Designation: XXXXX-XX

Include Ballot Rationale Here (Required for all Ballots)

Standard Practice for
Selection and Application of Vehicle Barriers[1]

This standard is issued under the fixed designation X XXXX; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Purpose—This practice provides the design requirements necessary to plan, design, construct, and maintain vehicle counter-mobility barriers used within entry control facilities (ECF) or as perimeter protection. This practice is to be used during the design of Department of Defense (DoD) facilities to ensure an optimal vehicle barrier system is selected by engineers and security personnel for a specific operation within an installation. Barrier performance, maintenance, and cost should all be optimized. It is intended to establish consistent requirements, standards, and design basis for barrier planning, design, construction, and maintenance for all military departments. This practice identifies design features necessary to ensure that infrastructure constructed today will have the flexibility to support future technologies, a changing threat environment, and changes in operations.

A vehicle barrier selection and placement process is presented herein along with criteria for the design, selection, installation, operation, and maintenance of security barrier systems. The selected barrier system shall effectively stop or disable or both vehicles that pose a threat, including explosive-laden vehicles, of breaching the perimeter of a protected area. Both passive (static or nonmovable) perimeter barriers and active (operational for access control) barriers at

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facility entrances are included. The examples presented in this practice are for illustration

purposes only and should be modified and adapted to satisfy installation specific constraints. This

practice is not intended to address procedural issues such as tactics and techniques; however, an

appropriately designed vehicle barrier system used within an entry control facility/access control

point (ECF/ACP) or along an installation perimeter can enhance and improve operations.

1. Scope

1.1 Commanders, security personnel, planners, designers, and engineers should use this

practice when designing vehicle barrier systems for entry control facilities (ECFs) or other

perimeter locations. Technical information considered generally known to professional

designers or engineers or readily available in existing technical references (unified facility criteria,

military handbooks, technical manuals, and so forth) has not been included.

1.2 This practice should be used in conjunction and coordination with UFC 4-020-01, *Security*

Engineering Facilities Planning Manual, UFC 4-020-02, *Security Engineering Facilities Design*

Manual, UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points*,

and UFC 4-022-03, *Security Engineering: Fences, Gates and Guard Facilities* to guide the user

through a selection process to establish a protective barrier system around a U.S. Department of

Defense (DoD) installation and designated restricted areas within the installation (enclave areas). A

systematic approach is used. The main issues to be considered during the selection and design of

a vehicle barrier include:

1.2.1 *Threat Analysis*—To quantify the potential threat. For threat analysis, refer to UFC 4-

020-01 and UFC 4- 020-02. The procedures in these manuals will quantify and qualify all

potential threats, including the "moving" vehicle bomb threat necessary for the determination of

the appropriate vehicle barrier for a given location.

1.2.2 *Performance*—To determine the appropriate levels of protection (both to personnel and property). An acceptable level of protection shall be defined by the installation commander.

1.2.3 *Access Control Measures*—Physical controls, operating procedures, and hardware and software features used in various combinations to allow, detect, or prevent access.

1.2.4 *Requirements*—Appropriate standoff distance to maintain a level of protection compatible with operational needs; passive or active barrier systems to stop the threat vehicle; barrier reliability and maintainability, safety, sabotage and malfunction protection, and cost effectiveness.

1.2.5 *Response*—Potential structural damage to the vehicle barrier from blast loads produced during an explosion.

1.2.6 *Liabilities*—Potential liability effects on the decision to protect assets against the effects of a terrorist act.

1.2.7 *Cost*—Security expenditures based on the value of the asset to be protected and the importance of the asset to national security and readiness. For protection against vehicle bombs, the potential loss of human life generally drives the cost of security, overriding the value of the property to be protected. The decision to use vehicle barriers and provide protection against terrorist vehicle bombs is primarily motivated by protection of personnel.

1.3 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standard*:

F2656 Test Method for Vehicle Crash Testing of Perimeter Barriers[2]

2.2 *ISO Standard:*

ISO/IEC 17025 General requirements for the competence of testing and calibration

laboratories[3]

2.3 *Federal Standards:*

Architectural Barriers Act Accessibility Standard[4]

SD-STD-02.1 Revision A Specification for Vehicle Crash Test of Perimeter Barriers and

Gates[5]

UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings[6]

3. Terminology

3.1 *Definitions Specific to This Standard:*

3.1.1 *active barrier systems, n*—active barrier requires some action, either by personnel,

equipment, or both, to permit or deny entry of a vehicle and the system has some form of moving

parts.

3.1.1.1 *Discussion*—Active barrier systems include barricades, bollards, beams, gates, and

active tire shredders.

3.1.2 *fixed barrier systems, n*—permanently installed or requires heavy equipment to move or

dismantle.

3.1.2.1 *Discussion*—Examples include hydraulically operated rotation or retracting systems,

pits, and concrete or steel barriers. Fixed barrier systems can be either active or passive.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@asstm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from http://www.accessboard.gov/ada%2daba/aba-standards-dod.cfm.

[5] Available from the U.S. Department of State, Bureau of Diplomatic Security, Office of Physical Security Programs, Physical Security Division, Washington, DC 20520-1403.

[6] Available from http://dod.wbdg.org/.

3.1.3 *passive barrier systems, n*—passive barrier has no moving parts and passive barrier

effectiveness relies on its ability to absorb energy and transmit the energy to its foundation.

3.1.3.1 *Discussion*—Highway medians (Jersey), bollards or posts, tires, guardrails, ditches,

and reinforced fences are examples of passive barriers.

3.1.4 *portable/movable barrier systems, n*—can be relocated from place to place.

3.1.4.1 *Discussion*—It may require heavy equipment to assist in the transfer. Hydraulically

operated, sled-type, barricade systems, highway medians, or filled 55-gal (208-L) drums that are

not set in foundations are typical examples. Portable/movable barrier systems can be either active

or passive.

3.2 *Acronyms*

ACP Access control point

BDAM Blast damage assessment model

CCTV Closed-circuit television

DBT Design basis threat

DoD U.S. Department of Defense

DoDISS DoD Index of Specifications and Standards

DoS U.S. Department of State

ECF Entry control facility

ERASDAC Explosive Risk and Structural Damage Assessment Code

FACEDAP Facility and Component Explosive Damage Assessment Program

FRF Fragment-retention film

MIL HDBK Military handbook

NAVFAC Naval Facilities Engineering Command

NFESC Naval Facilities Engineering Service Center

PDC Protective Design Center

4. Significance and Use

4.1 Vehicle barriers are primarily used as one of many elements that define perimeters that require a final denial barrier to be provided for certain restricted areas. In this practice, the focus is on the design, selection, and application of active and passive vehicle barriers.

4.2 *Impact*—The following direct benefits will result:

4.2.1 A standardized approach for identifying and justifying security and antiterrorism design criteria for DoD facilities;

4.2.2 A standardized nomenclature and criteria for asset, threat, and level of protection definition;

4.2.3 A standardized procedure for identifying costs for DoD facilities with security and antiterrorism requirements to a planning level of detail;

4.2.4 A standardized process for evaluating design criteria and protection options based on cost and risk management;

4.2.5 Guidance for incorporating security and antiterrorism principles into installation master planning; and

4.2.6 There are no adverse impacts on environmental, sustainability, or constructability policies or practices.

5. Vehicle Barrier Design Parameters

5.1 *General*

5.1.1 Vehicles loaded with explosives can detonate as a large bomb inflicting severe damage on critical military facilities and potentially injuring DoD personnel. Such vehicle bombs are effective terrorist tools because they facilitate the transport of large quantities of explosives to any desired location. When planning and selecting vehicle barriers to be used for facility perimeter

protection, the first step is to determine the design basis threat (DBT) for any given location in the facility. In Table X1.1, active vehicle barrier kinetic energy rating and vehicle penetration based on SD-STD-02.1, Revision A are provided. The DBT may vary within and around the installation. It can be affected by guidance instructions specific to the area and service specific guidance. UFC 4-010-01, as well as local and service specific guidance documents, should be consulted in defining DBTs at each location where barriers are required.

5.1.2 Several factors should be considered when setting up defense against the DBT: (1) the occupied structures in a particular area; (2) the barrier penetration capabilities of the DBT vehicle (based on the maximum vehicle velocity to the barrier location, the angle of impact, and the area around the barrier location); and (3) the structural response of and potential debris throw from the barrier, if the vehicle bomb detonates.

5.1.3 Both stationary and moving vehicle bombs need to be considered. To prevent effectively a moving vehicle from getting close to the intended target, the perimeter barrier shall absorb the kinetic energy produced by the total weight of the vehicle bomb (vehicle weight plus the weight of explosives and any other cargo in the vehicle) and the vehicle's maximum attainable speed at the point of impact. Thus, kinetic energy is a primary factor used to establish performance requirements for moving vehicle barriers.

5.1.4 Another primary consideration for either stationary or moving vehicle bombs should be the barrier's response to the load produced by detonation of the explosives in the vehicle. The amount of debris produced and subsequent debris throw distance should also factor into the selection of appropriate barriers.

5.2 *Site Survey*

5.2.1 The process of selecting and designing a barrier system begins with determination of the DBT and required levels of protection. Reference UFC 4- 020-01 and UFC 4-020-02 for methods

163 to determine the DBT and levels of protection (see Appendix X1). Next, preparations are made

164 for a site survey. First, a scaled map of the protected area shall be prepared from detailed plans of

165 the facility that shall include at least one block beyond the perimeter. This map should include the

166 relative locations, major dimensions, and descriptions of structures, roads, terrain and

167 landscaping, existing security features, and property perimeter. Any features outside the perimeter

168 (within one block or so) that could possibly be used to reduce vehicle speed, prevent access to the

169 perimeter barrier, shield structures from damage in the event of an explosion, or affect an

170 aggressor's progress in any other way should be shown on the site map as well. This map will

171 permit careful analysis of distances and topographical features between the perimeter and the

172 facility. The map identifies potential vulnerabilities. Because of the information included on any

173 such site map, it may need to be a classified document. Figure 1 shows an example site map for a

174 facility.

175   5.2.2 As shown in FIG 1, the individual segments of the perimeter can be attacked from a

176 variety of paths. For example, Building 827 with a controlled area on two sides of the perimeter,

177 the two remaining sides (Perimeter Roads "A" and "B") are vulnerable to a vehicle attack. The

178 entrance road and the extension of Perimeter Road "B" are perpendicular and lead directly to the

179 compound boundary. Each of these roads is a potential attack path. Certain segments of the

180 perimeter can be attacked from more than one street. In addition, for Perimeter Roads "A" and

181 "B", running parallel to the perimeter, there are an infinite number of impact points and angles

182 depending upon vehicle location and speed. As a result, a large number of potential impact

183 conditions (the combination of vehicle speed and impact angle) can occur at any point along the

184 perimeter boundary.

185   5.3 *Integrated Physical Security System*—Any vulnerabilities identified in the site survey

186 should be addressed by developing an integrated physical security protection system. DBTs

187 identified for the specific facility and current security requirements need to be considered. These

188 threats are determined by assessment of site-specific threats or are specified by an installation.

