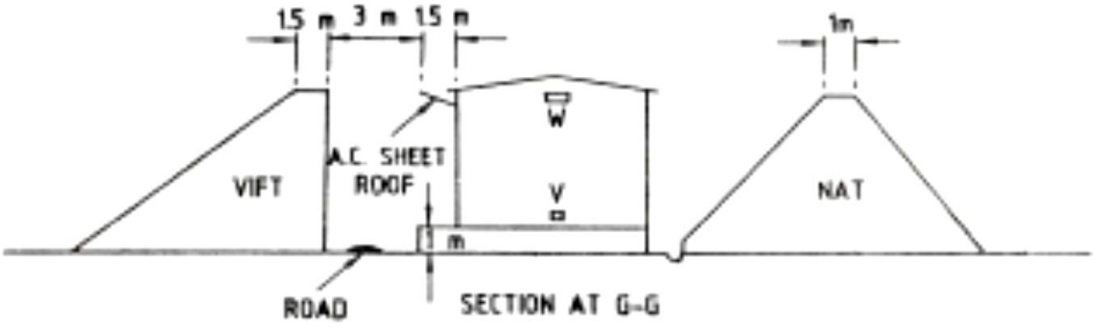
ABOVE GROUND SURFACE MAGAZINE RAIL AND ROAD SERVED ON THE OPPOSITE SIDES

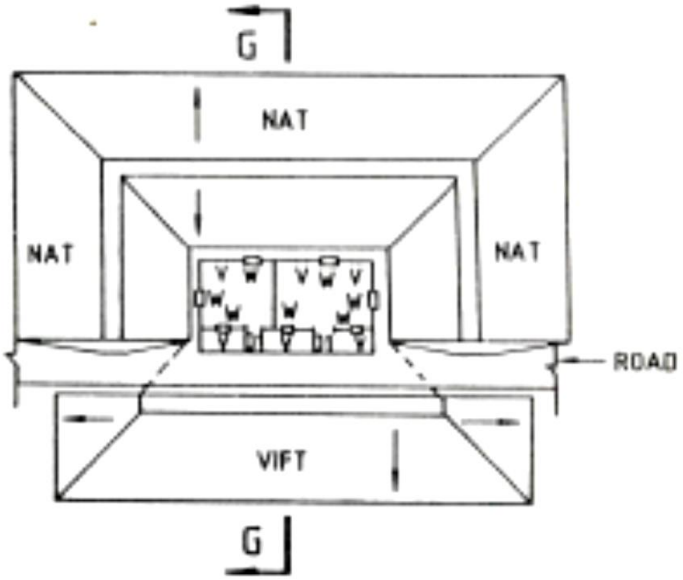


SECTION AT F-F



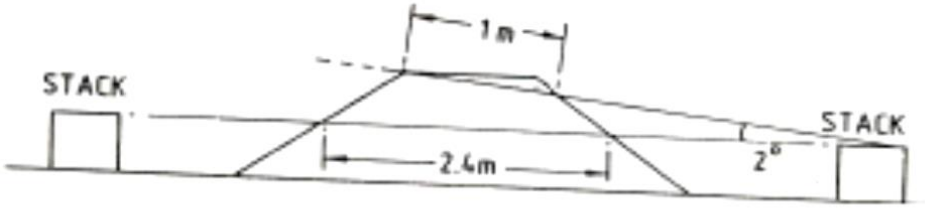
ABOVE GROUND SURFACE MAGAZINE (SMALL TYPE-ROAD SERVED)



