CHAPTER 6
PROTECTION OF THE TARGET MECHANISMS

6-1. General. This chapter addresses measures (such as berms and trenches) designed to conceal and protect the static and moving targets. The following items are discussed:

a. Emplacement configurations, along with guidance for selecting the required configuration and determining the allowable firing positions for ground vehicles or helicopters.

b. Various dimensional parameters to be considered in berm design.

c. Design charts used for determining the proper berm sizes, along with two design examples.

d. The need for proper compaction control and maintenance of the embankment.

e. Design conditions that should be investigated when considering trenches.

6-2. INFANTRY TARGET EMPLACEMENTS.

a. Design Basis. The emplacement configuration for a SIT is shown in drawings C-01 through C-04, appendix F, and for an IMT is shown in drawings C-05 and C-06, appendix F. The emplacement designs are configured for the ballistic characteristics of the 5.56-mm, 7.62-mm, 0.50-caliber, and/or 25-mm (M793) projectiles. The emplacement designs are based on the fact that personnel targets are not used in aerial gunnery exercises.

b. Wall Height. As shown in drawings C-01, C-02, C-04, and C-05, appendix F, the dimensional parameters that vary are the front wall height and, in the case of ascending slopes, the retaining wall height. The wall heights vary with the angle of fire. The angle of fire is defined as the angle (measured from the horizontal) created by the difference in elevation between the firing point and the top of the emplacement wall. The angle of fire is used to determine the wall height needed to protect the target mechanism and is only of concern when the target is at a lower elevation than the firing point. When the target is at a higher elevation than the firing point, the minimum wall height is applicable.

c. Berm Width.

(1) Determining Width. Recommended width for protective berms of infantry target emplacements are shown in figures 6-1 through 6-3. These berm widths are based upon weapon type, soil compactive effort, and the in-place soil density. However, the designer must also coordinate with the range trainer or user in order to determine the appropriate berm width for each target, since individual target sites may dictate added target protection. For example, when infantry target emplacements are sited in front of or behind an AMTC or SAT, the emplacements will need to be designed to withstand tank main cannon rounds.

(2) Berm Maintenance. Experience shows that, under normal usage, berms designed with the recommended widths will need maintenance about every 6 months.

6-3. ARMOR TARGET EMPLACEMENTS.

a. General Design Considerations. The armor stationary and moving targets are shown on drawing C-8, Appendix F. An alternative SAT configuration is shown on drawings C-09 and C-10, appendix F. The selection of the proper emplacement configuration is based upon the following parameters:

(1) The horizontal angle formed between the line of fire and a line perpendicular to the stationary target face.

(2) The difference in elevation between the firing point and the target.

(3) The distance from the firing point to the target.

When analyzing the allowable firing positions, the designer must remember that a clear line of sight to a target does not mean that the target may be safely engaged; therefore, the designer must also consider the emplacement configuration and the parameters listed above.

b. Designing for Ground Vehicles.

(1) Ballistic Characteristics. The analysis concerning the allowable firing positions for the M60 and M1 tank systems and the BFV's is based on the ballistic characteristics of the 105-mm, 25-mm, and 0.50-caliber projectiles. Because the ballistic characteristics of the 120-mm projectile are nearly identical to the 105-mm projectile, the allowable firing positions are considered to be the same for both.

(2) Projectile Curves. The allowable firing positions may be calculated by using the curves on figures 6-4 through 6-11. The curves are based on the two main emplacement configurations: (1) moving target emplacement with retaining wall (figures 6-4 through 6-7) and (2) stationary target emplacement with retaining wall (figures 6-8 through 6-11). Curves are provided for M490 TP-T (105 mm), M724 TPDS-T (105-mm), M793 (25-mm), and M20 API-T (0.50-caliber) weaponry. Each of the curves represents a firing range as indicated in the legend on each figure.

(3) Calculating Allowable Firing Positions. The allowable difference in elevation between the firing point and the target can be calculated using a particular horizontal angle of fire and distance to the target. For example, according to figure 6-4, for an M490 (105-mm) projectile fired at an angle of 40 degrees at a moving target 1,500 meters downrange, the firing point would be a