189 Comprehensive protection can be provided by coordinating physical barriers (such as fences,

190 active barriers, and passive barriers) with other security components and options. For example,

191 perimeter sensors, lights, and closed-circuit television (CCT) can be used to detect vehicles

192 attempting to penetrate the perimeter covertly. Sallyports can be used to detect bombs hidden in

193 vehicles entering a facility. Performance of the perimeter barrier can be enhanced with strategic

194 placement of bollards, ditches, and planters. A wide range of potential threats can be detected

195 early using clear zones as well. All barrier requirements should be coordinated with the entry

196 control facility (ECF) design guidance given in UFC 4-022-01. In FIG 2, some examples of

197 integrated physical security measures are illustrated.

198   5.4 *Attainable Vehicle Speed*

199   5.4.1 The speed of a vehicle at the point of impact on a vehicle barrier is a major parameter in

200 determining the required performance of the barrier. The impact is calculated from the initial

201 speed, v, the acceleration rate, a, and the distance, s, available for acceleration between the

202 starting point and the point of impact. Additional factors that shall be considered are the general

203 terrain, the surface condition of the path, and whether or not the path is straight, curved, or

204 banked. Information presented in FIGS 1-7 allows calculation of maximum attainable vehicle

205 speed, or suggests strategies for modifying possible attack paths to control vehicle speed.

206   5.4.2 The impact speed along the perimeter should be calculated for all possible driving paths

207 identified on the site survey map. The strategy for barrier system design, selection, and

208 installation can then be developed using this data.

209   5.4.3 The methods presented in this section for determining attainable vehicle speeds assume

210 flat roadway surfaces. Most roadways are not flat, either because of super-elevation or typical

211 roadway crowning and constructed transverse slopes. If a driver can use a non-flat roadway

212 surface to his advantage in attaining a higher speed, this needs to be taken into consideration. The

213 use of any geometrics in the selection of barriers and design of an ECF should only be provided

214 under the guidance of an engineer experienced in roadway/transportation engineering. Otherwise,

215 some of the assumptions for the methods in this section may be highly conservative and may lead

216 to designs that are treacherous for vehicles traveling at normal/design speeds, vehicles traveling

217 during wet conditions, or large commercial and emergency vehicles.

218   5.4.4 Consult with the AASHTO Roadside Design Guide and AASHTO Geometric Design of

219 Highways and Streets for roadway design and road geometry/geometric requirements (see

220 Appendix X1).

221   5.4.5 *Attainable Vehicle Speed on a Straight Path*—The highest attainable vehicle speed

222 results from a long, straight path between the starting point and a vehicle barrier.

223   5.4.5.1 *On a horizontal surface*—On a horizontal, straight path, the speed attainable by an

224 accelerating vehicle depends primarily on its initial speed, v_0, the acceleration, a, and the distance,

225 s, traveled during acceleration. The relationship among these parameters is given in Eq 1.

$$v = (v_0^2 + 2as)^{1/2} \tag{1}$$

227 Where:

228 v = Final vehicle speed (mph or kph),

229 v_0 = Initial vehicle speed (mph or kph),

230 a = Acceleration (ft/s^2 or m/s^2), and

231 s = Distance traveled (feet or metres).

232   (*1*) For convenience, Eq 1 is plotted as FIG 3 using a conversion factor for values in ft/s^2 and

233 mph.

234   (*2*) To illustrate its use, consider the case of a high-performance car accelerating on a 300-ft

235   (91.5-m), straight, horizontal path with initial speed, $v_0 = 25$ mph (15.53 kph) and acceleration, $a =$

236   11.3 ft/s^2 (3.4 m/s^2). The speed at the end of the path will be determined as follows:

237   (*a*) Locate $v_0 = 25$ mph (15.53 kph) on the vertical axis (Point A).

238   (*b*) Draw a horizontal line from Point A until it intersects the curve (at Point B) for $a = 11.3$ ft/s^2

239   (3.4 m/s^2).

240   (*c*) Draw a vertical line down from Point B until it intersects the horizontal axis (Point C). This

241   is the point from which velocity will be calculated.

242   (*d*) Locate Point D on the horizontal axis so that the distance between Points C and D is the

243   accelerating distance [300 ft (91.5 m) in this example].

244   (*e*) Draw a vertical line up from Point D until it intersects the curve (at Point E) for $a = 11.3$

245   ft/s^2 (3.4 m/s^2).

246   (*f*) Draw a horizontal line from Point E until it intersects the vertical axis (Point F).

247   (*g*) The value of the speed, v, at Point F, 61.5 mph (98.97 kph), is the answer.

248   **NOTE 1**—If $v_0 = 0$, the graph can be used to determine velocity from a dead start.

249   5.4.5.2 *On a slope*—Because of gravitational effect, to achieve the same final speed as that

250   on a horizontal path, the required distance for acceleration on a slope will be shorter (longer) if

251   the vehicle is traveling downhill (uphill). Let, s, be the acceleration distance needed to also attain

252   final speed, v, on a horizontal path, and let, s', be the acceleration distance needed to attain, v, on a

253   sloped path. The following relationship shown in Eq 2 applies:

254    $$s'/s = 1/[1 + (g/a)\sin\theta] \qquad \textbf{(2)}$$

255   Where:

256   s' = Acceleration distance needed to attain final speed on a sloped path,

257   s = Acceleration distance needed to attain final speed on a horizontal path,

258   g = Gravitational constant = 32.2 ft/s^2 (9.82 m/s^2),

259   a = Acceleration of the vehicle, ft/s^2 (m/s^2), and

260   θ = Angle between the slope and the horizontal in degrees.

261   (*1*) This correction factor relationship is plotted as FIG 4.

262   (2) To illustrate the use of FIG 4, consider the example used in 5.4.5.1, except the vehicle is

263   traveling downhill on a 5° slope. The steps are:

264   (*a*) Locate 5 degrees on the horizontal axis (Point A).

265   (*b*) Draw a vertical line up from Point A until it intersects the curve (at Point B) for $a = 11.3$ ft/s^2

266   (3.4 m/s^2).

267   (*c*) Draw a horizontal line from Point B toward the vertical axis and read off the s'/s value at the

268   intersecting Point C.

269   (*d*) The value of s'/s is 0.8. Because $s' = s \times (s'/s)$ and $s = 300$ ft (91.5 m), therefore $s' = 300$ ft

270   (91.5 m) × 0.8 = 240 ft (73.2 m).

271   (*3*) This example shows that to accelerate the vehicle to the same 61.5-mph (98.97-kph) speed,

272   a 5° slope will help shorten the accelerating distance from 300 ft (91.5 m) to 240 ft (73.2 m). It

273   clearly demonstrates the increased vulnerability caused by local terrain sloping down toward a

274   protected area. Modifying the local terrain is an effective way to minimize vulnerability.

275   5.4.6 *Attainable Vehicle Speed on a Curved Path*

276   5.4.6.1 Centrifugal force makes it difficult to drive fast on a curve unless the road surface is

277   properly banked. The centrifugal force, CF, of a vehicle moving on a curved path depends on its

278   weight, w, the radius of the curvature, r, the speed, v, and g = gravitational constant = 32.2 ft/sc^2 (9.82

279   m/s^2), as shown in Eq 3.

$$CF = wv^2/(gr) \qquad \textbf{(3)}$$

281   Where:

282   CF = centrifugal force (lb/kg),

283   w = vehicle weight (lb/kg),

284   r = radius of curvature (ft/m),

285   v = vehicle speed (mph/kph), and

286   g = gravitational constant = 32.2 ft/s^2 (9.82 m/s^2).

287   5.4.6.2 When the CF is large enough, it will overcome the road friction and a vehicle will skid.

288   The vehicle could also topple if its center of gravity is too high. Because skidding usually occurs

289   first, only this condition will be considered here. Road friction force, FF, equals the product of the

290   vehicle weight, w, and the friction coefficient, f, between the tires and the road surface, as shown in

291   Eq 4.

292     $$FF = fw \tag{4}$$

293   where:

294   FF = road friction force,

295   f = friction coefficient, and

296   w = vehicle weight.

297   **NOTE 2**—The value of friction coefficient, f, is between 0 and 1 and is highly variable. It

298   depends on the tire and its condition, the material and condition of the drive path, any oil or water

299   on the drive surface, and so forth. On a roadway, under normal conditions, $f = 0.6$ is usually used. If

300   unable to determine, use $f = 1$, which will provide a more conservative value.

301   (*1*) *On a horizontal surface*—The skidding speed (the speed at which skidding occurs), v_s, is

302   obtained by equating the centrifugal force and the road friction force, as shown in Eqs 5 and 6.

303     $$fw = w\, v_S^2/(gr) \tag{5}$$

304   Where:

305   f = friction coefficient,

306   w = vehicle,

307   v_s = weight skidding speed,

308   g = gravitational constant, and

309   r = radius of curvature.

310   (*a*) From which,

311
$$v_s = \sqrt{fgr} \tag{6}$$

312   Where:

313   v_s = skidding speed,

314   f = friction coefficient,

315   g = gravitational constant = 32.2 ft/s^2 (9.82 m/s^2), and

316   r = radius of curvature.

317   (*b*) Because v shall be made as small as possible for the most cost-effective protection, this

318   relationship suggests that options for the physical security planner include making the drive path

319   slippery, with a small radius of curvature, or both. The above relationship is plotted as FIG 5,

320   using f as a parameter using a conversion factor for values in ft and mph.

321   (*c*) Using FIG 5, with a chosen value of f (see **NOTE 2**) and the tolerable vehicle impact

322   speed of the selected barrier, a curved path can be designed to cause any vehicle driving above

323   that velocity to skid.

324   (*2*) *On a slope*—Unlike a straight downhill path (see 5.4.5), a curved downhill path is actually

325   effective in deterring vehicle attacks. This is because the extra velocity gained from traveling

326   downhill can easily cause the vehicle to skid or topple. Therefore, if a protected area has downhill

327   approach paths, the local terrain can be modified so that a straight driving path is impossible.

328 Caution should be exercised when designing roads to decrease velocity. Posting speed restrictions

329 along the path is strongly recommended to reduce the possibility of accidental skidding.

330 (*a*) To determine the final velocity at the end of a curved path, use the length of the curved

331 path as the acceleration distance in FIG 3 and as the acceleration distance needed to attain final

332 speed on a horizontal path (s) in FIG 3. Figure 4 can then be used to determine the velocity at

333 which the vehicle will skid.