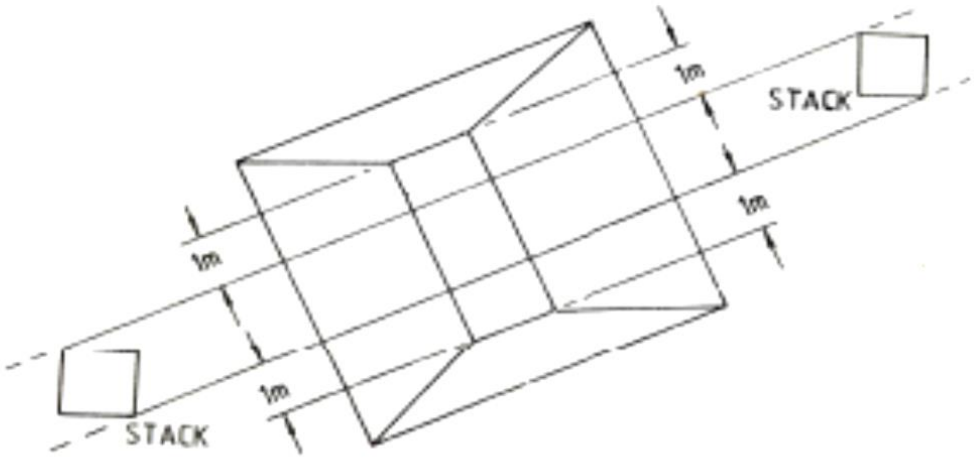


APPENDIX 3

DETERMINATION OF TRAVERSE HEIGHT ON LEVEL TERRAIN

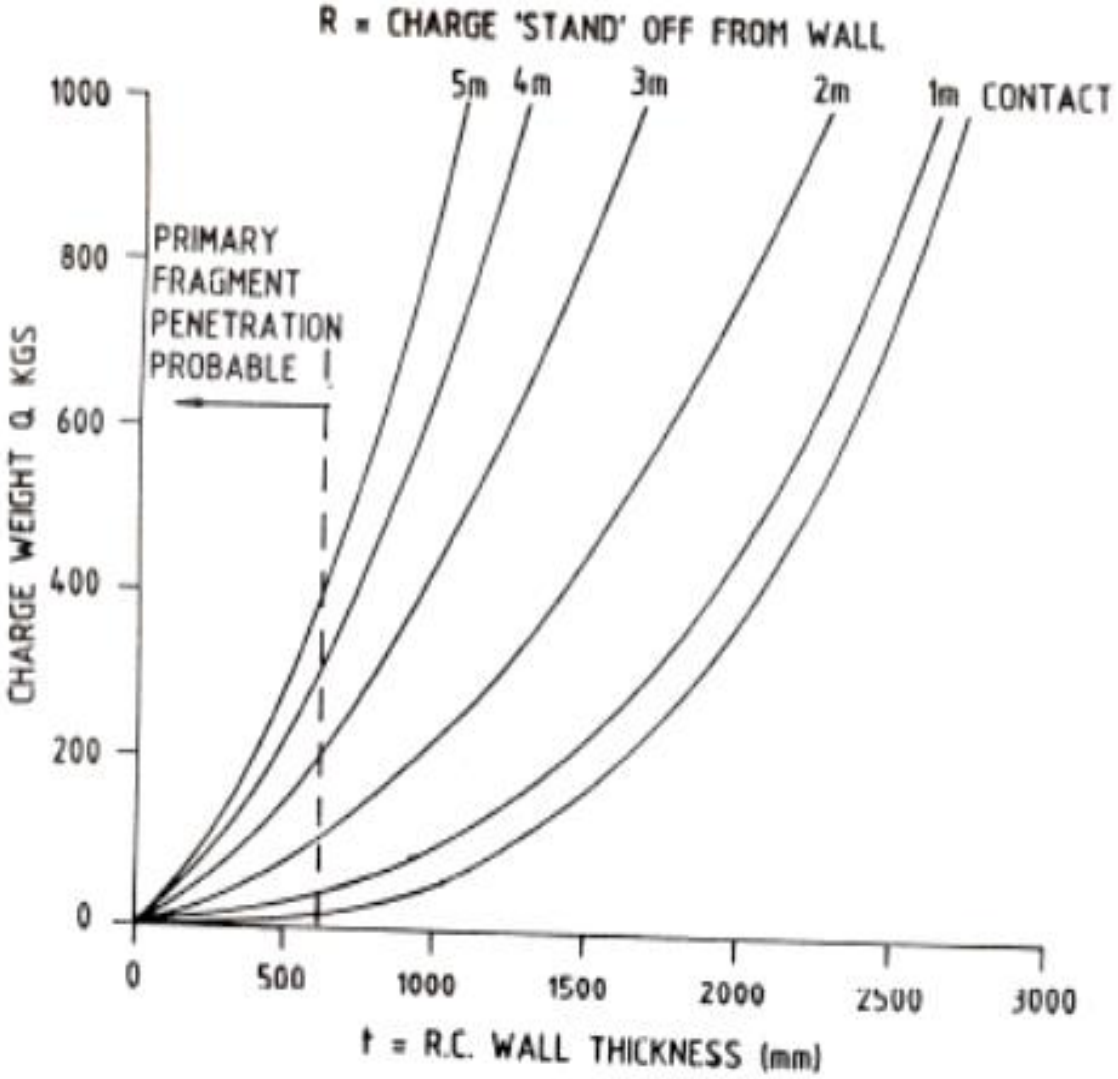


DETERMINATION OF TRAVERSE LENGTH



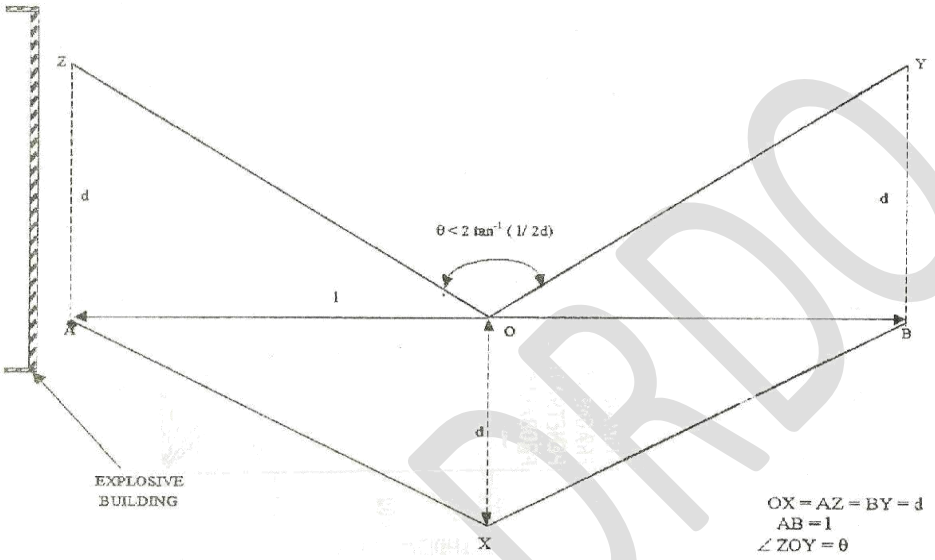
APPENDIX 4

GRAPH SHOWING THICKNESS OF RCC CONTAINER WALLS FOR DIFFERENT QUANTITIES OF EXPLOSIVES AT VARIOUS STAND-OFF-DISTANCE FROM THE WALL.