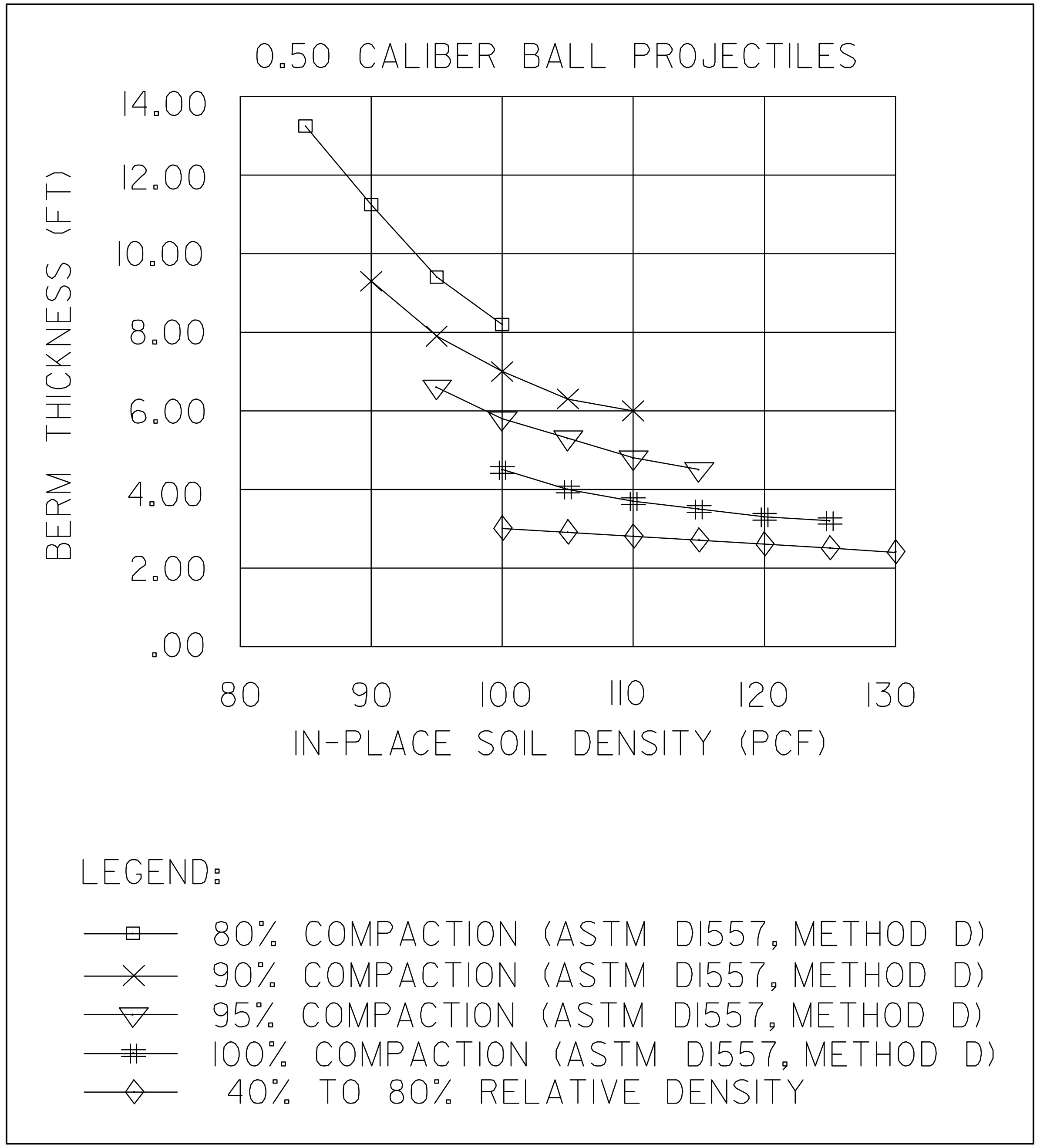


Figure 6-1. Recommended berm widths for 0.50-caliber projectiles

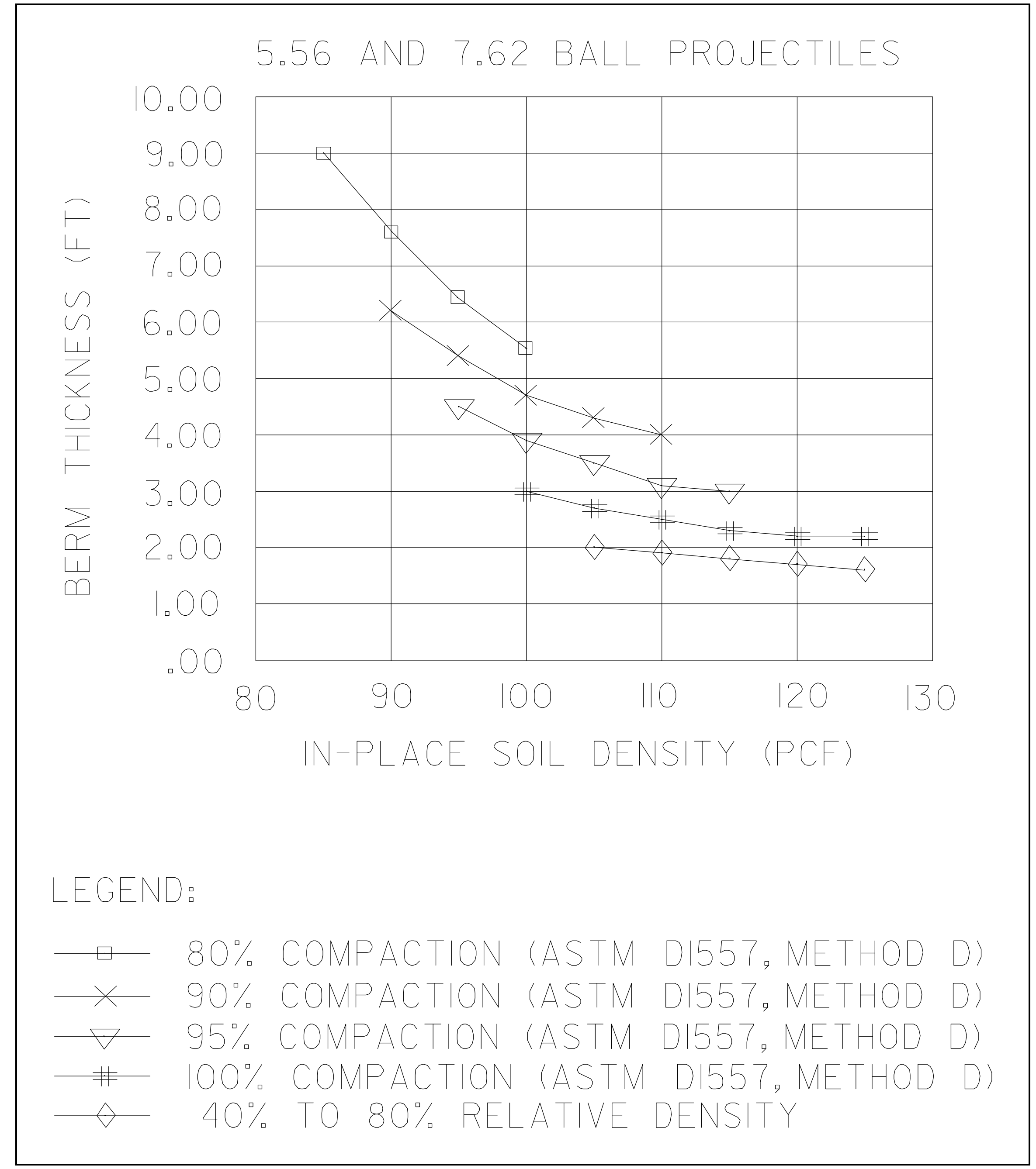


Figure 6-2. Recommended berm widths for 5.56-mm and 7.62-mm projectiles

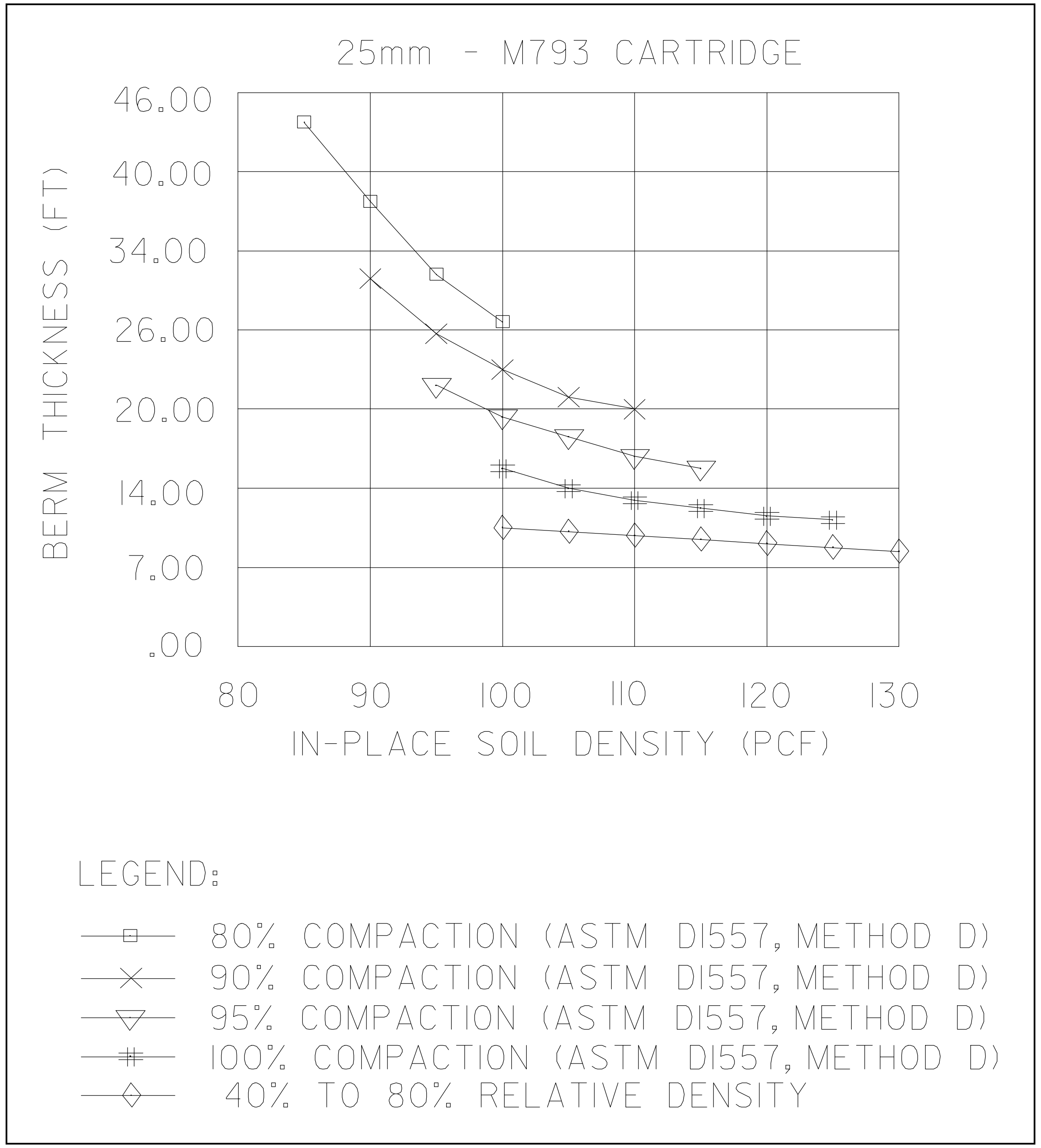


Figure 6-3. Recommended berm widths for 25-mm projectiles

maximum of 250 feet above the target. Therefore, with an elevation difference of less than 250 feet, the target can be safely engaged.

(4) Determining Target Mechanism Protection. Figures 6-4 through 6-11 may be used to select the required emplacement configuration. The target emplacements should be analyzed (based on site conditions) from each firing point in order to determine which emplacement configuration would protect the target mechanism. That analysis must be performed as part of the site-adaptation process. For figures 6-4 through 6-11, the elevation of the firing point was assumed to be equal to or greater than that of the target. If the firing point is higher than the target, the degree of protection for the target mechanism must increase. The worst case would be when projectiles are fired down towards a target. The required thickness of the protective berms based on the containment of the 105-mm and 120-mm projectiles is discussed in paragraph 6-5 below.

c. Designing for Helicopters. Some facilities require the ranges to accommodate helicopters. Because of the range layout and berm configuration, the helicopters must be limited to firing on select targets at specific elevations and ranges. The berm configurations required to protect the target mechanism have been developed from the ballistics data of the 20-mm and 30-mm projectiles, the 2.75-inch inert rocket, and the TOW missile. The required emplacement configurations for both the moving and stationary targets to be used in aerial gunnery exercises are shown on drawings C-08, C-09, and C-10, appendix F. The drawing shows that the berm height would be increased to 1.83 meters for moving target emplacements used for aerial gunnery. Furthermore, because masking any part of the target is unacceptable, the target, too, must be raised 300 millimeters in order to maintain the proper relationship to the top of the berm.

d. Below-Grade Emplacements. Although the emplacements shown on drawings C-08, C-09, and C-10, appendix F, use a berm and retaining wall system to protect the target mechanism, some installations may want a below-grade emplacement. However, before such an emplacement is selected, the following factors should be considered:

(1) The cost of the below-grade emplacement as compared to the cost of the berm and retaining wall configuration.

(2) The ability to drain the emplacements adequately.

(3) The ability to prevent infiltration of the emplacements by animals or wind-blown material.

(4) The ability to repair the emplacement or target mechanism quickly and economically, with minimal downtime for the range.

In terms of flexibility of firing conditions, the below-grade emplacements would not significantly increase the allowable firing positions. Therefore, the choice of an emplacement would be based on construction, maintenance, and repair considerations.

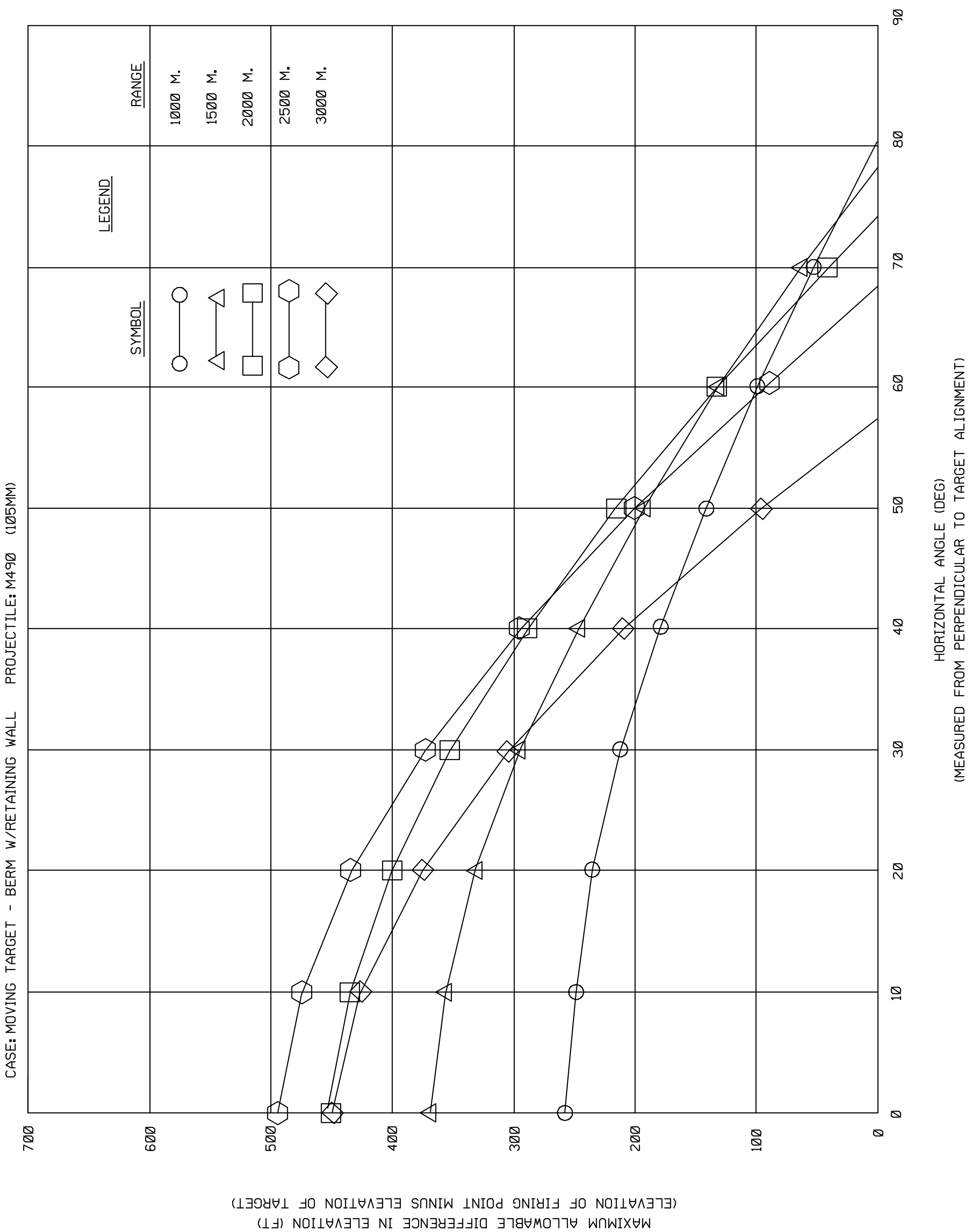


Figure 6-4. Allowable firing positions—moving target with retaining wall (105-mm, M490 projectiles)