334 5.4.7 *Attack Routes Parallel to the Barrier*

335 5.4.7.1 A reduction in energy transferred to a barrier can be accomplished by forcing a vehicle

336 to make an abrupt (short-radius) turn before impacting the barrier. Short-radius turns effectively

337 reduce vehicle speed by forcing the vehicle to slow down to avoid skidding, reducing the load

338 transfer if the impact angle is less than 90° to the barrier. Thus, the amount of energy that shall be

339 absorbed by a perimeter barrier depends on the impact angle, (see FIG 1, Perimeter Roads A and

340 B for a graphical representation of this angle of impact) and the final speed of the vehicle at

341 impact. The load transferred to the barrier is determined by the perpendicular component of the

342 velocity. By using FIGS 6 and 7, the impact angle directed toward the barrier, based on the offset

343 distance (distance between restricting barriers, that is, the distance between curbs or barriers that

344 will limit the available turning radius), can be determined. These figures are based on the

345 formulas provided in 5.4.6 and 5.4.7. Figures 6 and 7 show the impact angle versus speed for a

346 given offset distance for friction factors $f = 0.5$ and $f = 0.9$. The curves can be used to determine

347 the angle of impact, θ, knowing the values of the friction coefficient, f, speed at the start of the

348 turn, v, and the offset distance available.

349 5.4.7.2 Once the angle of impact is determined from FIGS 6 and 7, the speed component

350 perpendicular to the barrier, Vp, can be calculated using Eq 7, where $\sin\theta$ is the correction factor.

351 $$Vp = v \sin\theta \qquad (7)$$

Where:

Vp = speed component perpendicular to barrier,

v = speed at start of turn, and

θ = angle of impact.

5.4.7.3 For convenience, Table 1 provides a correction factor for Vp based on the speed of the vehicle at the beginning of the turn, the offset distance available for negotiating the turn, and a friction coefficient, $f = 1.0$ (the most conservative value). Thus, Vp is calculated by multiplying the initial speed of the vehicle by the correction factor from Table 1.

5.5 *Vehicle Kinetic Energy*

5.5.1 The kinetic energy of a moving vehicle is measured by its weight and speed, calculated as shown in Eq 8.

$$\text{KE (ft-lbf)} = 0.0334\ wv^2 \tag{8}$$

$$\text{KE (kgf-m)} = 0.0039\ wv^2$$

Where:

KE = kinetic energy in ft-lbs force (kgf-m),

w = vehicle total weight in lbs (kg), and

v = vehicle speed in mph (kph).

5.5.2 A vehicle shall have a certain amount of kinetic energy to penetrate perimeter security barriers. The vehicle shall penetrate these barriers to inflict damage on a protected facility. Since kinetic energy is a function of vehicle weight and speed, a heavy vehicle moving slowly and a lighter vehicle moving fast could have the same kinetic energy.

5.5.3 Kinetic energy for 4000- and 15 000-lb (1814- and 6804-kg) vehicles, traveling at various speeds, is shown in Table 2. Once the kinetic energy of the vehicle has been determined,

active and passive barriers that are capable of stopping the vehicle can be selected from the

information contained in Sections 6 and 7.

5.5.4 In some cases (with dead men, bollards, cabled concrete tee walls or chained vehicles,

and so forth) with some of these being unique expeditionary uses based on available material,

there may be a requirement for the design of system of barriers other than those listed herein. Those

cases may require the computation of an impact force to design that system. An impact force is a

high force or shock applied over a short time period. Since force is the product of mass times

acceleration for a mass, m, accelerating at an acceleration, then, assuming an ideal system, we can

set the impact force as mass times the difference in velocity for a time interval, dt. ($F = mXdv/dt$).

5.5.4.1 For example, a car that weighs 2.2 lb (1 kg) moving at 98 425 ft/min (500 m/s) and that

hits a "perfect" steel barrier where it uniformly decelerates from 98 425 to 0 ft/min (500 to 0 m/s) in

0.02 s, has an approximate impact force of 5620 lbf (25 000 N). Thus, a body, which decelerates

more quickly, has a greater effective impact force than one that decelerates more slowly.

6. Vehicle Barrier Selection, Design, and Installation

6.1 *Vehicle Barrier Types*—Vehicle barriers are categorized as either active or passive. Active

and passive barriers can be fixed or movable, depending on how they are made, operated, or used.

Some commercial barriers are dual classified when they meet the requirements for both categories

(for example, fixed-active, portable-passive, and so forth) There is no industry wide standard

terminology for vehicle barriers. For this practice, the definitions in 3.1 will be used.

6.2 *Design Considerations*—In addition to the calculation of the kinetic energy of a threat

vehicle described in Section 5, many factors shall be considered before selecting an appropriate

barrier system. UFC 4-022-01 is a required document for planning vehicle barrier design and

installation (see Appendix X1). An outline follows to serve as a checklist of key information that

398   is important to the facility planner, security professional, designer, user, and maintainer in the

399   design of barrier systems. Some of these issues are discussed in more detail following the outline.

400   6.2.1 *Design Basis Threat(s)*

401   6.2.1.1 *Attack vehicle(s)*

402   (*1*) Type,

403   (*2*) Weight,

404   (*3*) Maximum velocity,

405   (*4*) Contents, and

406   (*5*) Calculated kinetic energy.

407   6.2.1.2 *Points of attack*

408   6.2.1.3 *Path of attack(s)*

409   6.2.1.4 *Direction of attack(s)*

410   6.2.1.5 *Type of attack:*

411   (*1*) Single and

412   (*2*) Multiple vehicles.

413   6.2.1.6 *Country in which installation resides*

414   6.2.2 *Allowable Penetration beyond the Line of Barrier(s)*

415   6.2.3 *Sufficient Standoff Distance between Planned Barrier and Protected Structure*

416   6.2.4 *Existing or Desired Traffic Patterns*

417   6.2.4.1 *Levels of authorized traffic:*

418   (*1*) Peak levels and

419   (*2*) Average levels per day.

420   6.2.4.2 *Types of traffic:*

421   (*1*) Staff,

(*2*) Freight, and

(*3*) Visitors.

6.2.4.3 *Number of available traffic lanes:*

(*1*) One way only,

(*2*) Reversible, and

(*3*) Width and separation.

6.2.4.4 *Minimization of access points*

6.2.5 *Vehicle Barrier Operating Protocol(s)*

6.2.5.1 *Deploy and inspect*

(*1*) Maximum throughput rate:

- Per day and

- Per hour (peak).

6.2.5.2 *Threat dependent, local/remote option*

6.2.5.3 *Sally port interlock with other visual barriers*

6.2.5.4 *Automatic (emergency deployment)*

(*1*) Deployment signal source:

- Manual

- Velocity sensors

- Direction Sensors

- Other

(*2*) Minimum speed of deployment.

6.2.5.5 *Automatic (normal authorized traffic) vehicle identification means*

6.2.5.6 *Parade*

6.2.5.7 *Lockdown*

446   6.2.5.8 *Free flow*

447   6.2.6 *Site (Civil Engineering)*

448   6.2.6.1 Roadway layout:

449   (*1*) Number of lanes;

450   (*2*) Width;

451   (*3*) Flat/sloping/crowned;

452   (*4*) Islands, and so forth;

453   (*5*) Lane separator(s); and

454   (*6*) Boundary/passive barriers.

455   6.2.6.2 *Approaching or crossroad locations*

456   6.2.6.3 *Subsurface conditions*

457   6.2.6.4 *Berms*

458   6.2.6.5 *Landscaping*

459   6.2.6.6 *Buried utilities*

460   6.2.6.7 *Drainage*

461   6.2.6.8 *Frost line*

462   6.2.6.9 *Water-table height*

463   6.2.7 *Site (Facility Engineering)*

464   6.2.7.1 *Power distribution points*

465   6.2.7.2 *Communication lines:*

466   (*1*) Secure,

467   (*2*) Local,

468   (*3*) Existing network type, and

469   (*4*) Required network type (bus, ring, multiple rings, mesh, or combination).

470   6.2.7.3 *Drainage*

471   6.2.7.4 *Utility cabinets/equipment lockers*

472   6.2.7.5 *Lighting*

473   6.2.7.6 *Traffic signals/controls*

474   6.2.7.7 *Buried vehicle sensors*

475   6.2.8 *Site (General)*

476   6.2.8.1 *Environmental:*

477   (*1*) High/low temperatures,

478   (*2*) Rainfall,

479   (*3*) Snow,

480   (*4*) Frost line, and

481   (*5*) Other.

482   6.2.8.2 *Power sources*

483   (*1*) Location,

484   (*2*) Type:

485   •   Local and

486   •   Post-emergency backup, and

487   (3) Voltage/phase/frequency.

488   6.2.9 *Barrier Selection*

489   6.2.9.1 *DoS/DoD crash rating*

490   **NOTE 3**—Both the DoS and the DoD rate barriers based on full-scale crash tests conducted

491   by independent test laboratories or government-approved facilities. See U.S. Army Corps of

492   Engineers (USACE) Protective Design Center website for latest DoS and DoD certified barriers:

493   https://pdc.usace.army.mil/library/BarrierCertification/. The K in a rating refers to the kinetic

energy (KE) of the test vehicle at the moment of impact. A rating of K12, for example, indicates

KE of approximately 1 200 000 ft-lb (165 960 kg-m) of energy (15 000 lb at 50 mph [6818 kg at

80 kph]). A rating of K8 indicates 800 000 ft-lb (110 640 kg-m) of energy (15 000 lb at 40 mph

[6818 kg at 64 kph]) and K4 indicates 400 000 ft-lb (55 320 kg-m) of energy (15 000 lb at 30 mph

[6818 kg at 48 kph]). The L rating refers to the penetration of the vehicle beyond the front line of

the barrier. A rating of L3 indicates the truck penetrated less than 3.0 ft (0.9 m). A rating of L2

means penetration of less than 20.0 ft (6 m). L1 means the penetration was less than 50.0 ft (15

m).

6.2.9.2 *Active or passive*

6.2.9.3 *Temporary or permanent*

6.2.9.4 *Style of barrier(s):*

(*1*) Wedge, plate type (phalanx) (in ground/surface/shallow mount),

(*2*) Bollard,

(*3*) Rolling gate,

(*4*) Drop arm, and

(*5*) Transportable.

6.2.9.5 *Required aesthetics, if any*

6.2.9.6 *Flush mount barriers to road surface*

6.2.9.7 *Width of lane(s) to be protected*

6.2.9.8 *Number of lanes*

6.2.9.10 *Barriers to be operated:*

(*1*) Independently,

(*2*) Sets, and

(*3*) Sally port(s).

6.2.9.11 *Speed of operation:*

(*1*) Normal and

(*2*) Emergency.

6.2.9.12 *Number of operating cycles per barrier:*

(*1*) Per day and

(*2*) Per hour (peak).

6.2.9.13 *Available training from manufacturer*

6.2.9.14 *Availability of spare parts*

6.2.9.15 *Crash test results*

6.2.9.16 *Computer analysis results using BIRM 3D (PDC TR90-2)*

6.2.9.17 *Environmental protection:*

(*1*) Winterizing,

(*2*) Cooler (hydraulic power unit),

(*3*) Galvanizing, and

(*4*) Stainless steel.

6.2.9.18 *Barrier road surface:*

(*1*) Special texture and

(*2*) Excessive load (over 50000 lbs [22 680 kg]).

6.2.9.19 *Cost effectiveness*

6.2.10 *Foundation/Installation*

6.2.10.1 *Foundation restrictions:*

(*1*) Allowable depth of foundation extent of foundation allowable and

(*2*) Flush mount barrier system to road surface.