APPENDIX-5

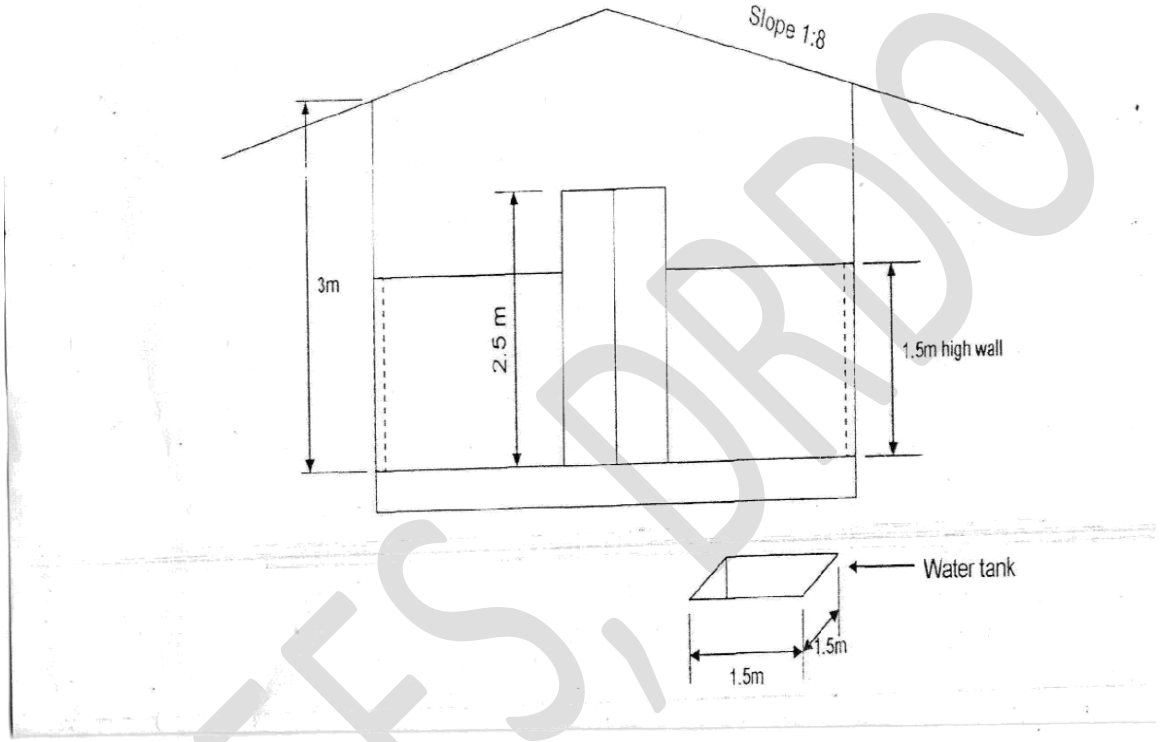
DOG-LEGGED ENTRANCE



DOG LEGGED ENTRANCE

Appendix-6

DIAGRAMATIC SKETCH OF WP SHED



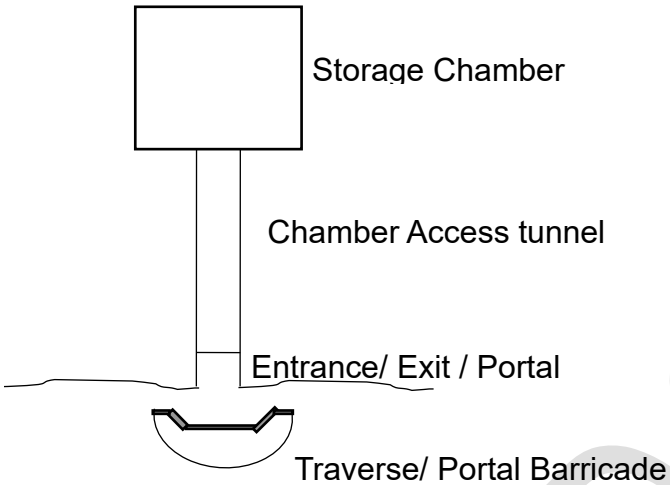


Figure-(a)

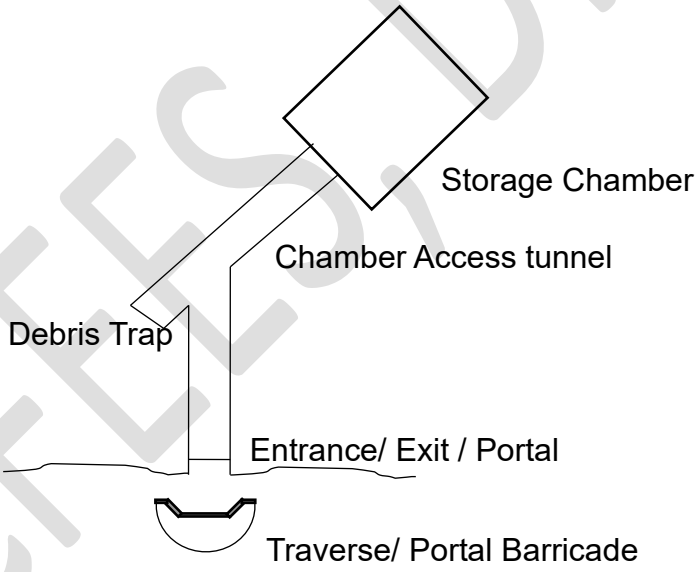


Figure-(b)

Single Chamber Storages

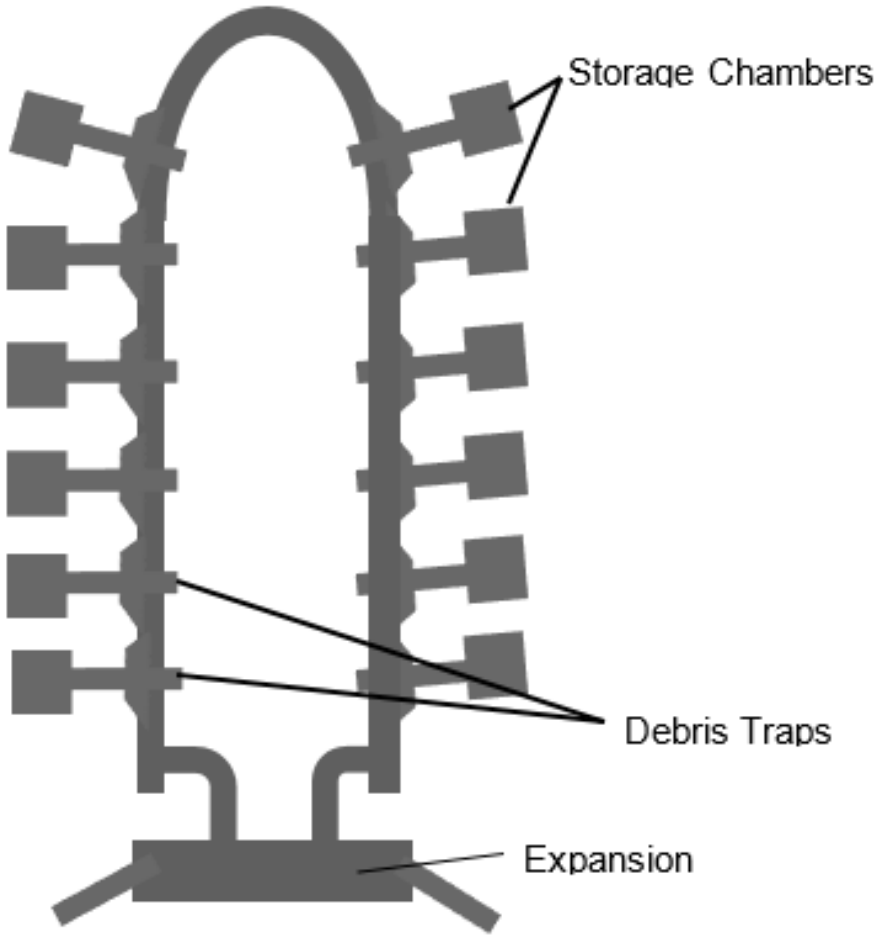


Figure-(a)