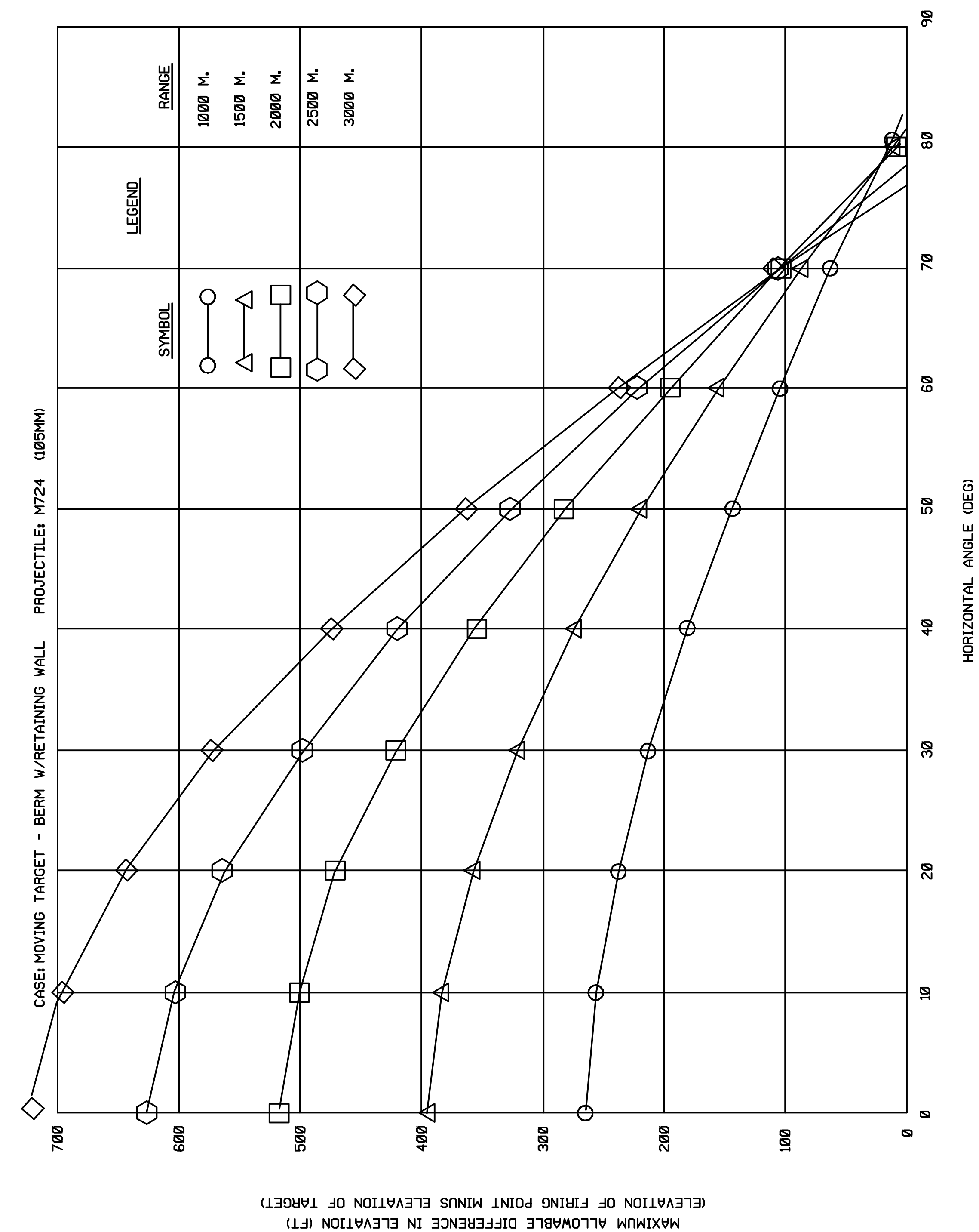


Figure 6-5. Allowable firing positions—moving target with retaining wall (105-mm, M724 projectiles)

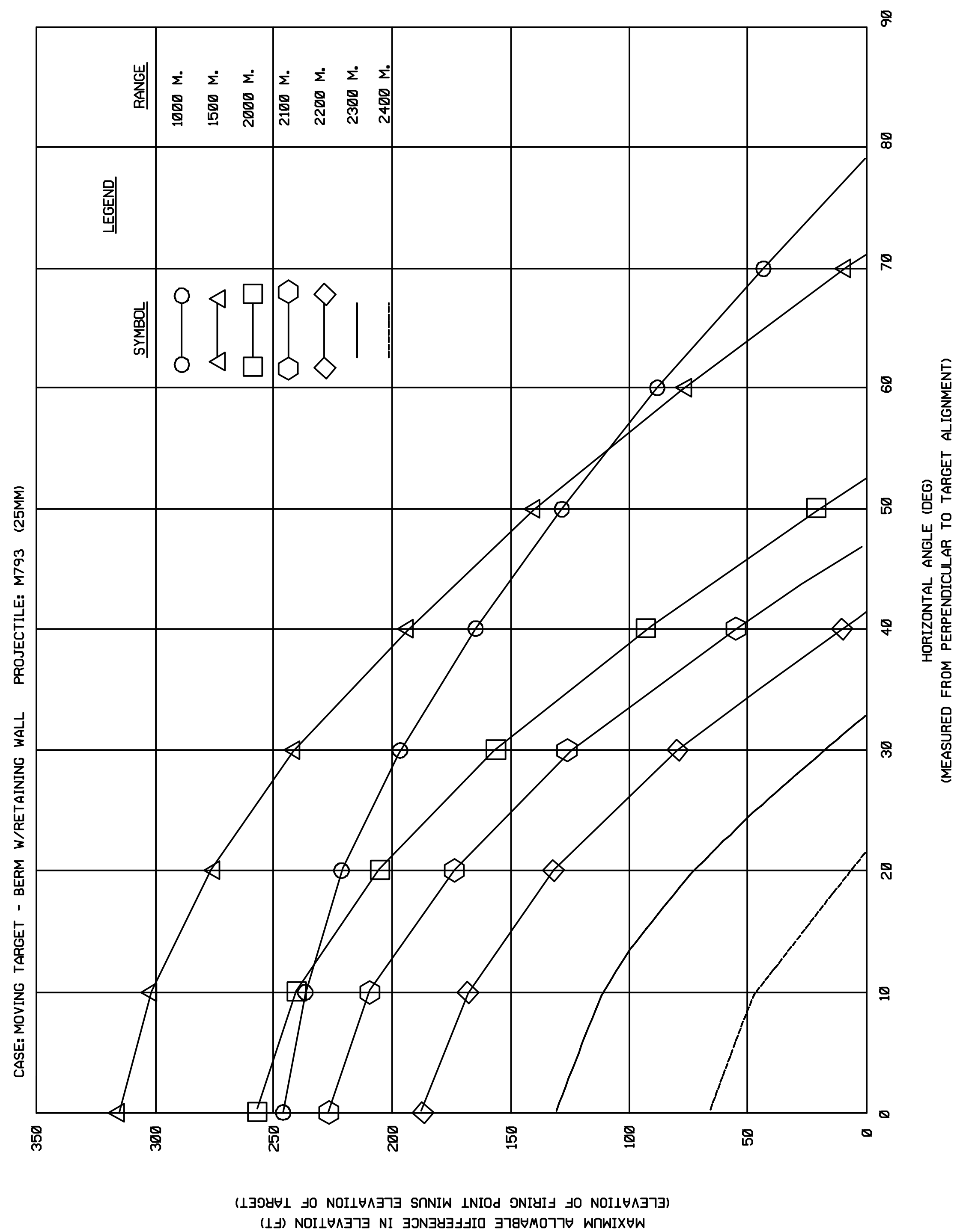


Figure 6- . Allowable firing positions—moving target with retaining wall (25-mm, M793 projectiles)