6.2.10.2 *Power source:*

542   (*1*) Distance from barrier line,

543   (*2*) Voltage/phase/frequency,

544   (*3*) Power available (watts), and

545   (*4*) Type of source.

546   6.2.10.3 *Location of enclosure for hydraulic power unit:*

547   (*1*) Existing building,

548   (*2*) Vault,

549   (*3*) Standalone, and

550   (*4*) Distance from barrier line.

551   6.2.10.4 *Drainage*

552   6.2.10.5 *Color*

553   6.2.10.6 *Special markings*

554   6.2.10.7 *Mounted lights*

555   6.2.10.8 *Equipment required to move barriers*

556   6.3 *Operating Systems Considerations*

557   6.3.1 *Control Circuits*

558   6.3.1.1 *Single barrier*

559   6.3.1.2 *Multiple barrier(s):*

560   (*1*) Local control(s),

561   (*2*) Local(s) with remote master(s),

562   (*3*) Remote empower and override, and

563   (*4*) Hand held.

564   6.3.1.3 *Sally port interlock*

565   6.3.1.4 *Master-to-slave interconnect:*

566   (*1*) Hard line,

567   (*2*) RF link, and

568   (*3*) Phone line and so forth.

569   6.3.1.5 *Remote/local status signal(s):*

570   (*1*) Status panel (visual indicators/audible):

571   • Barrier position (guard/open),

572   • Cycling, and

573   • Advance warning;

574   (*2*) Open beyond time-out; and

575   (*3*) Security level:

576   • Is there constant surveillance?

577   6.3.2 *Power-Off Operation*

578   6.3.2.1 *Hydraulic reserve/number of cycles*

579   6.3.2.2 *Control circuit/battery backup*

580   6.3.2.3 *Emergency standby power:*

581   (*1*) Dedicated and

582   (*2*) On site.

583   6.3.2.4 *Hydraulic hand pump*

584   6.3.3 *Power Failure Deployment:*

585   6.3.3.1 To full guard position and

586   6.3.3.2 To full open position.

587   6.3.4 *Warning/Safety Signs/Signals*

588   6.3.4.1 *Barrier closing/opening:*

589   (*1*) Lights,

590 (*2*) Horns, and

591 (*3*) Strobes and so forth.

592 6.3.4.2 Barrier in guard position:

593 (*1*) Lights,

594 (*2*) Horns, and

595 (*3*) Red traffic signal (steady/flashing).

596 6.3.4.3 *Barrier down and clear (yellow traffic signal)*

597 6.3.4.4 *Semaphore gate arms:*

598 (*1*) Gate arm synchronized with barriers interlocked:

599 • Gate down before barrier deployment and

600 • Barrier down before gate opening.

601 6.3.5 *Emergency Fast Operation (EFO)*

602 6.3.5.1 *Signal source:*

603 (*1*) Automatic sensors,

604 (*2*) Master(s)/slave panels(s), and

605 (*3*) Deploy barriers/speed.

606 6.3.5.2 *Lock Out:*

607 (*1*) Slave panels,

608 (*2*) Sub masters, and

609 (*3*) Automatic entrance controls.

610 6.3.5.3 *Deactivate (EFO):*

611 (*1*) *Signal source:*

612 (*a*) Local panel authority:

- Local guard

- Supervisor

  o Key switch

  o Personal identification number (PIN)

(*b*) Master panel authority/level

6.4 Some of these design and operating considerations, as well as other key issues, are

discussed in more detail in the following paragraphs.

6.4.1 *Fencing*

6.4.1.1 Fences should not be considered as protection against a moving vehicle attack. Most

fences can be easily penetrated by a moving vehicle and will resist impact only if reinforcement is

added. Fences are primarily used to:

(*1*) Provide a legal boundary by defining the outermost limit of a facility;

(*2*) Assist in controlling and screening authorized vehicle entries into a secured area by

deterring overt entry elsewhere along the boundary;

(*3*) Support detection, assessment, and other security functions by providing a "clear zone" for

installing lighting, intrusion detection equipment, and CCTV;

(*4*) Deter "casual" intruders from penetrating into a secured area by presenting a barrier that

requires an overt action to penetrate;

(*5*) Cause an intruder to make an overt action that will demonstrate intent; and

(*6*) Briefly delay penetration into a secured area or facility, thereby increasing the possibility

of detection.

6.4.1.2 In the field of security, perimeter barriers provide the first line of defense for a facility.

The true value of a perimeter security fence comes in its association with other components of a

security system. When perimeter security is required, the security fence forms the basic building

block for the rest of the system. UFC 4- 022-03 should be consulted for details on the use of

fencing in barrier systems (see Appendix X1).

6.4.2 *Location*—Active vehicle barriers can be located at facility entrances, enclave entry

points (gates), or selected interior locations (for example, entrances to restricted areas). Exact

locations may vary among installations; however, in each case, the barrier should be located as far

from the critical structure as practical to minimize damage due to possible explosion. Also, locate

support equipment (for example, hydraulic power, generator, batteries, and so forth) on the secure

side and away from guard posts to lower the threat of sabotage and injury to security personnel.

Passive barriers can be used at entry points if traffic flow is restricted or sporadic (that is, gates

that are rarely used). Passive barriers are normally used for perimeter protection. For more

information regarding the location of vehicle barriers, consult UFC 4-022-01 (see Appendix X1).

6.4.3 *Aesthetics*—The overall appearance of a vehicle barrier plays an important role in its

selection and acceptance. Many barriers are now made to blend in with the environment and be

aesthetically pleasing, minimizing a "fortress look."

6.4.4 *Safety*

6.4.4.1 An active vehicle barrier system is capable of inflicting serious injury. Even when

used for its intended purpose, it can kill or seriously injure individuals when activated

inadvertently, either by operator error or equipment malfunction. Warning signs, lights, bells, and

bright colors should be used to mark the presence of a barrier and make it visible to oncoming

traffic. These safety features shall always be provided to ensure personnel safety. The following

issues should be addressed to manufacturers and users to identify potential safety issues affecting

the selection of an active barrier system:

(*1*) Backup power;

(*2*) Emergency cutoff switch;

(*3*) Adequate lighting;

(*4*) Installation of safety options, such as alarms, strobes (or rotating beacons), and safety interlock detectors to prevent the barrier from being accidentally raised in front of or under an authorized vehicle; and

(*5*) *Army exception*—Installation of traffic safety schemes, that is, vehicle presence detection, vehicle platooning, and so forth as outlined in the "Standard Definitive Designs; Access Control Points for U.S. Army Installations" (see Appendix X1).

6.4.4.2 Once installed, vehicle barriers should be well marked and pedestrian traffic channeled away from the barrier system. For high-flow conditions, vehicle barriers are normally open (allowing vehicles to pass) and used only when a threat has been detected. In this case, the barrier shall be located far enough from the guard post to allow time to activate and close the barrier before the threat vehicle can reach it. For low-flow conditions, or where threat conditions are high, barriers are normally closed (stopping vehicle flow) and lowered only after authorization has been approved.

6.4.5 *Security*—Vehicle barriers shall be ready to function when needed. A potential for sabotage exists when barriers are left unattended or are located in remote or unsecured areas. For these installation conditions, tamper switches should be installed on all vehicle barrier access doors to controllers, emergency operation controls, and hydraulic systems. Tamper switches should be connected directly to a central alarm station so that security of the barrier system can be monitored on a continuous basis. Provide tamper-resistant screws at all controls and junction boxes.

6.4.6 *Reliability*—Many barrier systems have been in production long enough to develop an operations history under a variety of installation conditions. Reliability data from manufacturers

684 show less than a 3 % failure rate when these barriers are properly maintained. Some systems have

685 been placed in environments not known to the manufacturer, while others have developed

686 problems not anticipated by either the manufacturer or user. Most manufacturers will help resolve

687 problems that arise in their systems. Backup generators or manual override provisions are needed

688 to ensure continued operation of active vehicle barriers during power failure or equipment

689 malfunction. Spare parts and supplies should also be on hand to ensure that barriers are quickly

690 returned to full operation. If a high cycle rate is anticipated, or the environmental impact from

691 hydraulic fluid contamination is a concern, the selection of a pneumatic operating system is

692 recommended. Operate barrier system at least once every 24 h to assure performance for security

693 operations. Perform this operation at low-traffic period or before opening to traffic. Maintain log

694 of this operation.

695 6.4.7 *Maintainability*—Many manufacturers provide wiring and hydraulic diagrams,

696 maintenance schedules, and maintenance procedures for their systems. They should also have

697 spare parts available to keep barriers in continuous operation. The manufacturer should provide

698 barrier maintenance support in the form of training, operation manuals, and maintenance manuals.

699 Maintenance contracts are available from most manufacturers and are recommended to ensure

700 proper maintenance of the barrier and assurance that the barrier will function as intended.

701 Reliability and maintainability data are available from most manufacturers. Yearly maintenance

702 contracts are usually available from the manufacturer and should be included in the planning

703 process and budgeted. Maintenance contracts should include inspection, adjustment, cleaning,

704 pressure checks on hydraulic systems, and replacement of worn parts.

705 6.4.8 *Cost*—Traffic in restricted or sensitive areas should be minimized and the number of

706 access control points limited. Reducing traffic flow and the number of control points will increase

707 security and lower the overall cost of the system. Installation and operational costs are a

708 significant part of the overall cost of a barrier system and shall be addressed during the barrier

709 selection process. Complexity and lack of standardized components can result in high costs for

710 maintenance and create long, costly downtime periods. Reliability, availability, and

711 maintainability requirements on the system also affect costs. Annual maintenance needs to be

712 included in the cost of the system.

713   6.4.9 *Barrier Operations*—A barrier shall be capable of operating continuously with minimal

714 maintenance and downtime to satisfy security requirements properly. System failure modes shall

715 be evaluated to ensure that the barrier will fail in a predetermined position (open or closed) based

716 on security and operational considerations. Selecting a normally open (allowing access) or closed

717 (preventing access) option should be evaluated based on traffic flow conditions at the site (either

718 existing or expected) and the overall site security plan. Emergency operation systems (backup

719 generators or manual override systems) should be in place to operate the barrier in case of

720 breakdowns or power failure. Security personnel should be involved in the decision to deploy and

721 use a vehicle barrier system. If a normally open (allows traffic through) operation is selected,

722 there shall be sufficient distance between the guard and the vehicle barrier to allow for guard

723 reaction time to activate the barrier, barrier deployment time, and time required for selected safety

724 regimes. Certain barriers use locking pins (most notably crash-beam-type barriers) to lock down

725 the barrier. There have been incidents when controls were activated to raise the arm with locking

726 pins inserted causing damage to the beam portion of the barrier. Determine if the pin is required

727 for full performance of the barrier and inquire of the manufacturer if a sensor system is available

728 that detects the presence of the pin. Ensure training of personnel to verify pin status before

729 operation of crash beam barriers.

730   6.4.10 *Unobstructed Space*—Barriers installed in inner and outer security unobstructed space

731 shall be designed so they will not provide a protective shield or hiding place. Tall, continuous

732 barriers, such as planters, Jersey barriers, guardrails, and other similar passive vehicle barriers can

733 be a violation of mandated requirements, if installed in a designated unobstructed space.