Multi-chamber Storage Facility

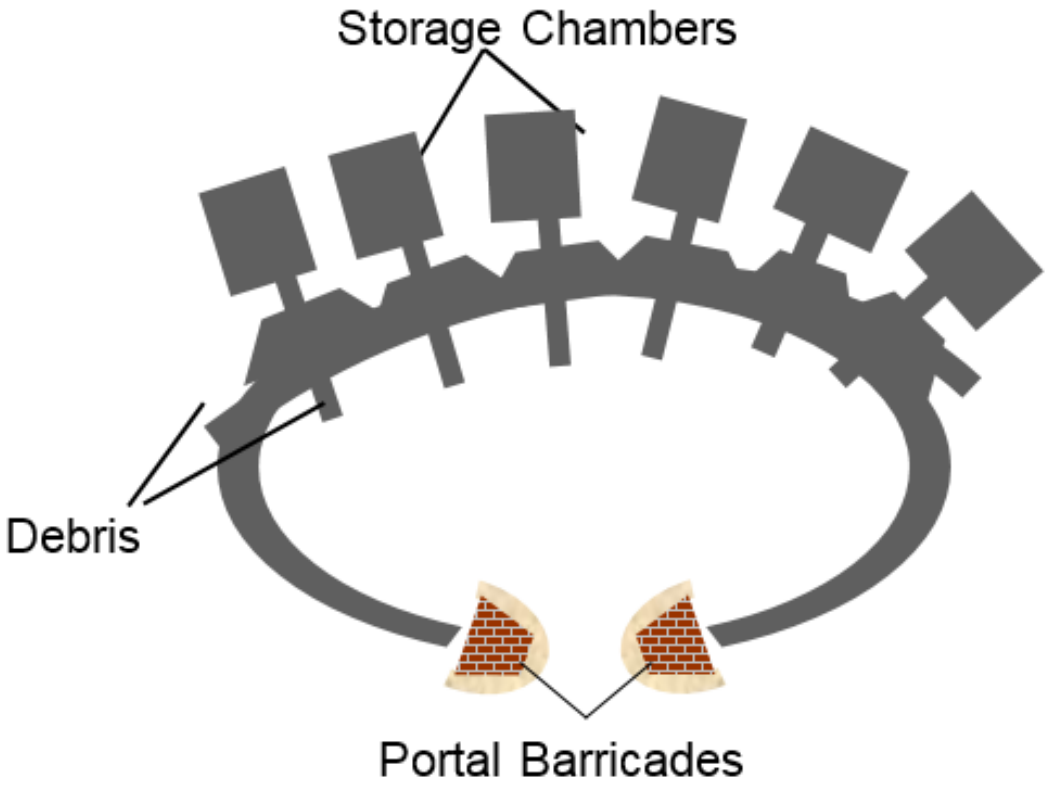
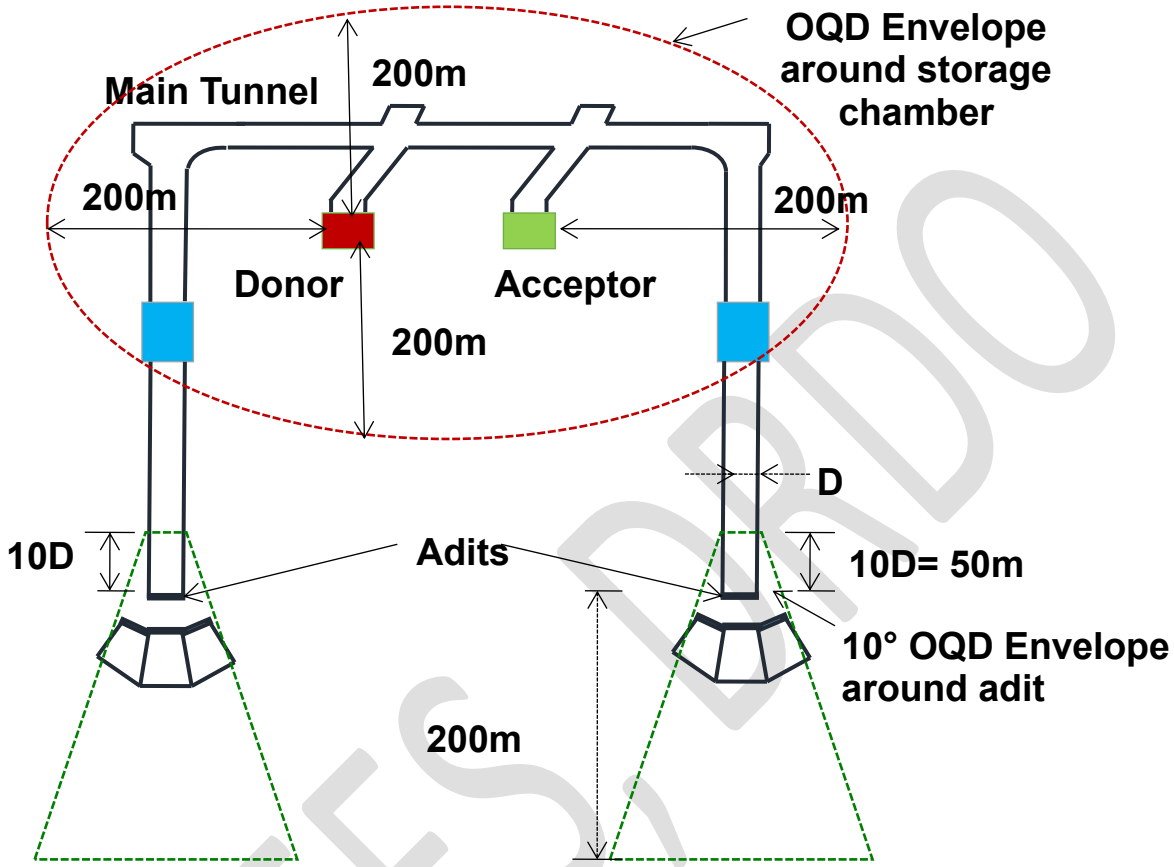
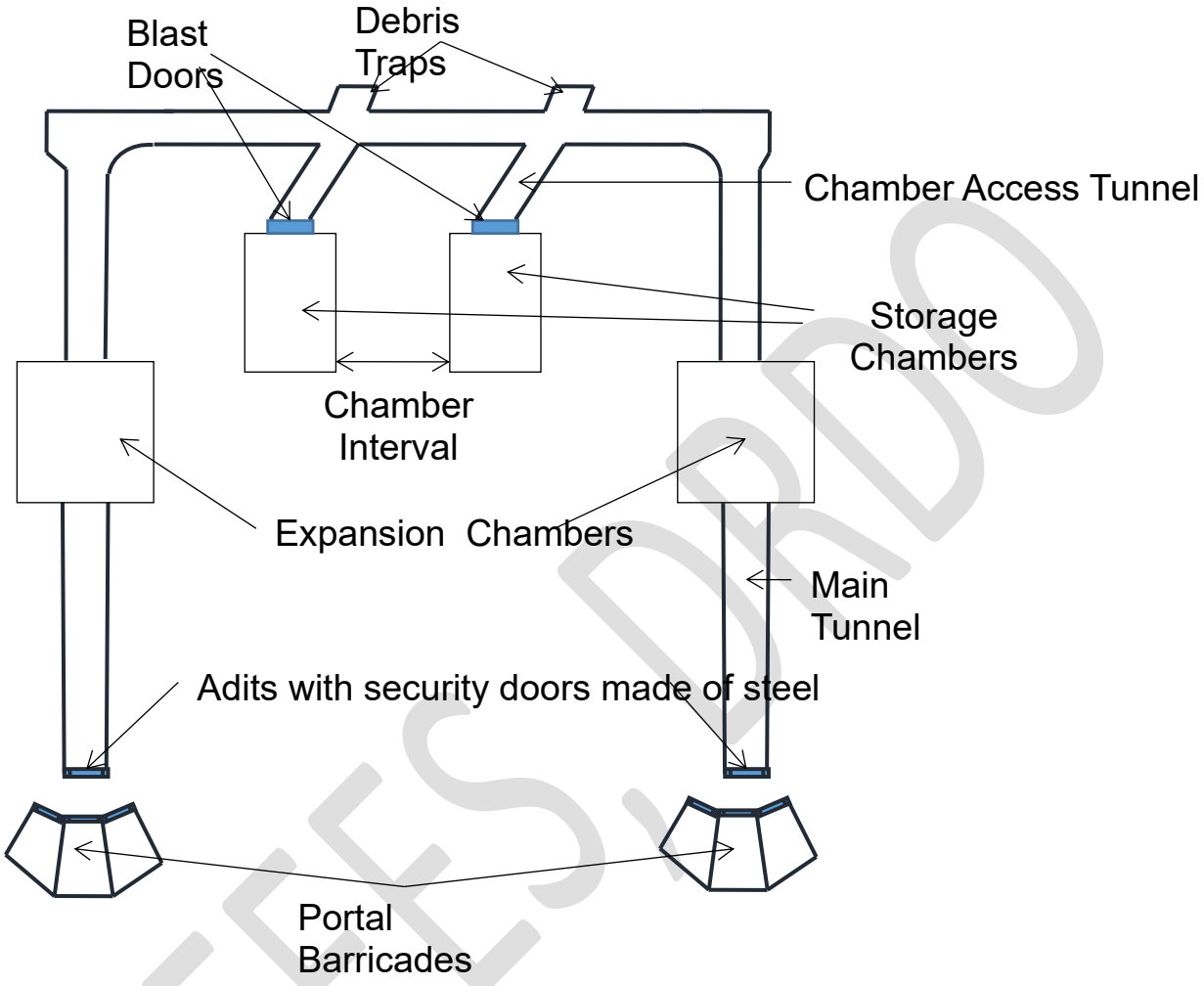