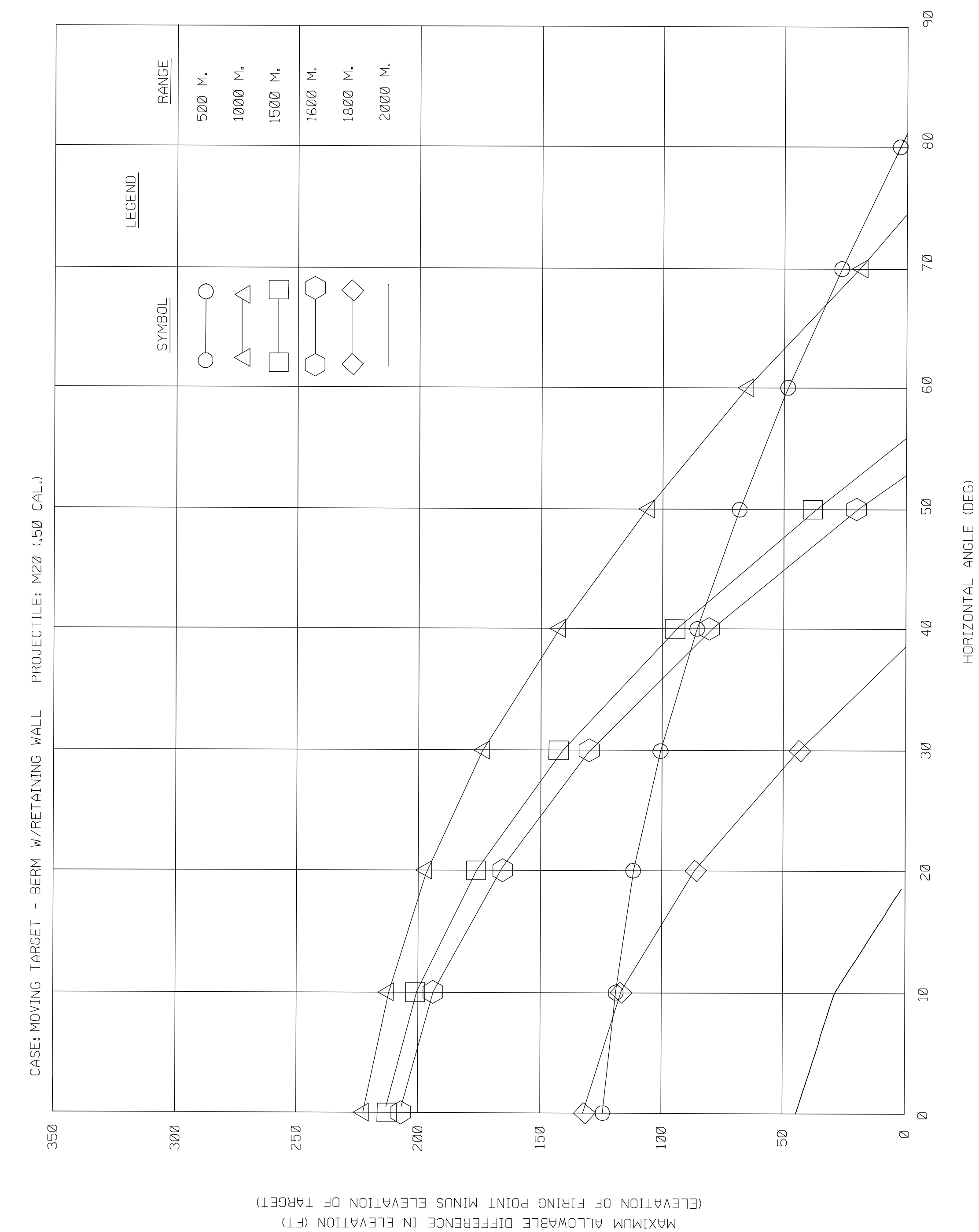
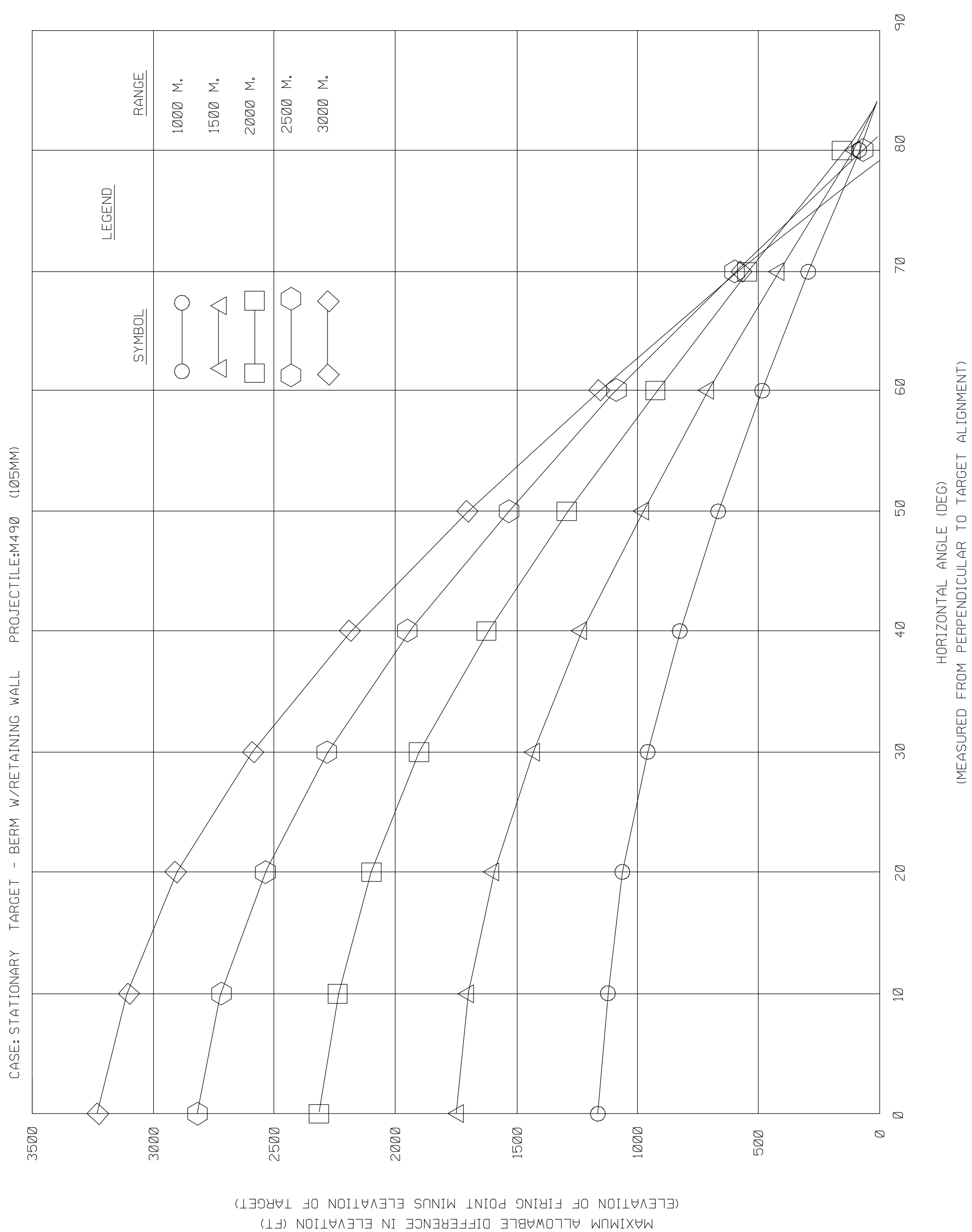


Figure 6-7
projectiles)



8. Allowable firing positions—stationary target with retaining wall (105-mm, M490

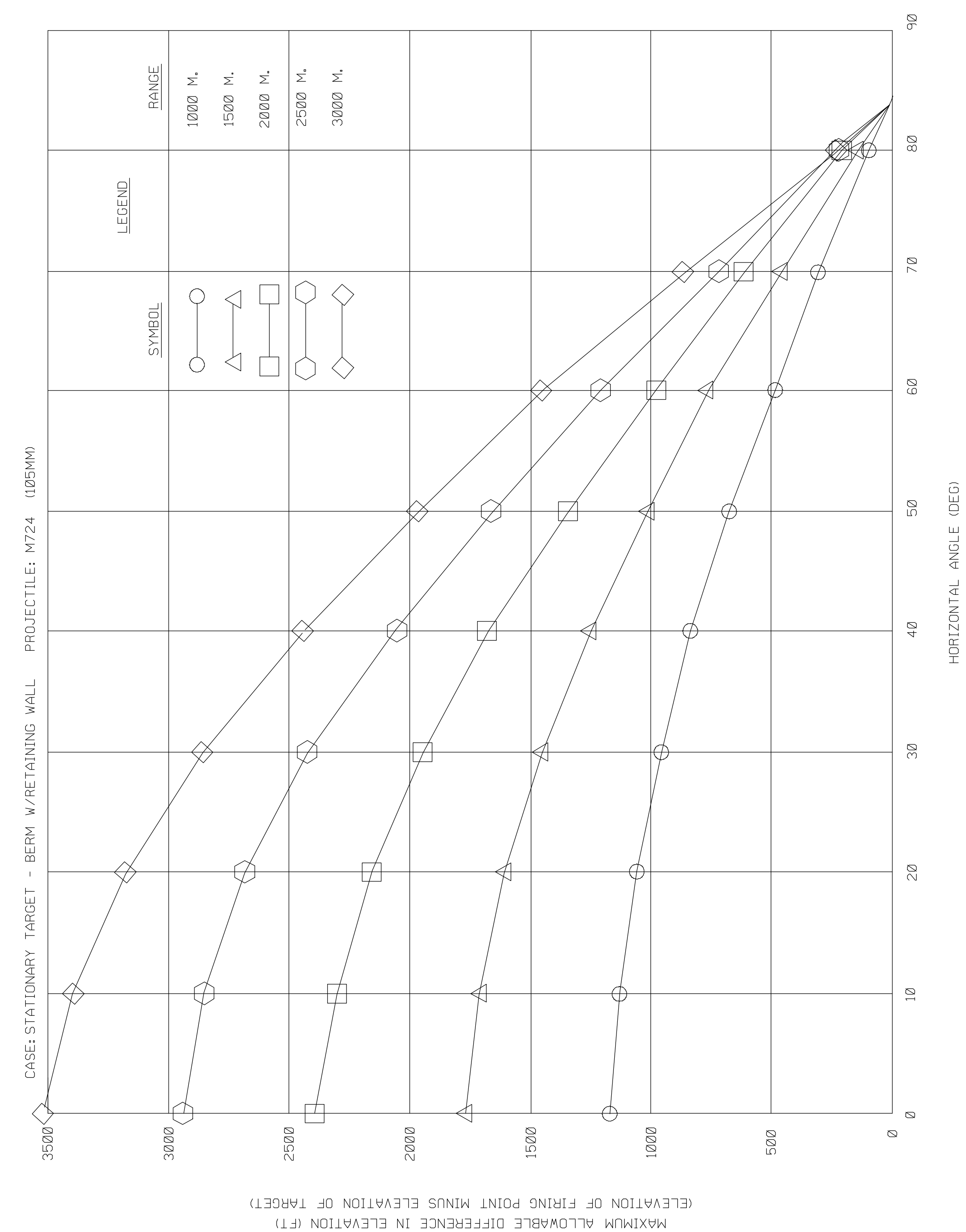


Figure 6-9. Allowable firing positions—stationary target with retaining wall (105-mm, M724 projectiles)

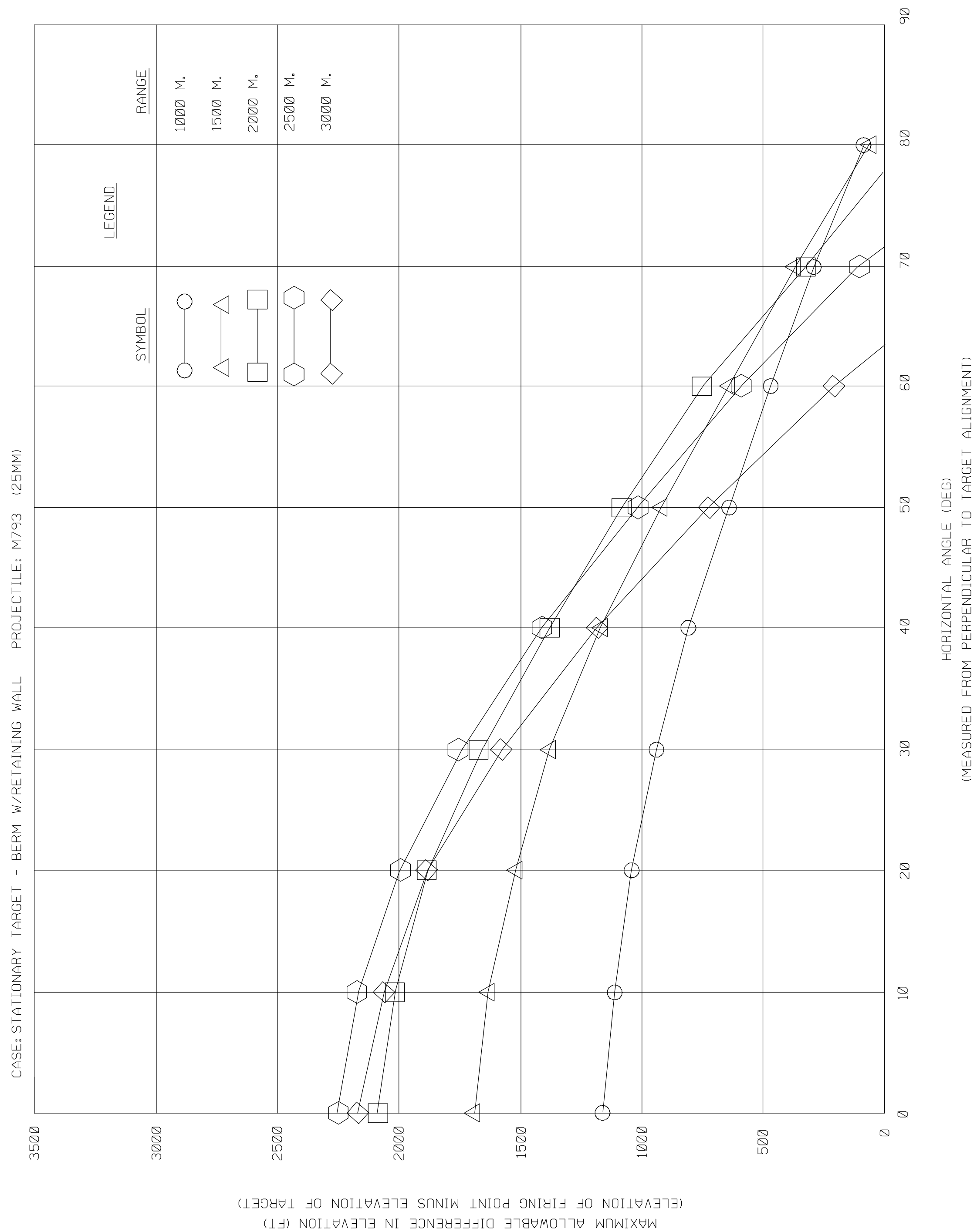


Figure 6-10. Allowable firing positions—stationary target with retaining wall (25-mm, M793 projectiles)