734 Placement of any barriers near or within this unobstructed space shall be coordinated with the

735 activity security officer.

736   6.4.11 *Environment*—The environment shall be considered during the selection process.

737 Hinges, hydraulics, or surfaces with critical tolerances may require heaters to resist freezing

738 temperatures and ice buildup. They may also require protection from excessive heat, dirt,

739 humidity, saltwater, sand, high-water table, and debris. If options for protection against

740 environmental conditions are not available, the system may be unsuitable for a specific location.

741 Maintenance should be increased or compensating options (that is, sump pumps, heaters,

742 hydraulic fluid coolers, and so forth) or both selected for vehicle barriers subject to severe

743 environmental conditions to ensure acceptable operation. In cold regions and during winter

744 months, it is recommended to increase operation of the barrier system to cycle hydraulic fluids

745 through lines. See 6.4.6.

746   6.4.12 *Installation Requirements*—The vehicle barrier selected shall be compatible with the

747 available power source and other security equipment installed at the selected site, such as

748 perimeter intrusion detection and CCTVs designed to detect and assess covert penetration of the

749 perimeter. Power requirements can vary depending upon the manufacturer and location of the

750 installation.

751   6.4.13 *Facility Compatibility*—The chosen barrier system shall be compatible with other

752 security components in place at a site. For example, an active barrier system should not be

753 installed adjacent to an unhardened, chain-link fence because the fence then becomes the weakest

754 path. The cost and value of the active barrier as a preventive measure is then lost. Any decisions

755 on facility compatibility should be coordinated with UFC 4-022-01 (see Appendix X1).

6.4.14 *Operator Training*—Most manufacturers recommend operator training for active barrier systems. Operator training prevents serious injury and legal liability, as well as equipment damage caused by improper operations. If a manufacturer does not provide a thorough program for operator training, the user should develop a checklist for normal and emergency operating procedures.

6.4.15 *Options*—Manufacturers offer a number of optional features that can be added to the baseline systems. Some options enhance system performance, while others improve maintainability or safety. Options increase system cost and may also increase maintenance requirements. Selection of options depends on operational, safety, security, site, and environmental conditions. The manufacturers of certified DoS anti-ram vehicle barriers can be contacted to determine available options for specific vehicle barrier systems. These manufacturers can provide guidance on available options and will make recommendations that will enhance barrier operations.

6.4.16 *Operational Cycle*—The frequency of operation shall be considered in the selection process. Where traffic flow is light, a manually operated or removable passive system may work well at considerable savings. However, for high-traffic conditions (especially during peak hours), an automatically controlled system designed for repeated and fast open-and-close operations (pneumatic or hydraulic) would be more desirable. The use of one or more barriers at an entry point can also improve throughput.

6.4.17 *Methods of Access Control*

6.4.17.1 When selecting an active barrier, consider how vehicles will be allowed access. If a vehicle must be searched for explosives, a sally port design should be used that will trap the vehicle between two active barriers while it is being searched. This will prevent the vehicle from proceeding into the secured area before it has been searched and prevent escape (see FIG 2).

6.4.17.2 Access control can be accomplished with a staffed guard station or, remotely, using card or biometric access control devices that automatically activate the barrier (subject to random searches). The barrier can also be operated from a protected location other than the entry control point using CCTV and remote controls. Access control systems are available as options from vehicle barrier manufacturers (see manufacturer-specific website for additional information). Vehicle-sensing loops on the secure side of the vehicle barrier should always be included to prevent activation of the barrier until the vehicle has completely cleared the system. If card access control systems are used, procedures shall be included to prevent tailgating (authorized vehicle shall wait until the barrier has closed completely before proceeding).

6.4.18 *Cost Effectiveness*—Tradeoffs on protective measures may include:

6.4.18.1 Locating the vehicle barrier to provide optimum separation distance;

6.4.18.2 Slowing down vehicles approaching the barrier using obstructions or redesign of the access route;

6.4.18.3 Barrier open to permit access versus closed to prevent access;

6.4.18.4 Active versus passive barriers;

6.4.18.5 *System-activating options*—Manual versus automatic, local versus remote, and electrical versus hydraulic; and

6.4.18.6 Safety, reliability, availability, and maintainability characteristics.

6.4.19 *Liabilities*—Possible legal issues resulting from accidents (that is, deaths, injuries) and legal jurisdiction (that is, state, local, foreign country) shall be deliberated with the installation legal representatives when deciding to install an active vehicle barrier system.

6.5 *Additional Design Considerations*—The following actions are also to be considered when selecting and installing barrier systems.

803 6.5.1 If the location of a vehicle barrier is in an area of high water table, consider using a

804 surface mounted or shallow profile barrier system. Below-ground barriers can be installed if the

805 required installation depth is above the water table. If the excavation cannot be drained, water

806 collection could cause corrosion, and freezing weather may incapacitate the system.

807 6.5.2 When barriers are installed at entrance and exit gates, also consider installing passive

808 barrier systems along the remaining accessible perimeter of the protected area.

809 6.5.3 Protection of individual buildings or zones within the perimeter is generally more cost

810 effective than extensive protection of a large facility perimeter. For example, passive barriers

811 installed in areas in which vehicles cannot reach, just to complete a perimeter barrier system, are

812 not effective use of security funding.

813 6.5.4 Since most types of active barriers can be easily sabotaged, consider installing active

814 barriers only in areas where they can be under continuous observation.

815 6.5.5 Barriers should be used to divert traffic or prevent entry or exit. Installation of barriers

816 immediately adjacent to guard posts is not desirable because the possibility of injury should be

817 minimized. Consider keeping vehicle barriers as far from guard posts as possible.

818 6.5.6 Barriers should be installed on the exit side of an access control point as well as the

819 entrance.

820 6.5.7 Long, straight paths to a crash-resistant barrier can result in increased vehicle speed and

821 greater kinetic energy upon possible impact. When this cannot be avoided, installation of a

822 passive-type barrier maze should be considered to slow the vehicle.

823 6.5.8 Design passive barrier systems to comply the requirements of the DEPSECDEF

824 Memorandum, "Access for People with Disabilities" dated 31 Oct. 2008 (see Appendix X1). The

825 memorandum updates the DoD standards for making facilities accessible to people with

826 disabilities. The U.S. Access Board issued an update of the accessibility guidelines that the

827   DEPSECDEF Memorandum implements with military unique requirements specified in the

828   memorandum attachment called the Architectural Barriers Act (ABA) Accessibility Standard.

829   6.6 *Barrier Capability*

830   6.6.1 In general, vehicle-crash-resistant barriers should be considered at vehicle access points

831   to sensitive areas and enclaves. Active and passive barriers should be tested against specific

832   threats (vehicle weight and speed). Passive-barrier-only designs can be analyzed using finite

833   element analysis or computer programs specifically developed to analyze performance of vehicle

834   barriers. It is recommended that passive barriers be physically tested before being used. All active

835   barriers concepts are required to be physically tested in accordance with DoS/ASTM standards

836   before deployment. Supplemental gate and fencing reinforcements may also be needed to provide

837   the same level of protection.

838   6.6.2 The acceptable penetration distance will vary among installations depending on the

839   locations of the barriers relative to the assets to be protected. The appropriate penetration distance

840   for a given facility should be determined by the threat and risk assessments and physical security

841   survey results as indicated by the process outlined in UFC 4-020-01 and UFC 4-020-02. For an

842   illustration, refer to Example 1 in Appendix \1\D/1/ of this document.

843   6.6.3 In the example, the barrier system selected as a candidate barrier shall be capable of

844   stopping the vehicle and allowing little or no penetration. Sufficient standoff distance is not

845   available to protect Building 827 from the expected explosive-loading conditions. Possible

846   options would include moving the barriers further away from the target, closing the perimeter

847   roads to traffic, hardening Building 827 against increased blast-loading conditions, or accepting

848   additional risk to the structure.

849   6.6.4 For static perimeter barriers, note that weight alone will not prevent penetration. As

850   described in 7.2.2, concrete barriers used to protect against vehicle impact should be anchored to a

851   concrete foundation, if the impact angle is expected to exceed 30°.

852   6.7 *Vehicle Barrier Certification*

853   6.7.1 When the DoS published SD-STD-02.01, Revision A, the penetration distance of a

854   vehicle into a barrier was limited to 1 yd (1 m). The DoS list of certified barriers was developed

855   under Revision A and all barriers allowing penetration in excess of 1 yd (1 m) were removed from

856   the list. Most DoD components have sufficient standoff and can use barriers that allow penetration

857   distances in excess of 1 yd (1 m). Because of this and other needs, the requirement for a national

858   standard for crash testing of perimeters was established.

859   6.7.2 Test Method F2656 has been published and is being adopted by both DoD and DoS for

860   certification/approval of vehicle barriers. This test method includes more vehicle types and

861   differing penetration depths. The ASTM test vehicles, overall test protocol, instrumentation,

862   measurements, and report requirements are standardized to provide consistent procedures and

863   requirements for barrier manufacturers and accredited testing facilities.

864   6.7.3 Under Test Method F2656, barrier manufacturers are required to use an accredited

865   independent testing laboratory. Laboratory accreditation shall be done in accordance with

866   ISO/IEC 17025. Laboratories that are not ISO/IEC 1705 accredited but whose testing protocols

867   are accepted by a federal agency may also conduct tests for a period of one year after performing

868   the first test using Test Method F2656. However, it is unlikely that this acceptance will be

869   extended beyond those facilities that have previously been given permission to conduct tests in

870   accordance with the current DoS anti-ram vehicle barrier testing criteria. Without the federal

871   agency acceptance, the testing facilities will be required to complete accreditation beforee crash

872   testing of vehicle barriers under this ASTM test method.

873 6.7.4 The PDC will continue to maintain a list of approved anti-ram vehicle barriers for DoD.

874 Currently, DoS is maintaining their list as well. Barriers on either the DoS list or the DoD list are

875 approved for use on DoD projects. If a time comes when the DoS list is no longer kept, the PDC

876 will take the information from the DoS list and incorporate it into the DoD list to make it a

877 comprehensive list of barriers for DoD application. Note that not all DoD sites have standoff

878 suitable for barriers that allow more than 1 yd (1 m) of penetration. The list of DoD approved

879 anti-ram vehicle barriers and the DoS list of certified anti-ram vehicle barriers are available on the

880 PDC web site: https://pdc.usace.army.mil/library/BarrierCertification.

881 6.7.5 Any barrier that is on the current DoS-certified anti-ram vehicle barrier list may be used

882 by DoD, as well as any barriers listed on the current DoD approved anti-ram vehicle barrier list.

883 The DoD list includes information on permissible barrier widths as well as information on

884 penetration of the vehicle during the impact test. Barrier systems shall be installed in the "as

885 certified" condition. Only those widths contained in the DoS and DoD approved anti-ram barrier

886 lists are considered acceptable for DoD use.