Figure- (b)

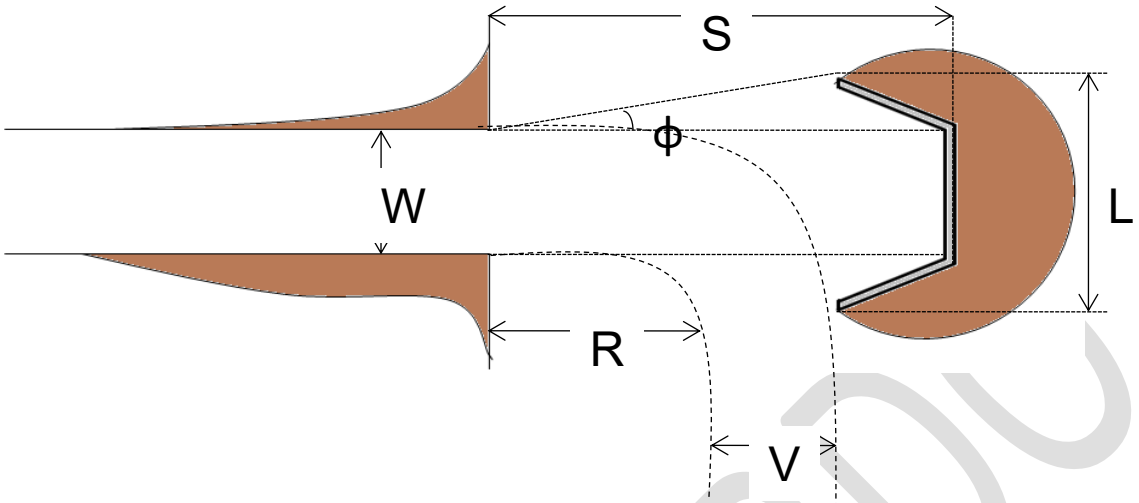
Multi-chamber Storage Facility



Various Quantity Distances required for two-chambered underground ammunition storage facility of 40 MT NEC capacities per chamber