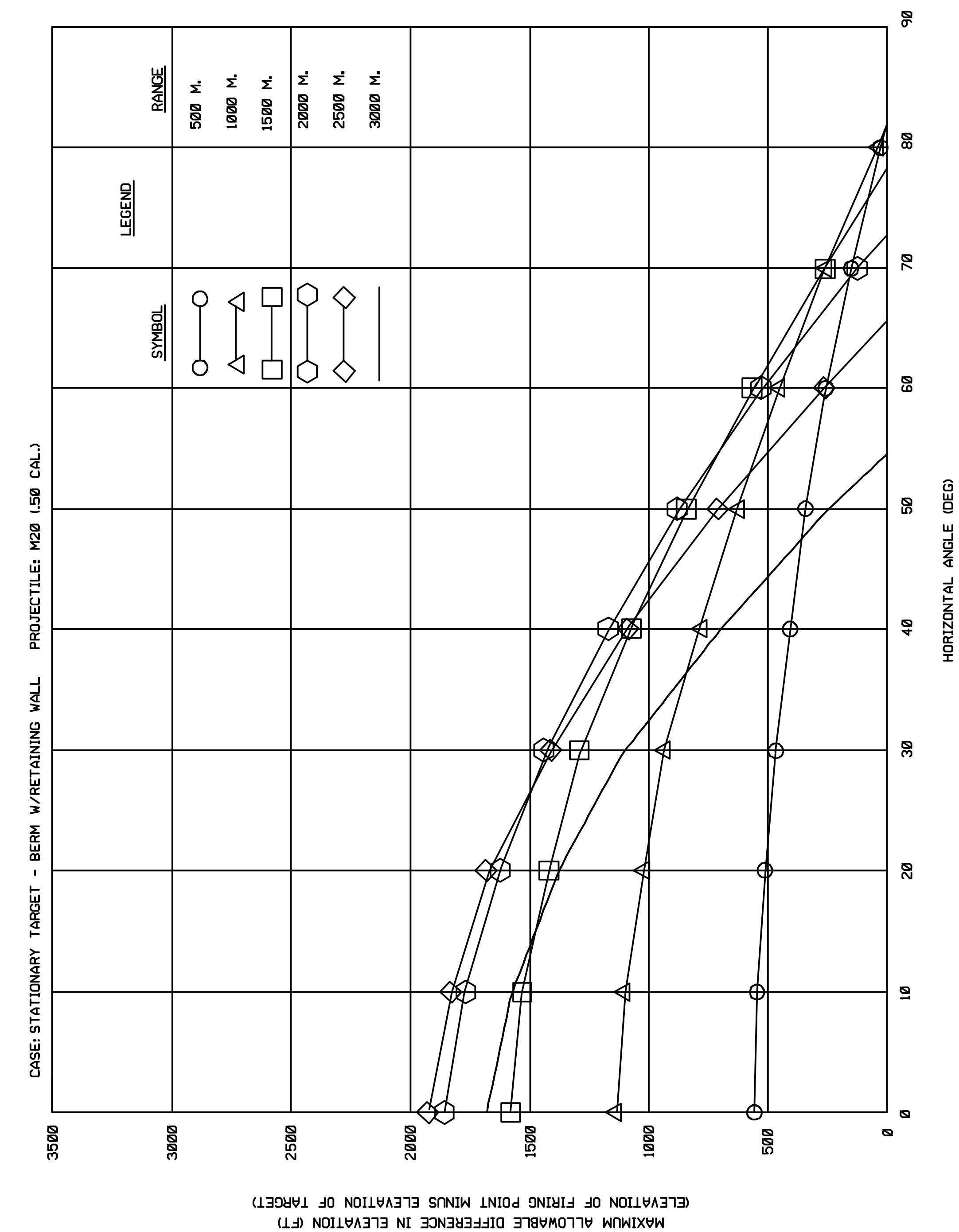


Figure 6-11. Allowable firing positions—stationary target with retaining wall (0.50 caliber, M20 projectiles)

6-4. SOIL TESTING. To determine the appropriate berm thickness, the designer must first determine the predominant soil type and the typical maximum dry density, preferably from previous soil tests conducted in the area. If no previous test results are available, moisture-density relationships for the various soil types to be used in berm construction should be determined. Regardless, normal testing for moisture and density control must be conducted during construction in order to ensure the integrity of the design.

6-5. DIMENSIONAL DESIGN. The primary objectives in designing the protective berms are to minimize the disturbance of the existing ground surface and to ensure that sharp departures in landforms are avoided. Two of the dimensional design parameters that have a significant impact on those objectives are berm width and berm slopes, which are discussed below.

a. Berm Width.

(1) Projectile and Soil Types. For protection against 105-mm and 120-mm projectiles, the recommended berm width has been computed for dry densities ranging from 85 to 120 pcf. The results are presented by soil type in figures 6-12 through 6-15 and apply to 120-mm, or smaller, projectiles. The width, as determined from those figures, is the minimum crest width needed. Soils not included in the curves (i.e., ML with LL greater than 30, MH, OL, and OH) are considered to be unsuitable for berm construction. For protection against 5.56-mm, 7.62-mm, 0.05-caliber, and 25-mm projectiles, the recommended berm thicknesses are shown in figures 6-1 through 6-3.

(2) Calculating Berm Width. Each figure shows the range of typical densities for a particular soil type. The curves show the variation in thickness with different degrees of compaction. With a higher degree of compaction, the crest width of the embankment decreases. Varying the degree of compaction will reduce the volume of earthwork and the area of land affected by construction activities. Note that the in-place dry density is used to chart berm width on the design curves. For example, for a site composed predominantly of CL material with a laboratory maximum dry density of 115 pcf to be compacted to 95-percent, first calculate the in-place dry density:

$$115 \text{ pcf} \times 0.95 = 109 \text{ pcf}$$

Then, to determine the recommended berm width from figure 6-13, draw a line from 109 pcf on the X axis up to the curve labeled 95-percent and over to the recommended crest width of 30 feet on the Y axis. Similarly, if 90-percent laboratory maximum dry density were used for compaction, the required width would be 42 feet.

(3) Compaction. As can be seen in figures 6-12 through 6-15, the degree of compaction has a significant impact on the required berm width, particularly with respect to fine-grained soils. The most important consideration in selecting the percent of compaction for the protective berm is settlement, especially where the moving target mechanisms are partially on fill and partially on natural ground. The fill should be constructed so that differential settlement and possible subsequent damage to the target mechanisms will not occur. The minimum compaction of the embankment should be 90-percent laboratory maximum dry density for cohesive soils and 95-percent laboratory maximum dry density for cohesionless soils.

(4) Composite Berms. A composite berm (that is, a berm incorporating concrete or gravel into the design) may further reduce the thickness of the protective berm. The equivalency of inches of gravel or concrete per foot of soil is shown in figure 6-16. If, for example, the protective berm had an in-place dry density of 105 pcf, then 1 foot of soil could be replaced by 1.3 inches of concrete or 2.7 inches of gravel. (See paragraphs 6-6 and 6-7 for design examples of typical composite berm sections.) The minimum concrete thickness should be 6 inches and the minimum gravel thickness should be 1 foot. The minimum crest width of the soil should be 9 feet for the periodic operation of maintenance equipment.

(a) Gravel Backing. The gravel used in the construction of the composite berm should be well graded, similar to a crusher-run material. The presence of sand-size particles is important to the stability and compaction characteristics of the gravel backing. The gravel should be compacted to 100-percent laboratory maximum dry density. It is important to confine the gravel material with a layer of compacted soil. The confinement of the gravel helps the compaction of the material and helps contain the material if a shell were to impact the gravel zone. (See paragraph 6-7 for an example of a gravel composite berm.)

(b) Soil Layer. The layer of compacted soil should be about 6 to 12 inches thick. The gravel should be placed to the required berm height indicated in paragraph 6-7, with the compacted soil added to that height. Although the soil will mask the lower 6 to 12 inches of the target, it should not significantly affect target firing.

(5) Concrete Backing. In figure 6-16, the curve for the concrete backing has been computed using a concrete compressive strength of 3,500 psi. If less concrete strength is to be used, the thickness of the backing should be increased using the following equation:

$$\text{required thickness} = (\text{recommended thickness}) \left[\frac{3500 \text{ psi}}{X}\right]^{1/2}$$

where the Recommended Thickness is determined from figure 6-16 and X is the compressive strength of the proposed concrete. In design example 2 (paragraph 6-7), if 2,000 psi concrete were used, the required thickness of concrete would be:

$$2.6 \text{ feet} \left[\frac{3500 \text{ psi}}{X}\right]^{1/2} = 3.4 \text{ feet}$$

When a vertical concrete retaining wall is used as the concrete backing, no reinforcement other than that required for structural considerations will be necessary.