887 **7. Active and Passive Barriers**

888 7.1 *Active Barrier Systems*

889 7.1 Commercially available active vehicle barrier systems are presented in this section as

890 generic representations. Inclusion of any equipment in this section does not constitute an

891 endorsement, nor is this a complete listing of vehicle barriers that are commercially available. The

892 equipment shown here is for illustration purposes only. Selection of a specific barrier should be

893 based on site conditions and results of the design, selection, and installation checklist provided in

894 Section 6. Results of this checklist can be used to establish cost, operational, performance, and

895 environmental requirements. The checklist results can also be used to select the optimum active

896 and passive barriers from those presented in this section. Users are advised to consult with

897   manufacturers on current and more detailed information regarding products and options

898   available.[7] Currently, barriers are being tested to be in conformance with Test Method F2656.

899   DoS and DoD are beginning to accept vehicle barriers systems tested in conformance with Test

900   Method F2656.

901   7.1.2 Barrier systems used shall be listed in either the DoS certified or DoD approved anti-ram

902   vehicle barrier lists. Barrier widths shall be "as certified/approved" on these lists. Alternatively, if

903   a barrier system's width is between the widths of two listed barrier systems that are identical

904   except for their widths, then that barrier system is also acceptable. Exceptions and acceptable

905   widths will only be taken from the DoD anti-ram vehicle barrier list. The design and structural

906   materials of the vehicle barrier furnished shall be the same as those used in the crash tested

907   barrier. Crash test shall have be performed and data compiled by an approved independent testing

908   agency in accordance with either Test Method F2656 or SD-STD-02.01. Barriers tested and

909   certified on the previous DoS standard, SD-STD02.01, April 1985, and listed on the DoD

910   approved anti-ram vehicle barrier list are also acceptable.

911   7.1.3 *Portable Vehicle Barriers*

912   7.1.3.1 *Description*

913   (*1*) The portable vehicle barrier shown in FIG 8 is a movable, self-contained, portable

914   roadway barrier referred to as the vehicle surface barrier system (Example 1). It can be controlled

915   as a manned checkpoint. Example standard equipment for this sample portable vehicle barrier is a

916   50-ft (15.2-m) cord attached to a control box. For unmanned control, options include either an

917   electric card reader or keypad. The self-contained hydraulic system is located in the curb panels

918   and sealed to prevent fluid leaks. The unit can be placed on any roadway or other flat surface

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[7] See U.S. Army Corps of Engineers (USACE), Protective Design Center, Omaha District (https://pdc.usace.army.mil/library/BarrierCertification for latest versions of DoS and DoD certified anti-ram vehicle barriers.

919 (with passive barriers installed to prevent bypass). Once the electricity is connected, the system is

920 operational. This barrier is best used for temporary installations in which high water table is a

921 concern or portability is a requirement. Contact the manufacturer for current cost information.

922 Example performance data are shown in Table 3 as Example 1.

923 (*2*) A second example of a portable barrier system is depicted in FIG 9. This portable high-

924 security anti-terrorist vehicle crash barrier can be towed into position by a medium-sized truck.

925 The barrier can be deployed in 15 min and can be operated either locally or remotely. The wheels

926 are stored on the side, and the vehicle ramps are folded out upon deployment. Its deployment,

927 retrieval, and operation are all hydraulic and push button controlled. The system can be equipped

928 with a battery operated power unit or a hydraulic power unit operated on a locally supplied power

929 or full manual system or combination. Example performance data are provided in Table 3 as

930 Example 2.

931 (*3*) Another portable barrier system (Example 3) is shown in FIG 10. This barrier is designed

932 to be rapidly deployed in an emergency situation and fully operational in 15 min. It can be towed

933 to a site by a truck then lowered into position using built-in jacks. The barrier can be an instant

934 road block and installed in areas where foundation work cannot be safely or quickly poured.

935 Stabilizers on the back side of the unit serve as additional reinforcement. The electrohydraulic

936 version of this barrier uses standard relay logic to allow control of the barrier with the supplied

937 push-button control station. Example performance data are provided in Table 3 as Example 3.

938 (*4*) A fourth example of a portable barrier system is illustrated in FIG 11. This maximum

939 security vehicle arrest barrier can be relocated and deployed in less than 20 min upon arriving at

940 its intended setup destination. The barrier does not require excavation and will not mark or

941 damage the road surface. Although it is normally operated manually, it can be supplied with a

hydraulic operating system. Example performance data are provided in Table 3 as Example 4.

7.1.3.2 *Testing*

(*1*) The vehicle surface barrier (Example 1) was tested by the Naval Facilities Engineering Command (NAVFAC), Naval Facilities Engineering Service Center (NFESC) at a vehicle barrier test bed in China Lake, California. Upon impact, the cab of a 15 200-lb (6909-kg) truck, moving at 50.5 mph (81 kph), was crushed. The portable vehicle barrier, with the truck on top, slid 9.2 ft (2.8 m).

(*2*) Both the Examples 2 and 3 portable barrier systems have been certified by DoS as Level K4/L1 barriers. They will stop and disable a 15 000-lb (6818-kg) truck moving at 30 mph (48 kph). The manufacturers can provide crash test data.

(*3*) The Example 4 portable barrier system has several versions. The version depicted in FIG 11 has been crash certified by DoS as K12/L2. It will stop a 15 000-lb (6818-kg) truck traveling at 50 mph (80 kph). Specific crash test data can be obtained from the manufacturer.

7.1.4 *High-Security Barricade System*

7.1.4.1 *Description*—The high-security barricade systems, shown in FIGS 12 and 13, are self-contained, hydraulically or pneumatically operated units that, depending on the model, rise to various heights. These barriers are intended for high-speed impact conditions. Models are available for site conditions in which shallow foundations are required. Performance data for an example system are shown in Table 4.

7.1.4.2 *Testing*—Numerous manufacturers now produce DoS-certified high-security barriers that have been formally crash-tested.[7] The manufacturers should provide crash data for DoS-certified models. An example model was tested by Sandia National Laboratories with a 6000-lb (2727-kg) vehicle, traveling at 50 mph (80 kph), that penetrated the barrier 27 ft (8.2 m) and an 18 000-lb (8182-kg) vehicle, traveling at 30 mph (48 kph), that penetrated 29 ft (8.8 m). Another

model was tested by the Southwest Research Institute for the DoS using a 15 000-lb (6818-kg)

vehicle, traveling at 50 mph (80 kph), that penetrated less than 3 ft (0.9 m). A manufacturer tested

a third model, using a 15 000-lb (6818-kg) vehicle, traveling at 50 mph (80 kph), that penetrated

less than 3 ft (0.9 m).

7.1.5 *Bollard System*

7.1.5.1 *Description*

(*1*) Numerous manufacturers now produce DoS-certified bollard systems that have been

formally crash tested.[7] The manufacturers should provide crash data for DoS certified models.

The example bollards shown in FIG 14 are 10-in. (25.4-cm) diameter steel bollards that are 30 in.

(0.76 m) high. They can be lifted into position either manually [60-lb (27-kg) pull] or

hydraulically. The compact size and ease of operation make this system particularly well suited as

either a standalone or a backup to existing pedestrian gates in the single-post configuration. They

can also be used to secure wide entrances when the cost for installing larger systems becomes

prohibitive. Flush mount top of bollard system to surrounding pavement is required.

(*2*) Hydraulically operated bollards can be operated individually or in sets, with up to 24

bollards controlled from a single hydraulic power unit. Typical performance data are shown in

Table 5.

(*3*) See 6.5.8 for handicap accessibility requirements.

7.1.5.2 *Testing*—Sandia National Laboratories tested an example model with a 15 180-lb

(6900-kg) vehicle at 32 mph (51 kph) penetrating the barrier 12.2 ft (3.7 m). An example model

was tested by the NFESC and DoS with a 10 000-lb (4545-kg) vehicle at 40 mph (64 kph) that

failed to penetrate the barrier.

7.1.6 *Crash Beam Barrier System*

7.1.6.1 *Description*

(*1*) Numerous manufacturers now produce DoS-certified crash beam barrier systems that have been formally crash-tested.[7] The manufacturers should provide crash data for DoS-certified models. Crash beam barrier systems, such as the one shown in FIG 15, are cable-reinforced, manually or hydraulically operated, bollard-mounted barriers.

(*2*) The beam is counterbalanced and lifts at one end to allow vehicle access. This system is frequently used for low-impact conditions (when vehicle speed can be limited) and as the interior barrier (after a primary high impact barrier) for vehicle inspection areas or sally ports. Typical performance data for an example barrier are shown in Table 6. See 6.4.9 for specific operation requirements for crash beam systems.

7.1.6.2 *Testing*—The example crash beam barrier has been tested by the NFESC at the China Lake test facility. A 10 000-lb (4545-kg) vehicle at 17 mph (27 kph) impacted the sample barrier and rebounded. There is now a K12 certified crash beam barrier system available as well.

7.1.7 *Crash Gate System*

7.17.1 *Description*—A crash gate system, such as the example system illustrated in FIG 16 is a sliding gate that offers pedestrian access and resistance to heavy vehicle impact. The example system is electromechanically operated with a 30- to 100-ft/min (9- to 30-m/min) sliding speed (instantly reversible). Safety infrared sensors and front edge obstacle sensors are standard features. A tested manual version of a crash gate is also available. Gate systems are normally used where aesthetics is an issue or a wide opening is required [up to 25-ft (7.6 m) clear opening]. Most systems can be used for both portable and permanent construction. Typical performance data are shown in Table 7.

7.1.7.2 *Testing*—Three tests have been conducted on the example crash gate system by the NFESC, in conjunction with DoS, using vehicles weighing approximately 15 000 lbs (6818 kg).

1013   At speeds of 34 and 40 mph (55 and 65 kph), the vehicle did not penetrate the sliding gate. At 55

1014   mph (89 kph), the vehicle penetrated the sliding gate 5.5 ft (1.7 m).

1015   7.1.8 *Ground Retractable Automobile Barrier (GRAB)*

1016   7.1.8.1 *Description*—A GRAB is an attenuating device designed to span a roadway or traffic

1017   lane to bring an encroaching vehicle to a controlled stop and prevent its passage. An example

1018   system consists of a steel anchor post at each end, four hydraulic energy absorbers, and a

1019   cable/net assembly. The anchor posts are made from two sections of A36 steel pipe—a fixed 25-

1020   mm thick inner pipe with a 305-mm outer diameter and a 19-mm thick, 381-mm outer diameter

1021   outer pipe—free to rotate around the anchor post. Reusable hydraulic cylinders are set between

1022   the anchor posts and the net (two at each end). The net consists of upper and lower 19-mm

1023   diameter extra high-strength (EHS) wire strands, with a 16-mm diameter wire rope in the center

1024   and 16-mm diameter wire rope woven up and down along the width of the net and attached to the

1025   top, middle, and bottom cables with clamps.

1026   7.1.8.2 *Testing*—The example GRAB was tested to the National Highway Research Program

1027   (NCHRP) Report 350 test Level 2, with both the 1800-lb (820-kg) car and the 4400-lb (2000-kg)

1028   truck impacting at the third point of the net at a nominal speed of 45 mph (70 km/h). Both

1029   vehicles were stopped smoothly with no significant roll, pitch, or yaw. The maximum dynamic

1030   deflection of the example GRAB was 20.7 ft (6.3 m) with the car and 21.7 ft (6.6 m) with the

1031   truck.