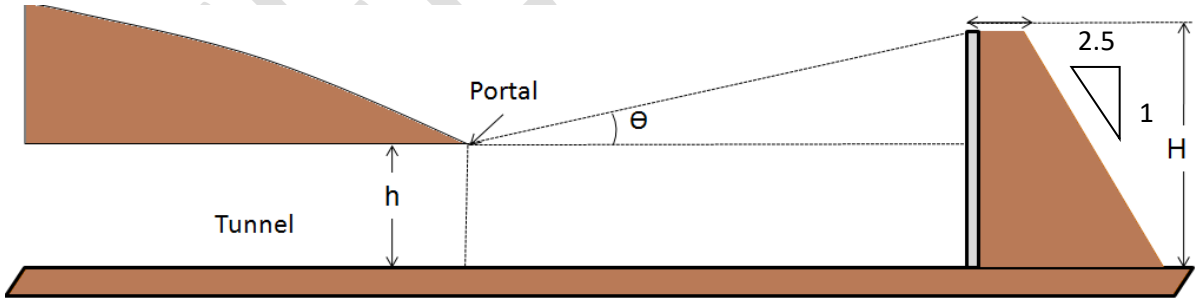


Hazard Mitigation Features



S= Standoff distance from the portal (1 to 3 tunnel widths)
R= Turning radius of munition transport vehicles
V= Width transport vehicles
L= Length of barricade
W= Tunnel width at portal
Φ= Single angle (10 degrees minimum)

Figure-(a) Portal Barricade Location and Length (Plan View)



C= Crest width
H= Height of tunnel
H= Height of barricade
Θ= Elevation angle (10 degrees minimum)

Figure-(b) Portal Barricade Height (Elevation View)

Appendix-12

Basic Design Parameters for Underground Facility (up to 40 MT NEC HD 1.1)

- Layout of the underground explosives storage facility may be straight / 'U' shaped, Depending upon the piece of land available.
- Minimum scaled cover thickness {Actual Thickness/ $(NEC)^{1/3}$} of 0.35 has to be provided.

Storage Chamber

- Size: May vary with NEC to be stored
- Loading Density < 10 kg/m3
- Structure should withstand an internal pressure of 5 bar and Ground shock of 10 g for 30 ms duration

Tunnel

- Width: It will depend on user's operational requirement
- Clear height: It will depend on users requirement
- Length: It will depend on tunnel gradient (to be decided by user), and cover thickness and height of the camber
- Should withstand internal pressure of 10 bars, where cover thickness is less than 1m

Chamber Access Tunnel

- Width: It will depend on user's operational requirement
- Clear height: It will depend on users requirement
- Inclination to main tunnel: 40° to 70°
- Length: It will depend of inclination angle, distance of the chamber from the main tunnel and No. of chambers.

Hazard Mitigation Features

To contain or mitigate the hazardous effects of an explosion, such as air – blast and debris (fragments), hazard mitigation features like debris traps, expansion chambers and Traverse/ portal barricades have to be provided.

Debris Traps: Debris traps have to be provided to entrap debris blown through the tunnel from an explosion

- Depth: It should be at least 1.5 times the tunnel width.
- Width: It should be at least 20% more than tunnel width.
- Clear height: It should be 10% taller than the tunnel height.

Expansion Chamber

- Width: It should be at least three times the width of the tunnel.
- Length: It should be equal to its width.
- Height: It should be equal to tunnel height.

Traverse/ Portal Barricade:

- **Location:** In front of a portal and cantered on the extended axis of the tunnel
- **Distance from the tunnel opening:** Not less than the width of the tunnel and not more than three times the width of the tunnel
- Will be based on the turning radius and operation width required for a vehicle or MHE

Design of the Traverse/ Portal Barricade

Face of the barricade toward the portal:

- Vertical and concave in plan and oriented perpendicular to the tunnel axis, with wing walls on either side of the face angled at 30º to 60º towards the portal
- RCC, with a minimum thickness of 0.31 m or a thickness equal to the 10% of the barricade height, whichever is greater

Width of the barricade faces (excluding wing walls):

Intercept an angle of at least 10 º to the right and left of the extended tunnel width

Height along its entire width:

Intercept an angle of at least 10 º above the extended height of the tunnel

List of Standard Drawings

CHAPTER 1.1: ESH FOR HD 1.1 AMMUNITION

Section	Type of Building		Previous Reference STEC Pamphlet No. 3, Year 2017		New Drawing No.	Page No.
	Size (m)	Feature	Drawing No	Page No		
5.	36 X18	One Side Road	DGOS/1.1/36 X 18/1	6-8	CFEES/ESH/HD1.1X18/OSR/1 to 3	1-3
6.	24X21	One Side Road	DGOS/1.1/24 X 21/1	9-11	CFEES/ESH/HD1.1/24X21/OSR/1 to 3	4-6
7.	18X18	One Side Road	DGOS/1.1/18 X 18/1	12-14	CFEES/ESH/HD1.1/18X18/OSR/1 to 3	7-9
8.	18X12	One Side Road	DGOS/1.1/18 X 12/1	15-17	CFEES/ESH/HD1.1/18X12/OSR/1 to 3	10-12
9.	36X18	Both Side Road	DGOS/1.1/36 X 18/2	18-20	CFEES/ESH/HD1.1/36X18/BSR/1 to 3	13-15
10.	24X21	Both Side Road	DGOS/1.1/24 X 21/2	21-23	CFEES/ESH/HD1.1/24X21/BSR/1 to 3	16-18
11.	18X18	Both Side Road	DGOS/1.1/18 X 18/2	24-26	CFEES/ESH/HD1.1/18X18/BSR/1 to 3	19-21
12.	18X12	Both Side Road	DGOS/1.1/18 x 12/2	27-29	CFEES/ESH/HD1.1/18X12/BSR/1 to 3	22-24
13.	36 x	Road and Rail	DGOS/1.1/36 x	30-32	CFEES/ESH/HD1.1/36X18/RAR/1 to	25-27