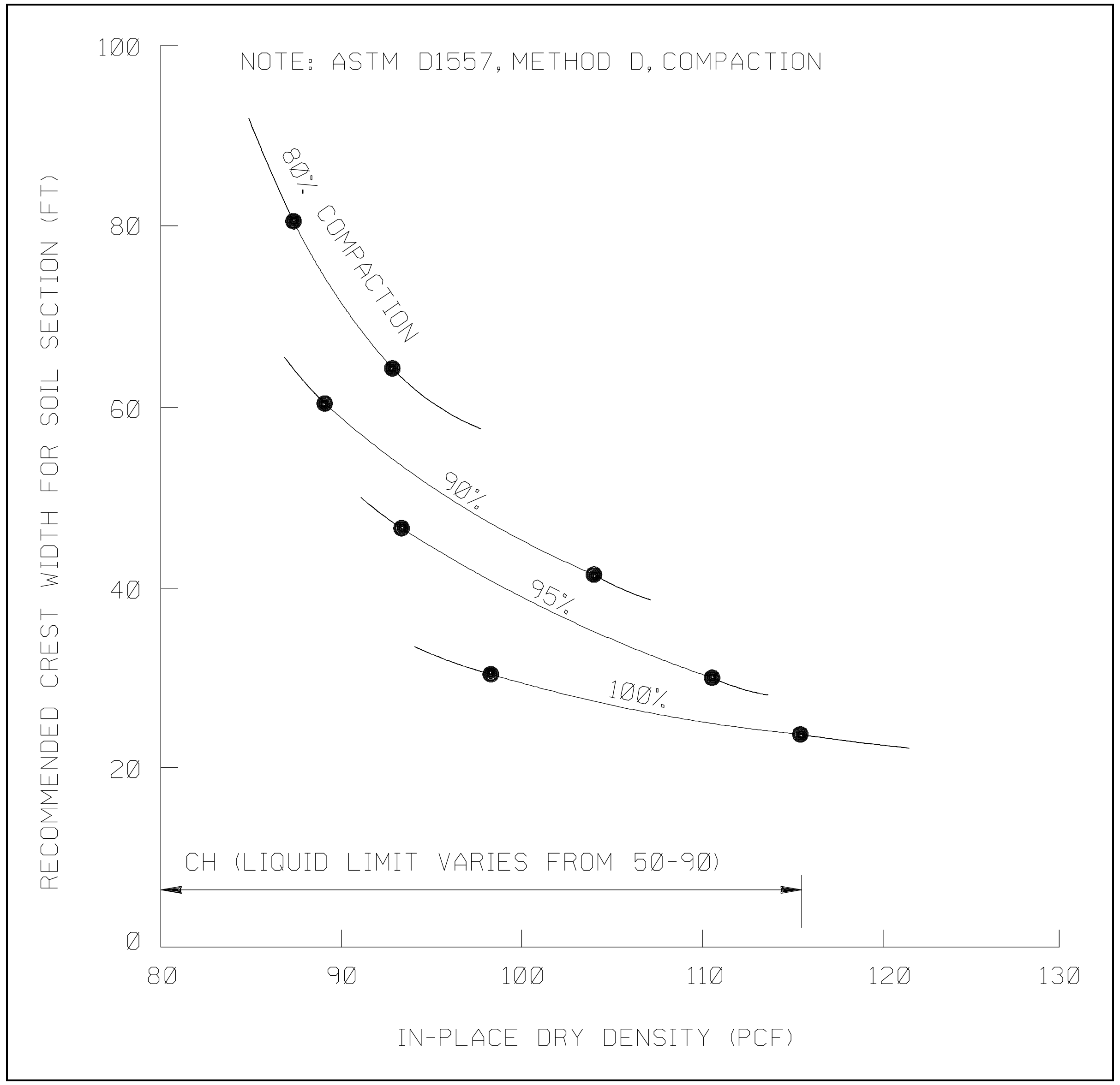


Figure 6-12. Required thickness of soil section versus dry density for CH soils (25-mm, 105-mm, and 120-mm projectiles)

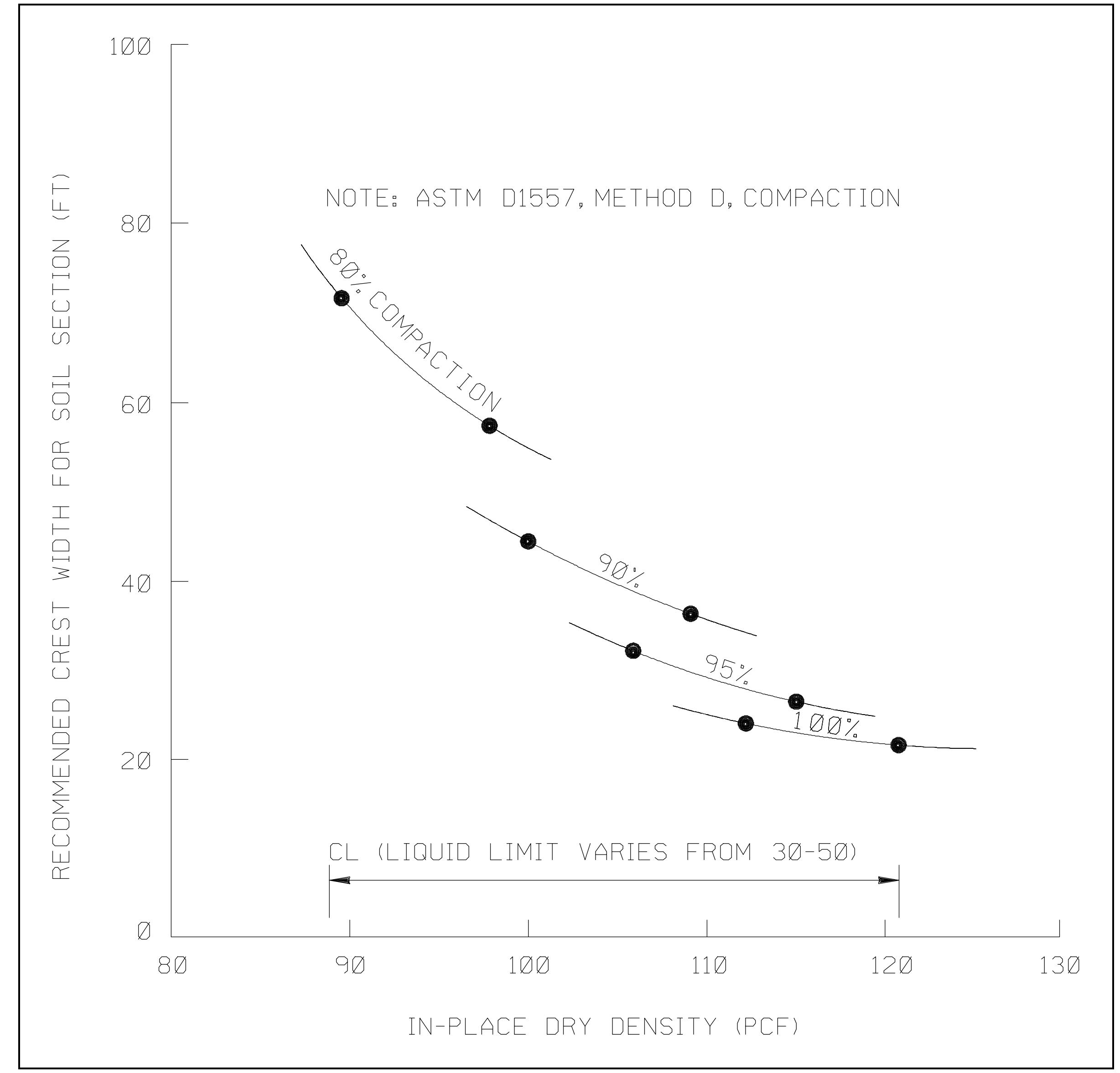


Figure 6-13. Required thickness of soil section versus dry density for CL soils (25-mm, 105-mm, and 120-mm projectiles)

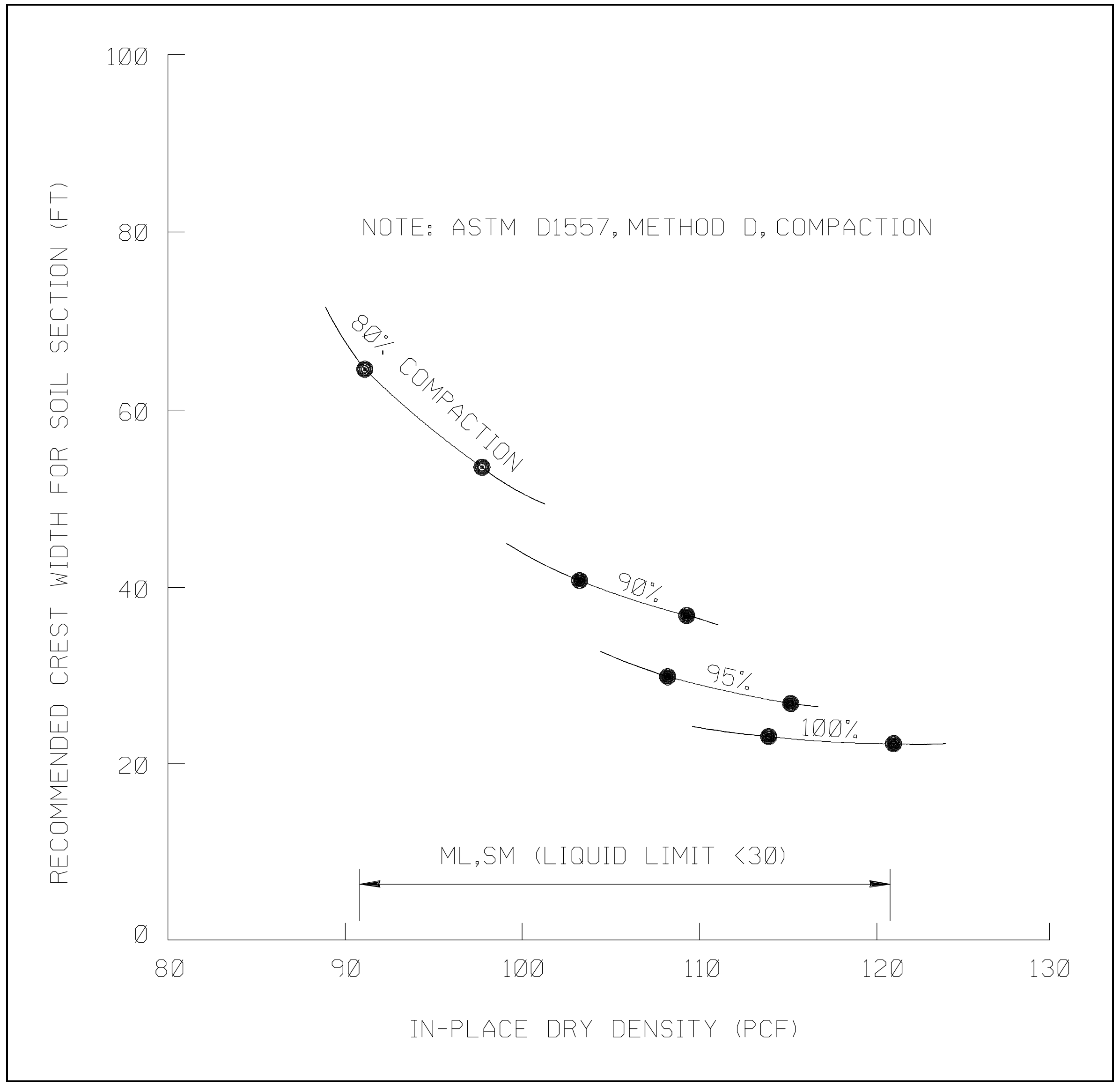


Figure 6-14. Required thickness of soil section versus dry density for ML and SM soils (25-mm, 105-mm, and 120-mm projectiles)