1032   7.1.9 *Maximum Security Barrier (MSB)*

1033   7.1.9.1 *Description*

1034   (*1*) The MSB vehicle barrier (see example in FIG 17) is a hydraulically operated barrier, 31 in.

1035   (79 cm) high by 14 ft (4.3 m) wide. It has a fully electronic, programmable controller that

1036   provides a range of functions. Multiple barriers can be controlled from a single hydraulic power

1037 system. Typical models can be moved without roadway rebuilding. Installation can be completed

1038 in 24 h by bolting the barriers to the roadway. Some specific models are certified by DoS.

1039 (*2*) This type of barrier can also be an underground, flush-mounted barrier, as shown in FIG

1040 18. Most MSB models are similar in construction and operation, varying only in the height of the

1041 barrier and surface foundation pad construction. Typical performance data are shown in Table 8.

1042 (*3*) The MSB also is available as a surface-mounted barrier with a gate arm. It has been crash

1043 tested by the manufacturer, however they are not DoS certified. This system is frequently used for

1044 low-impact conditions (when vehicle speed can be limited) and as the inside barrier (after a

1045 primary high-impact barrier) for vehicle inspection areas or sally ports. Typical performance data

1046 are shown in Table 8.

1047 7.1.9.2 *Testing*—The Example 1 barrier was tested by NFESC in conjunction with DoS. A 14

1048 980-lb (6809-kg) vehicle at 50.3 mph (81 kph) failed to penetrate.

1049 7.2 *Passive Barrier Systems*—The following is a compilation of passive vehicle barrier

1050 systems used at DoD facilities. Included are generic systems that can be constructed with the aid

1051 of self-help manuals using standard and locally available materials. Some of the systems have not

1052 been formally tested but should inflict substantial damage on a vehicle if impacted. A

1053 consolidated list of passive barriers, kinetic energy, and penetration data is provided in Appendix

1054 X1. See 6.5.8 for handicap accessibility requirements.

1055 7.2.1 *Concrete-Filled Bollard*

1056 7.2.1.1 *Description*—Passive steel bollards can be constructed locally and are an effective

1057 means of enhancing security against vehicular bomb attacks. Approved bollards are constructed of

1058 structural steel pipe filled with concrete. The steel pipe should have a minimum outside diameter

1059 of 8-in. (20-cm), 1/2-in. (1.2-cm) wall, and be a minimum of 7 ft (2.1 m) in length. The bollards

1060 should extend 3 ft (0.9 m) above the ground level from a continuous footing with minimum width

1061 of 2 ft (0.6 m), as shown in FIGS 19 and 20. The bollards should be positioned 3 ft (0.9 m) ft

1062 apart on center (see example layout in FIGS 20 and 21). Bollards should never be placed on the

1063 un-secure side (outside) of a fence where they can be used as a climbing aid.

1064 7.2.2 *Concrete Median*

1065 7.2.2.1 *Description*—A concrete highway median (also known as a Jersey bounce or Jersey

1066 barrier) can be effectively used as a perimeter vehicle barrier but only if the medians are securely

1067 fastened together. It can either be erected from precast tongue-and-groove sections or cast in place

1068 with special concrete-forming equipment. It is especially effective for impact angles less than 30°

1069 and is appropriate for locations where access roads are parallel to the barrier. Complete

1070 penetration is possible with light vehicles; however, damage to the vehicle will be extensive. If

1071 the potential impact angle from threat vehicle is expected to exceed 30°, anchor the barrier to the

1072 foundation. These barriers should be set in a concrete foundation, as shown in FIG 22. Also,

1073 barriers need to be securely connected with a minimum of one ¾-in. (2-cm) steel cable tying them

1074 together to be effective.

1075 7.2.2.2 *Testing*—A non-reinforced, anchored, concrete median barrier was tested with a 4000-

1076 lb (1818- kg) vehicle at 50 mph (81 kph). The vehicle penetrated the barrier 20 ft (6 m). The

1077 vehicle had extensive front-end damage, and the occupants would have received serious to critical

1078 injuries. During the impact, a section of the barrier was broken and overturned. These barriers

1079 should be set in a concrete foundation, as shown in FIG 22, for applications in which the impact

1080 angle exceeds 30°. The barriers need to be securely tied together to be effective.

1081 7.2.3 *King Tut Blocks*

1082 7.2.3.1 *Description*—Non-reinforced concrete blocks can be used effectively as vehicle

1083 barriers or to slow the speed of oncoming vehicles as shown in FIG 23. The placement of the

1084 blocks is shown in Table 9. These blocks can be cast in place and should be anchored to the

1085   ground so that movement or removal is difficult. Both FIG 23 and Table 9 are for passenger

1086   vehicles only. If trucks are considered, the ability to control POV speeds is lost. Thus, POV and

1087   truck traffic shall be separated for optimum serpentine use.

1088   7.2.3.2 *Testing*—No formal crash testing has been conducted; however, the mass of this type

1089   of concrete construction should perform at least as well as a concrete median (FIG 22).

1090   7.2.4 *Concrete Planter*

1091   7.2.4.1 *Description*—A concrete planter barrier (FIG 24) offers permanent protection from

1092   vehicle penetration and can also be aesthetically pleasing.

1093   7.2.4.2 *Testing*—This barrier was tested with a 15 000-lb (6818-kg) vehicle traveling at 47 mph

1094   (75.6 km/h). The vehicle did not penetrate the barrier. The planter is DoS K12 certified.

1095   7.2.5 *Excavations and Ditches*

1096   7.2.5.1 Ditches offer a simple method of rapidly securing a lengthy perimeter against a

1097   moving vehicle tactic. They can function as permanent anti-vehicle barriers if the required ditch

1098   profile is well maintained, or they can provide a temporary barrier before another permanent

1099   vehicle barrier system is installed. The ditch profile, including the approach slope, is critical to its

1100   ability to function as a vehicle barrier.

1101   7.2.5.2 There are two vehicle attack methods against a ditch: (1) a slow covert attack in which

1102   the vehicle attempts to cross the ditch by approaching at a oblique angle almost parallel to the

1103   ditch and going down and then up along the profile of the ditch and (2) a fast attack in which the

1104   vehicle approaches perpendicular to the ditch at high speed and attempts to jump the ditch. In the

1105   latter case, the flexibility in the vehicle suspension system and inertia of the vehicle can allow the

1106   front wheels to roll over the far edge of the ditch even if they do not fully clear the ditch. Also,

1107   ditches are vulnerable to coordinated attacks in which the ditch profile is modified in the initial

1108   attack and then a moving vehicle attack is mounted across the ditch before it can be repaired.

7.2.5.3 Soil berms adjacent to the protected side of the ditch provide additional resistance to vehicle attack, but they also can make the ditch a more effective hiding place for attackers on foot. This negative aspect of berms is less significant when there are elevated observation positions near the ditch. Soil berms and placement of spoil from ditch excavation on the attack side of the ditch should not be used because they provide a ramp effect, or launch angle over the ditch for a fast vehicle attack, increasing the capability of a vehicle to jump the ditch.

7.2.5.4 Numerous profiles for anti-vehicular ditches have been proposed in previous DoD documents that were based on ditches used primarily to slow tank attacks. These profiles were not tested against simulated moving terrorist vehicle bombs until recently when similar ditches were tested in the United Kingdom. The following conclusions were determined from the United Kingdom tests:

(*1*) Asymmetric V-shaped ditches with an inclined angle greater than 65° and a total width and depth equal or greater than 16.4 and 4 ft (5 and 1.2 m), respectively, were able to stop the test vehicle.

(*2*) The approach terrain on the attack side of the ditch should not have any incline or spoil and preferably should have a slight decline.

(*3*) Ditches will stop a fast vehicle attack provided the vehicle drops more than 75 % of its wheel diameter in the space provided.

(*4*) Trapezoidal ditches should be avoided in general because of a concern that a vehicle can drive in and out of the ditch in a slow attack.

7.2.5.5 The United Kingdom tests were not part of a comprehensive design project for anti-vehicular ditches that allowed the ditch profile to be optimized based on both resistance to moving vehicle attack and practical construction considerations. A study by NAVFAC was conducted to use observations from the United Kingdom tests, simple analyses of moving vehicle trajectories

over various ditch profiles, and a survey of large commercial vehicle geometry information to design the three anti-vehicular ditches shown in FIGS 25-27. In all three figures, the protected side of the ditch is on the left.

7.2.5.6 Trajectory simulations of medium-sized suburban utility vehicles (SUVs)[7] at velocities up to 50 mph (81 km/h) showed that the vehicle impact angle relative to the inclined slope on the far side of the ditch was at least 43° for all the ditch profiles in FIGS 25-27.

7.2.5.7 The trajectory simulations were based on a simple physics derivation that ignored air resistance and specific vehicle geometry characteristics. In Figure 28, a trajectory analysis in which the approach angle at impact for the vehicle at 50 mph (81 km/h) is 43° is shown. This approach angle is sufficient to prevent the front bumper from clearing the top edge of ditch for a range of commercial utility vehicles including Jeeps, Land Rovers, SUVs, and Hummers (except a Hummer 1) based on a limited survey of the geometry of these vehicles by NAVFAC Atlantic. This survey also indicated that a 42° side slope or greater was sufficient to cause all the surveyed vehicles to tip if they were trying to cross the ditch at an oblique angle in a covert attack.

7.2.5.8 Most vehicle surveys focused on the lower bumper reference line height of the vehicles, which affects the maximum approach impact angle that could allow a vehicle to clear the ditch, and the maximum side slope angle. The approach angle and lower bumper reference line are illustrated in FIG 29 from the International Organization of Motor Vehicle Manufacturer's (OICA). Based on a limited survey of SUVs by the OICA, the lower bumper reference height ranged from 13.4 to 19.7 in. (340 to 500 mm). This information was used with a survey of SUV vehicle specifications to determine maximum vehicle approach angles and side slope angles shown in FIGS 25-27. The side slope in Table 10 is the transverse angle the vehicle can be at without tipping over.

7.2.5.9 The berms in FIGS 25 and 26 are essentially safety factors and they are recommended given the approximations in the analyses used to design the ditch profiles. The profile in FIG 25 provides the highest amount of resistance against a moving vehicle threat, but it requires a stabilized slope, such as concrete riprap or sandbag cover, since natural soil cannot maintain a 45° slope. The profile in FIG 26 provides less resistance against a moving vehicle threat, but sandy soil can theoretically maintain a 34° slope. Finally, the profile in FIG 27 is similar to FIG 26 except that it does not have the additional safety factor of a berm for stopping a moving vehicle threat. As mentioned previously, the berm may be considered unacceptable because it may provide a potential hiding place for attackers on foot. The declined approach slope helps to some effect to offset the reduced resistance to a moving vehicle threat caused by deletion of the berm.