	18		**18/3**		**3**	
14.	**24 x 21**	**Road and Rail**	**DGOS/1.1/24 x 21/3**	**33-35**	**CFEES/ESH/HD1.1/24X21/RAR/1 to 3**	**28-30**
15.	**18 x 18**	**Road and Rail**	**DGOS/1.1/18 x 18/3**	**36-38**	**CFEES/ESH/HD1.1/18X18/RAR/1 to 3**	**31-33**

CHAPTER 1.2: ESH FOR HD 1.2 AMMUNITION

16.	**18 x 12**	**Road and Rail**	**DGOS/1.1/18 x 12/3**	**39-41**	**CFEES/ESH/HD1.2/18X12/RAR/1 to 3**	**34-36**
17.	**36 x 18**	**Both Side Road**	**DGOS/1.2/36 x 18/1**	**42-44**	**CFEES/ESH/HD1.2/36X18/BSR/1 to 3**	**37-39**
18.	**24 x 21**	**Both Side Road**	**DGOS/1.2/24 x 21/1**	**45-47**	**CFEES/ESH/HD1.2/24X21/BSR/1 to 3**	**40-42**
19.	**18 x 18**	**Both Side Road**	**DGOS/1.2/18 x 18/1**	**48-50**	**CFEES/ESH/HD1.2/18X18/BSR/1 to 3**	**43-45**
20.	**18 x 12**	**Both Side Road**	**DGOS/1.2/18 x 12/1**	**51-53**	**CFEES/ESH/HD1.2/18X12/BSR/1 to 3**	**46-48**
21.	**36 x 18**	**Road and Rail**	**DGOS/1.2/36 x 18/2**	**54-56**	**CFEES/ESH/HD1.2/36X18/RAR/1 to 3**	**49-51**

22.	**24 x 21**	**Road and Rail**	**DGOS/1.2/24 x 21/2**	**57-59**	**CFEES/ESH/HD1.2/24X21/RAR/1 to 3**	**52-54**
23.	**18X18**	**Road and Rail**	**DGOS/1.2/18 x 18/2**	**60-62**	**CFEES/ESH/HD1.2/18X18/RAR/1 to 3**	**55-57**
24.	**18X12**	**Road and Rail**	**DGOS/1.2/18 x 12/2**	**63-65**	**CFEES/ESH/HD1.2/18X12/RAR/1 to 3**	**58-60**

CHAPTER 1.3: ESH FOR HD 1.3 AMMUNITION

Section	**Type of Building**		**Previous Reference STEC Pamphlet No. 3, Year 2017**		**New Drawing No.**	**Page No.**
	Size (m)	**Feature**	**Drawing No.**	**Page No**		
25	**36 X18**	**Both Side Road**	**DGOS/1.1/36 X 18/1**	**66-68**	**CFEES/ESH/HD1.3X18/OSR/1 to 3**	**61-63**
26	**24X21**	**Both Side Road**	**DGOS/1.1/24 X 21/1**	**69-71**	**CFEES/ESH/HD1.3/24X21/OSR/1 to 3**	**64-66**
27	**18X18**	**Both Side Road**	**DGOS/1.1/18 X 18/1**	**72-74**	**CFEES/ESH/HD1.3/18X18/OSR/1 to 3**	**67-69**
28	**18X12**	**Both Side Road**	**DGOS/1.1/18 X 12/1**	**75-77**	**CFEES/ESH/HD1.3/18X12/OSR/1 to 3**	**70-22**
29	**36X18**	**Road and Rail**	**DGOS/1.1/36 X 18/2**	**78-80**	**CFEES/ESH/HD1.3/36X18/BSR/1 to 3**	**73-75**
30	**24X21**	**Road and Rail**	**DGOS/1.1/24 X 21/2**	**81-83**	**CFEES/ESH/HD1.3/24X21/BSR/1 to 3**	**76-78**

31	**18X18**	**Road and Rail**	**DGOS/1.1/18 X 18/2**	**84-86**	**CFEES/ESH/HD1.3/18X18/BSR/1 to 3**	**79-81**
32	**18X12**	**Road and Rail**	**DGOS/1.1/18 x 12/2**	**87-89**	**CFEES/ESH/HD1.3/18X12/BSR/1 to 3**	**82-84**

CHAPTER 2.1: IGLOO

Section	**Size in Metre**	**Entry**	**With/Without Platform**	**Height (m)**	**Capacity (MT NEC)**	**New Drawing No**	**Page No**
5	**7X7**	**Front Entry**	**Without Platform**	**3.6**	**5**	**CFEES/IGL/HD1.1/5T NEC/3.6m/1 to 6**	**1-6**
6	**9X15**	**Front Entry**	**With Platform**	**4.2**	**15**	**CFEES/IGL/HD1.1/15T NEC/4.2m/1 to 6**	**7-12**
7	**9.5X18**	**Front Entry**	**With Platform**	**4.2**	**25**	**CFEES/IGL/HD1.1/25T NEC/4.2m/1 to 6**	**13-18**
8	**9.5X36**	**Front Entry**	**With Platform**	**3.6**	**75**	**CFEES/IGL/HD1.1/75T NEC/3.6m/1 to 6**	**19-24**
9	**9.5X36**	**Front Entry**	**Without Platform**	**3.6**	**75**	**CFEES/IGL/HD1.1/5T NEC/3.6m/1 to 6**	**25-30**
10	**9.5X36**	**Front Entry**	**With Platform**	**4.2**	**75**	**CFEES/IGL/HD1.1/75T NEC/4.2m/1 to 6**	**31-36**
11	**9.5X36**	**Side Entry**	**Without Platform**	**5.2**	**75**	**CFEES/IGL/HD1.1/75T NEC/5.2m/1 to 6**	**37-42**
12	**9.5X36**	**Side Entry**	**Without Platform**	**8.0**	**75**	**CFEES/IGL/HD1.1/75T NEC/8.0m/1 to 6**	**43-48**
13	**19X36**	**Front Entry**	**Without Platform**	**3.6**	**136**	**CFEES/IGL/HD1.1/136T NEC/3.6m/1 to 6**	**49-54**
14	**19X36**	**Front Entry**	**With Platform**	**4.2**	**136**	**CFEES/IGL/HD1.1/136T NEC/4.2m/1 to 6**	**55-60**
15	**18X36**	**Side Entry**	**Without Platform**	**5.2**	**136**	**CFEES/IGL/HD1.1/136T NEC/5.2m/1 to 10**	**61-70**
16	**19.4x36**	**Front Entry**	**With Platform**	**5.2**	**136**	**CFEES/IGL/HD1.1/136T NEC/5.2m/1 to 6**	**71-76**
17	**18X36**	**Side Entry**	**Without Platform**	**8.0**	**136**	**CFEES/IGL/HD1.1/136T NEC/8.0m/1 to 10**	**77-86**