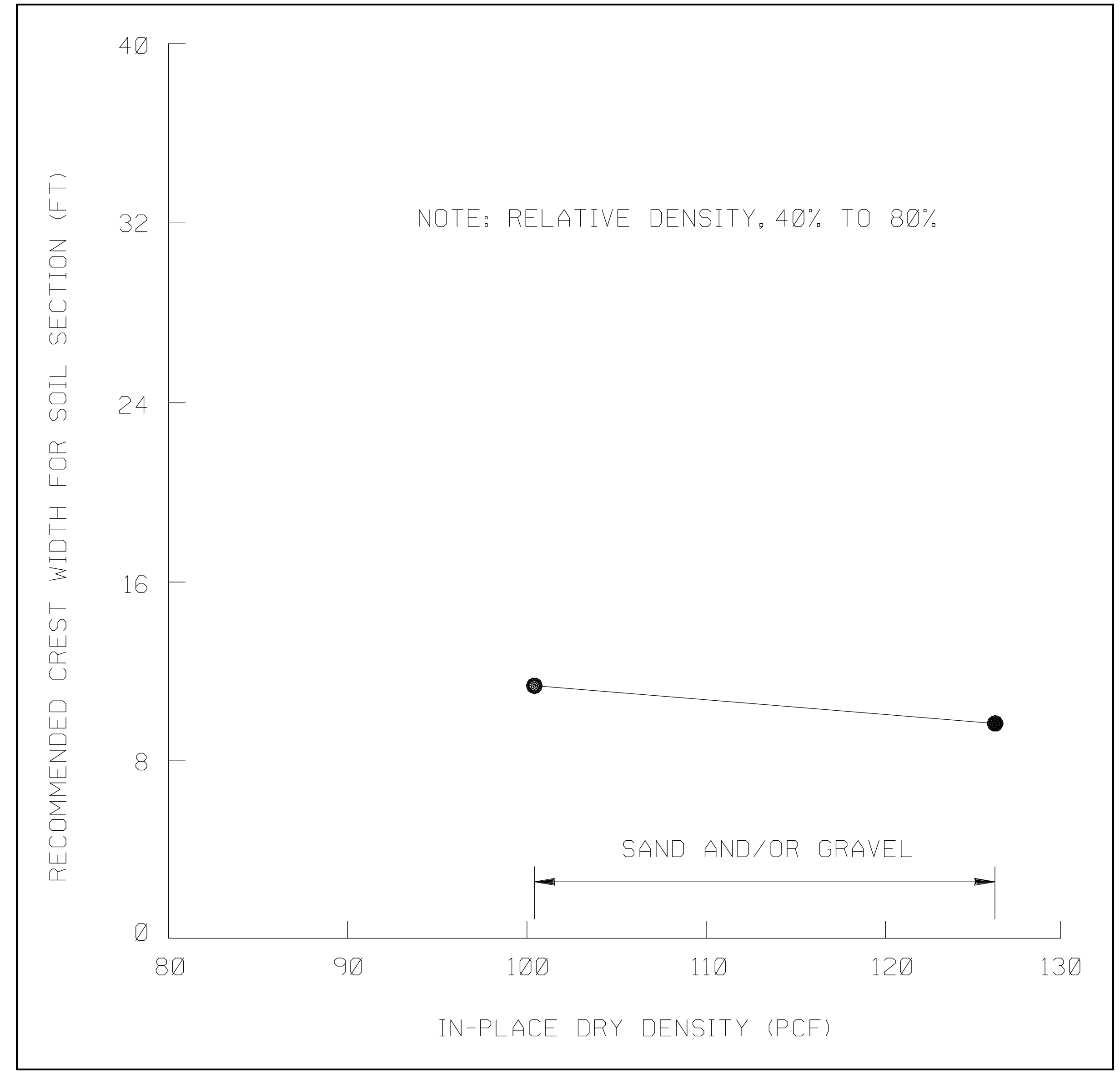


Figure 6-15. Required thickness of soil section versus dry density for sand or gravel soils (25-mm, 105-mm, and 120-mm projectiles)

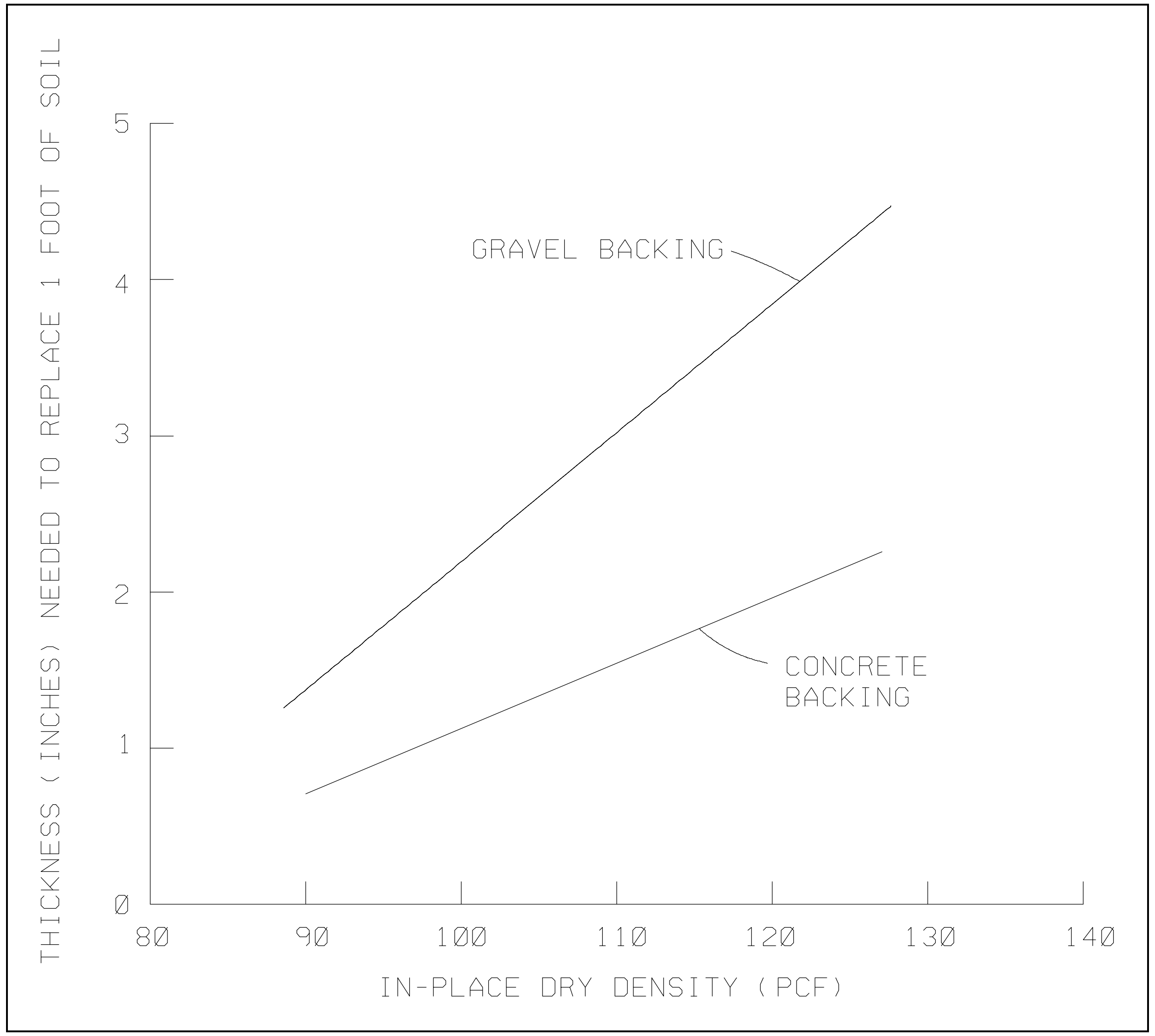


Figure 6-16. Composite berm design

b. Berm Slopes.

(1) Parameters. The other primary objective in the design of the berms is to avoid sharp departures in land forms, berm slopes for soil or gravel should be no steeper than 3 horizontal to 1 vertical, which is based on maintenance and erosion considerations.

(2) Designing with Two Slopes. To minimize earthwork, a berm with two slopes might be an alternative. The slope facing the firing line should be the flatter slope in order to avoid abrupt changes in the land surface, and the opposite slope should be the steeper. The steeper slope should be checked for stability when the target emplacement is placed at the top of the slope (as shown in Design Example 1, paragraph 6-6) and the back of the embankment involves over 1.52 meters of fill.

(3) Gravel. Where gravel is used to construct a composite berm, a slope on the soil-gravel interface of 1 horizontal to 1 vertical is not unreasonable.

(4) Concrete. Where a vertical retaining wall is used (as is the case with some moving target emplacements), extra care is required when compacting the backfill and pervious drainage materials against it.

6-6. BERM DESIGN EXAMPLE NO. 1. This example illustrates the concepts for proper berm design and how to calculate the required thickness of a berm.

a. Assumptions.

(1) Soil.

(a) The predominate soil type is SM.

(b) The typical laboratory maximum dry density is 120 pcf.

(2) Embankment.

(a) A 3 horizontal to 1 vertical slope on the side facing firing line.

(b) A 2.5 horizontal to 1 vertical slope on the backside.

b. Design of a Typical Berm for AMTC's. AMTC's are designed with an 200-millimeter-thick concrete retaining wall against the berm (see figure 6-17).

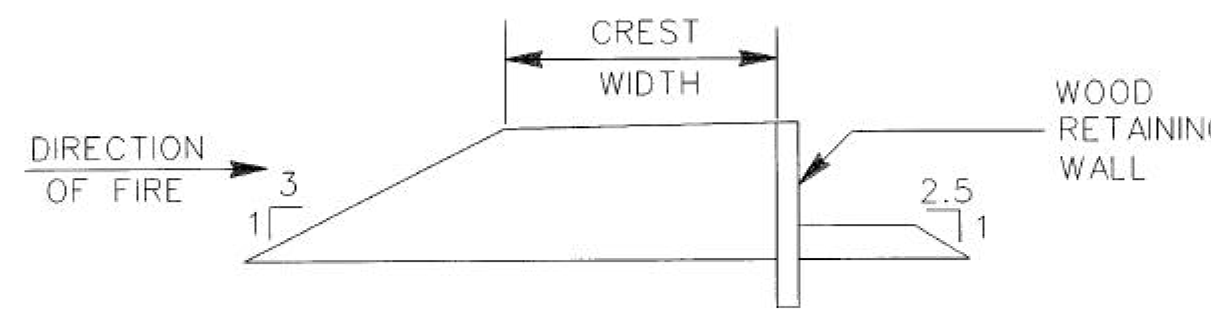


Figure 6-17. AMTC berm section

c. Crest Width. Calculate the in-place dry density for 90-, 95-, and 100-percent compaction as in paragraph 6-5, and determine the crest widths using figure 6-14:

(1) At 90-percent compaction:

(a) In-place density is (0.90) (120 pcf) = 108 pcf.