CHAPTER 2.2: UNIT RISK PRINCIPLE BASED BUILDINGS (URP)

Section	Type of Building and Specification	Size (m)	Capacity (MT NEC)	New Drawing No	Page No
18	HD1.1 Storage Chamber, URP	5.0 X 6.0 X 4.2	1.1	CFEES/URP/HD1.1/1.1T NEC /4.2m/ 1 to 5	87-91
19	HD1.1 BRAHMOS Storage, URP	2.7 X 12.6 X 2.1	1.1	CFEES/URP/HD1.1/BRAHMOS/ 2.1m/ 1 to 10	92-101
20	HD1.1 Explosive Storage Structure, URP	6.0 X 12.0 X 3.6	2.0	CFEES/URP/HD1.1/2T NEC/ 3.6m/ 1 to 9	102-110
21	HD1.3 Multi Compartment 1X2 Config., URP	10.5 X 10.5 X 4.2	50	CFEES/URP/HD1.3/50T NEC/ 4.2m/ 1A to 1B	111-112
22	HD1.3 Multi Compartment 1X3 Config., URP	14.0 X 14.0 X 4.2	50	CFEES/URP/HD1.3/50T NEC/ 4.2m/ 2A to 2B	113-114
23	HD1.3 Multi Compartment 2X3 Config., URP	14.0 X 14.0 X 4.2	50	CFEES/URP/HD1.3/50T NEC/ 4.2m/ 5 to 12	115-122

CHAPTER 2.3: HIGH PERFORMANCE MAGAZINE (HPM)

Section	Type of Building	Size (m)	Capacity (MT NEC)	New Drawing No	Page No
24	HD1.1 Storage Chamber, URP	10.0 X 8.0 X 3.6	5	CFEES/URP/HD1.1/1.5T NEC /3.6m/ 1 to 12	123-134

CHAPTER 2.4: UNDER GROUND EXPLOSIVE STORAGE STRUCTURE - VERTICAL SHAFT

Section	Type of Building	Size (m)	Capacity (MT NEC)	New Drawing No	Page No
25	HD1.1 Storage Chamber, UGV	7.8 X 15.6 X 4.2	5/Chamber	CFEES/UGV/HD1.1/1.5T NEC /4.2m/ 1 to 7	135-141
26	HD1.1 Storage Chamber, UGV	20X40X5.0	40/Chamber	CFEES/UGV/HD1.1/1.5T NEC /5.0m/ 1 to 20	142-161

CHAPTER 2.5: DISPOSAL CHAMBER (BLAST CONTAINMENT STRUCTURE)

Section	Type of Building	Size (m)	Capacity (MT NEC)	New Drawing No	Page No
27	HD1.1 0Kg NEC Disposal Facility	702	1.0	CFEES/ADF/HD1.1/1Kg NEC /7.2m/ 1 to 5	135-141
28	HD1.1 0Kg NEC Disposal Facility	11/0	8.0	CFEES/ADF/HD1.1/8Kg NEC /11.0m/ 1 to 5	142-161

CHAPTER 2.6: BLAST DOOR DRAWINGS

Section	Type of Building and Specification	Size (m)	New Drawing No	Page No
29	Blast Door (above Ground Structure)	2.5 x 2.5	CFEES/BD/HD 1.1 / 2.5m X 2.5m / 01	172
30	Blast Door (above Ground Structure)	3.0 x 2.6	CFEES/BD/HD 1.1 / 3.0m X 2.6m / 01	173
31	Blast Door (above Ground Structure)	3.0 x 2.8	CFEES/BD/HD 1.1 / 3.0m X 2.8m / 01	174
32	Blast Door (above Ground Structure)	3.6 x 4.0	CFEES/BD/HD 1.1 / 3.6m X 4.0m / 01	175
33	Blast Door (above Ground Structure)	4.0 x 4.5	CFEES/BD/HD 1.1 / 4.0m X 4.5m / 01	176
34	Blast Door (above Ground Structure)	4.3 x 2.0	CFEES/BD/HD 1.1 / 4.3m X 2.0m / 01	177
35	Blast Door (above Ground Structure)	2.25 x 2.0	CFEES/BD(UG)/HD 1.1 / 2.25m X 2.0m / 1 to 2	178-179
36	Blast Door (Under Ground Structure)	2.0 x 2.0	CFEES/BD(UG)/ HD 1.1 / 2.0m X 2.0m / 1 to 2	180-181
37	Blast Door (Disposal Facility)	1.5 x 2.05	CFEES/BD(DISP)/ HD 1.1 / 1.5m X 2.05m / 01	182

CHAPTER 2.7: ISO CONTAINERS WITH MODULAR TRAVERSES

Section	Type of Building and Specification	Size (FT)	New Drawing No	Page No
38	1 T NEC HD1.1 ISO CONTAINER	20	CFEES/ISO/HD 1.1 / 1 T NEC/20 FT/01	183
39	2.5 T NEC HD1.3 ISO CONTAINER	20	CFEES/ISO/HD 1.3 / 2.5 T NEC/20 FT/02	184