(b) Required crest width is 38 feet.

(2) At 95-percent compaction:

(a) In-place density is *(0.95) (120 pcf) = 114 pcf.*

(b) Required crest width is 27 feet.

(3) At 100-percent compaction:

(a) In-place density is 120 pcf.

(b) Required crest width is 22 feet. Select 95-percent compaction as the most reasonable balance between earthwork and compacting effort; therefore, the required thickness would be 27 feet.

d. Concrete Width. Determine the allowance for the 8-inch concrete retaining wall. For an in-place density of 114 pcf, according to figure 6-16, 1.75 inches of concrete would replace 1 foot of soil; therefore, 8 inches of concrete would replace 4.6 feet of soil.

e. Berm Width. The required width of the protective berm is *7 feet - 4.6 feet = 22.4 feet.*

6-7. BERM DESIGN EXAMPLE NO. 2. The following example illustrates the concepts for proper berm design and how to calculate the required width of a composite berm.

a. Assumptions.

(1) Concrete. Compressive strength is 3,500 psi.

(2) Soil.

(a) Predominant soil type is CL.

(b) Typical laboratory maximum dry density is 115 pcf.

b. Embankment. Assume the layout of the site necessitates the use of the smallest berm possible. Therefore, start with 2.5 horizontal to 1 vertical side slopes (see figure 6-18).

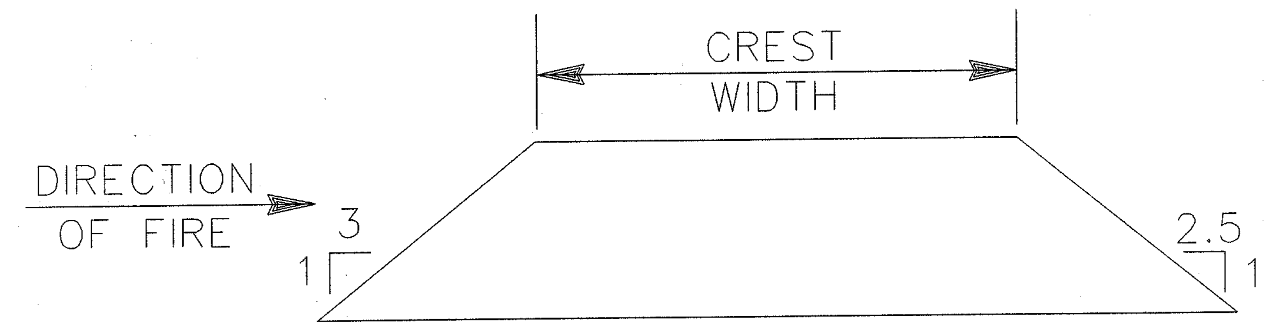


Figure 6-18. Homogeneous berm section

c. Design of Homogeneous Berm. The following table was developed by the method presented above in paragraph 6-5a(2). Select 95-percent compaction, which would be the maximum practical density to which this type of material can be compacted. Therefore, the required width at the crest would equal 30 feet.

% Compaction	In-place Density (pfc)	Required Width (ft)
90	103.5	42
95	109.0	30

d. Design of Composite Section.

(1) Concrete.

(a) In-place dry density of the soil is 109 pcf.

(b) According to figure 6-16, 1.5 inches of concrete are equivalent to 1 foot of soil.

(c) Using a minimum crest width of 9 feet, the width of soil to be replaced is

30 feet - 9 feet = 21 feet

(d) The required thickness of concrete to replace 21 feet of soil is

$$21 \text{ ft. of soil } X \left[\frac{1.5 \text{ in. of concrete}}{\text{ft. of soil}}\right] X \left[\frac{1 \text{ ft.}}{12 \text{ in.}}\right] = 2.6 \text{ ft.}$$

(e) The composite section would appear as shown in figure 6-19.

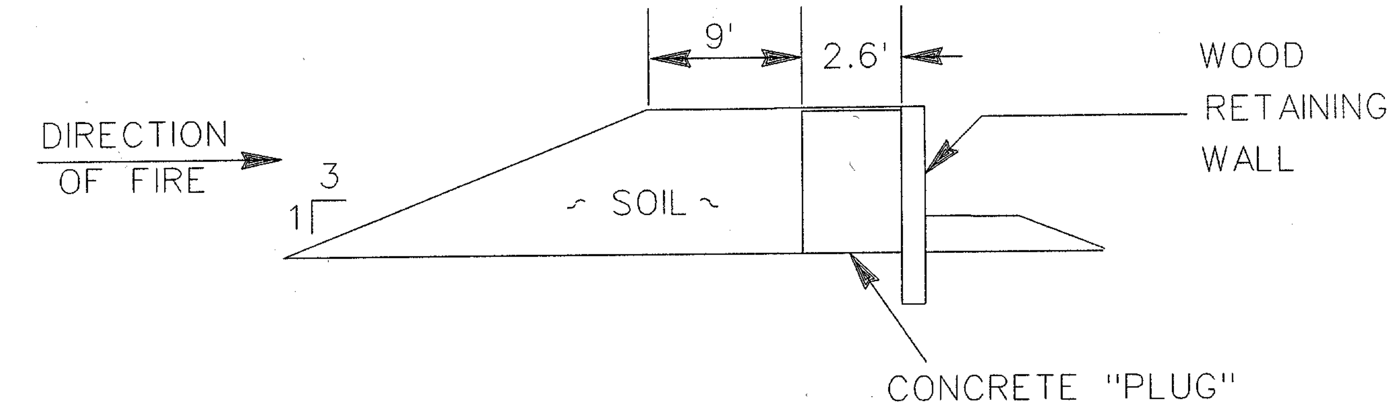


Figure 6-19. Concrete composite berm section

(2) Gravel.

(a) In-place dry density of soil is 109 pcf.

(b) According to figure 6-16, 3 inches of gravel are equivalent to 1 foot of soil. Using a minimum crest width of 9 feet, the width of soil to be replaced would equal 21 feet (as before).

(c) The required width of gravel to replace 21 feet of soil is

$$21 \text{ ft. of soil } X \left[\frac{3 \text{ in. of gravel}}{\text{ft. of soil}}\right] X \left[\frac{1 \text{ ft.}}{12 \text{ in.}}\right] = 5.3 \text{ ft.}$$

(d) The composite section would appear as shown in figure 6-20.

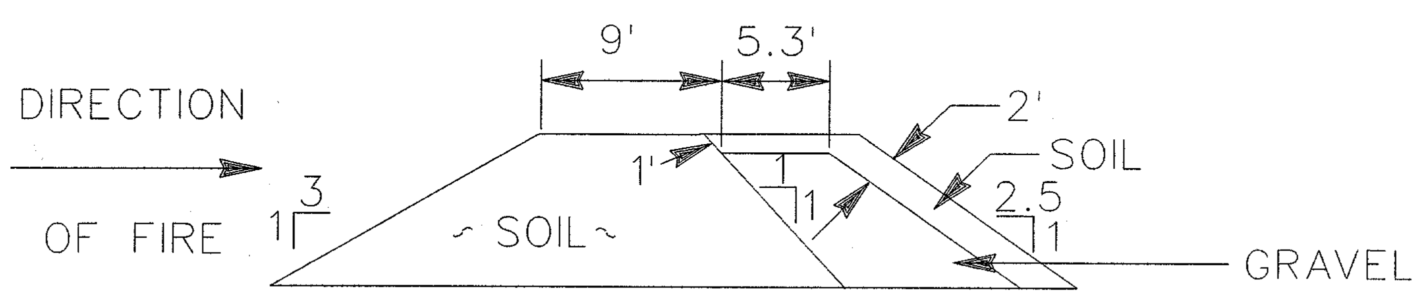


Figure 6-20. Gravel composite berm section

6-8. COMPACTION CONTROL. The construction of the protective berms should be carefully monitored because the design width is based on the achievement of a certain density. Monitoring is especially critical for the lower densities (i.e., 92 to 115 pcf) where the thickness is highly dependent upon the density. Careful control of the density is important in order to minimize differential settlement in the embankment, which may result in damage to the target mechanisms. The construction of the protective berms should be controlled in the same manner as any other earth embankment. Once the compaction data have been analyzed for the specific site, the values of density determined in the field should be compared to those used in the design, thereby ensuring the integrity of the berm.

6-9. PROTECTIVE BERM MAINTENANCE.

a. Frequency. The berms, constructed as recommended in this design manual, should require major maintenance approximately every 6 months and periodic maintenance between training cycles. As each facility establishes a performance record of its berms, the time between major maintenance periods may be adjusted by increasing the berm width to fit site-specific needs of the installation; however, increased maintenance would then be required on the range, and proper equipment would be needed to maintain the berms. If the range is heavily used, the frequency of required maintenance may be significantly higher than what has been experienced for some installations. Also, maintenance for the stationary target berms will probably be required at closer intervals than for the moving target berms.

b. Periodic Maintenance. The periodic maintenance needed between training cycles consists basically of smoothing out areas where shells have impacted. Also, some additional soil may be used to increase the berm width in an emergency, keeping the berm serviceable until major maintenance can be performed. Some material might be stockpiled for emergency maintenance if it is not readily available.

c. Major Maintenance. Major maintenance will be required when portions of the berms become heavily damaged. Major maintenance involves the removal and replacement of material in the impacted area. After major maintenance, the material must be recompacted to the specified densities so that targets are adequately protected.

6-10. TRENCHES (BELOW-GRADE EMPLACEMENTS). The use of trenches is a method of enemy defense that can bring another element of realism to a training range. Furthermore, the placement of trenches in reverse slopes might be considered when trying to use existing terrain with minimal disturbance. However, a number of conditions associated with trenches may preclude their general use:

a. The emplacement must be adequately drained.

b. Trenches are susceptible to infiltration from water and wind-borne alluvial materials, including drifting snow.

c. Retaining walls will be needed to support the walls of a trench, preventing short rounds from causing a failure.

d. Problems with excavation must be considered, particularly in rock or areas affected by high ground water.

e. Access to the target mechanism for maintenance must be provided.

f. The target mechanism must be protected. The thickness of the natural material in front of the emplacement should be compared to the required thickness shown in figures 6-1 through 6-3 and 6-12 through 6-16 in order to determine whether additional material needs to be placed on the slope facing the firing line.

g. Each of the problems listed above should be addressed before trenches are chosen. Furthermore, the maintenance of the material in front of the emplacement will involve the same procedures as defined in paragraph 6-9 above, since the use of trenches does not minimize the importance of maintenance.