7.2.6 *Guardrails*

7.2.6.1 *Description*

(*1*) Standard highway guardrails or median barriers can be used as perimeter vehicle barriers (FIG 30). Guardrail design procedures can be found in the AASHTO Roadside Design Guide, , AASHTO Geometric Design of Highways and Streets, and in many state DOT standard drawings. Guardrails are normally designed to redirect vehicles approaching at angles less than or equal to 25° and are not recommended as perimeter vehicle barrier for approach angles greater than 25°.

(*2*) A cable guardrail (AASHTO Type G1) consists of three $^3/_4$-in. (2-cm) diameter steel cables, spaced 3 in. (7.6 cm) apart. The posts used are S3 × 5.7 steel, spaced at 16-ft (5-m) intervals. The height, measured from the surface to the top rail, is 30 in. (76 cm). From the end post, all three cables are turned down at a 45° angle and anchored to buried concrete deadmen.

(*3*) A W-beam flexible guardrail (AASHTO Type G2) consists of a 12-gauge "W" section bolted to S3 × 5.7 steel posts, spaced at 12-ft 6-in. (3.7-m 15-cm) intervals. A blocked-out W beam (AASHTO Type G4) guardrail system uses a 12-gauge "W" section bolted to W6 × 8.5

1180 posts, spaced at 6-ft 3-in. (2-m 7.6-cm) intervals. The AASHTO Guide for Selecting, Locating

1181 and Designing Traffic Barriers provides four-post and blocking alternatives for this guardrail

1182 system. A thrie beam (AASHTO Type G9) guardrail system consists of a steel thrie beam bolted

1183 to W6 × 8.5 steel posts at 6-ft 3-in. (2-m 7.6-cm) intervals.

1184   (*4*) A box-beam guardrail (AASHTO Type G3) system consists of a 6- by 6- by 0.180-in. (15-

1185 by 15- by 0.5-cm) steel tube bolted to S3 × 5.7 steel posts, spaced at 6-ft 4-in. (2-m 10-cm)

1186 intervals.

1187   7.2.6.2 *Testing*—The cable guardrail system successfully redirected both low profile 3500-lb

1188 (1587-kg) vehicles and a 4100-lb (1850-kg) van, as well as other 4000-lb (1814-kg) vehicles,

1189 during testing for impact angles of 25° or less. Tests of the W beam system resulted in redirection

1190 of a vehicle with an impact angle of 25°, but the redirected vehicle was airborne for a distance of

1191 50 ft (15 m). During testing of the blocked-out W beam system, the barrier successfully redirected

1192 low-profile vehicles with impact angles of equal to or less than 25°. This system caused several

1193 vans and other vehicles with high centers of gravity to overturn after impact. Tests of the thrie

1194 beam system provided a smooth redirection of vehicles when the impact angle was 25° or less.

1195 The box beam guardrail system tested provided excellent redirection of the vehicle.

1196   7.2.7 *Heavy Equipment Tires*

1197   7.2.7.1 *Description*—Heavy equipment tires, half-buried in the ground and tamped to hold

1198 them rigid, can be effective vehicle barriers (FIG 31). Use tires that are 7 to 8 ft (2.1 to 2.4 m) in

1199 diameter. Heavy equipment tires can usually be obtained locally from salvage operations for the

1200 cost of hauling them away.

1201   7.2.7.2 *Testing*—Buried equipment tires were tested using a 3350-lb (1523-kg) vehicle

1202 traveling at 51 mph (82 kph). The vehicle penetrated the barrier 1 ft (0.3 m). The tires used were

1203 36 ply, 8 ft (2.4 m) in diameter, and weighed 2000 lbs (909 kg) each.

1204   7.2.8 *Tire Shredders*

1205   7.2.8.1 *Description*—Tire shredders can be either surface mounted or imbedded as shown in

1206 FIG 32.These devices are normally used for traffic control purposes and are designed to slow or

1207 stop a vehicle by deflating their pneumatic tires. These units are available from a number of

1208 commercial manufacturers. Delta Scientific Corporation manufactures the unit shown in FIG 32.

1209 When a vehicle drives over the mechanism in the wrong direction, the spikes penetrate the tire

1210 casing, which quickly deflates the tires, making the vehicle difficult to operate for extended

1211 periods. These systems should not be considered vehicle barriers. Tire shredders are not

1212 recommended where vehicle traffic drives over these devices at speeds exceeding 5 mph (8 km/h).

1213 These systems may also not be effective against modern "run flat" tires, heavy-duty truck tires, or

1214 extra-wide tires that can bridge over two or more spikes. Tire shredders have a very limited

1215 capability to stop a vehicle.

1216   7.2.8.2 *Testing*—These systems have not been formally tested and, as indicated in 7.2.8.1, are

1217 not considered a vehicle barrier.

1218   7.2.9 *Steel Cable Barriers*

1219   7.2.9.1 *Description*—As shown in FIG 33, there are several configurations for steel cable

1220 barriers. Site requirements, configuration, and environment shall be carefully considered before

1221 selecting a cable system for a particular application.

1222   7.2.9.2 *Testing*—Systems such as those shown in Fig 33 have not been formally tested.

1223 However, two 3/4-in. (1.9-cm) diameter cables attached to a 200-ft (61-m) section of fence, minus

1224 fabric, with deadman anchors at both ends were tested with a 4000-lb (1818-kg) vehicle at 52 mph

1225 (84 kph). The vehicle was stopped within 13 ft (4 m) and then pushed back to the impact point.

1226 For additional considerations, details, and design guidance relating to the use of steel cables in

1227 fencing and gates, refer to UFC 4-022-03.

1228   7.2.10 *Steel-Cable-Reinforced Chain-Link Fencing*

1229   7.2.10.1 *Description*—Without some reinforcement, a standard chain-link fence can be

1230   penetrated easily by a light vehicle with little or no damage. However, standard fencing can be

1231   reinforced to provide a cost-effective method to protect against the threat of penetration by light

1232   vehicles, as in FIGS 33 and 34. Although no required pre-tension is specified for the cable, it is

1233   generally considered acceptable that it should be snug and not have significant sag. Routine

1234   (usually daily) perimeter inspection should include checking for visible sagging. At this time,

1235   there is no specific sag measurement benchmark, so checking for "visible" sag is a conservative

1236   approach. Regularly scheduled inspections should also check for corrosion of fittings, including

1237   the turnbuckles, anchor bolts, U-bolts, any swaged fittings, and cable clamps. Cable clamps

1238   should be inspected as well to insure no nuts have become loose. For additional considerations,

1239   details, and design guidance relating to the reinforcing of fencing and gates, refer to UFC 4-022-

1240   03.

1241   7.2.10.2 *Testing*—Sandia National Laboratories tested a barrier consisting of a chain-link

1242   fence reinforced with a 3/4-in. (1.9-cm) cable. In this test, a 3350-lb (1523-kg) vehicle traveling at

1243   23.5 mph (38 kph) penetrated the barrier 7 ft (2.1 m). A 4050-lb (1841-kg) vehicle, traveling at

1244   50.6 mph (82 kph), penetrated 26 ft (7.9 m), and the cable failed at the impact location. A test

1245   using two cables with no fabric was impacted by a 4000-lb (1814-kg) vehicle, traveling at 52 mph

1246   (84 kph), and the vehicle penetrated 13 ft (4 m) and then pushed back to the original fence line.

1247   Engineering analysis of various cable restraint configurations, using the BIRM computer model

1248   (PDC-TR90-2), is shown in Table 11.

1249   7.2.11 *Reinforced Concrete Knee Walls*

1250   7.2.11.1 *Description*—When a perimeter wall or fence line needs to also serve as a vehicle

1251   barrier, it shall meet passive vehicle barrier standards. This can be achieved by using a reinforced

1252 concrete knee wall structure. A knee wall barrier is a wall resting on a footing. The entire footing

1253 and part of the wall are imbedded in the existing soil or in a crushed stone mix. Figures 35-37

1254 show representative cross sections of this type of barrier.

1255   7.2.11.2 *Testing*—Reinforced concrete knee walls have been formally tested. A configuration

1256 similar to FIG 35 was tested with a 15 000-lb (6818-kg) vehicle traveling at 50 mph (80 kph). The

1257 wall effectively stopped the attack vehicle within 3.28 ft (1 m).

1258   7.2.12 *Plastic Barrier Systems*

1259   7.2.12.1 *Description*—Plastic barrier systems (FIG 38) are available from several

1260 manufacturers.[7] They are molded in a configuration similar to the Jersey bounce or barrier shown

1261 in FIG 22. These barriers weigh approximately 130 lbs (59 kg) empty and 1600 to 1800 lbs (726

1262 to 816 kg) when filled with water. The units are made from polyethylene plastic and come in 6-ft

1263 (2-m) sections that are easily transported. An interlocking section and steel pipe are used to link

1264 the sections together. Linking the sections is strongly recommended to provide added resistance to

1265 vehicle impact and reduce lateral movement. Surface mounting of these units limits their use as

1266 effective vehicle barriers, except for low-speed impacts [less than 15 mph (24 km/h)] and angles

1267 less than 25°.

1268   7.2.12.2 *Testing*—Example plastic barriers, filled with sand, have been crash tested, as

1269 described in X3.1.

1270   7.2.13 *Expedient Barrier Systems*

1271   7.2.13.1 When barrier systems are required quickly with no time for ordering manufactured

1272 barriers, common construction items or available construction vehicles can be used as barriers.

1273 Materials such as large-diameter concrete and steel pipes can form makeshift barriers. Even large

1274 construction vehicles (for example, dump trucks and earth-moving equipment) that have heavy

1275 mass and size can be used, or modified for use, as expedient barrier systems. Some examples are:

1276   (*1*) Sections of 3-ft (0.9-m) large-diameter, corrugated metal or reinforced concrete pipe can

1277   be placed on end and filled with sand or earth.

1278   (*2)* Steel pipe can be stacked and welded together in a pyramid.

1279   (*3*) Construction vehicles can be anchored together with cable or chain.

1280   7.2.13.2 These expedient measures can provide effective protection against vehicle-ramming

1281   attacks. Because no testing has been done on these systems, it is important that these barriers be

1282   stabilized and anchored to prevent displacement by a threat vehicle.

1283   7.3 *Vehicle Barrier Performance*

1284   7.3.1 Full-scale testing of vehicle barrier systems is only one way to obtain information on the

1285   performance capabilities of vehicle barriers. Testing provides evidence that the selected barrier

1286   will effectively absorb the impact of a threat vehicle. Tests may be conducted by independent

1287   testing laboratories, government agencies, or the manufacturer. Some tests are properly

1288   documented or witnessed by authorities or both while others are not. Only tests conducted by

1289   independent laboratories or government agencies should be accepted.

1290   7.3.2 It is important to interpret the test results correctly. For example, "full penetration" could

1291   mean that the vehicle passed through a barrier and was still capable of movement after penetration

1292   or it could mean the vehicle payload penetrated through a barricade, but the vehicle was

1293   incapacitated. Whenever possible, carefully review the actual test report before selecting a barrier

1294   system. For commercially available active barriers, these reports are usually accessible from the

1295   manufacturer. Such review may not always be possible

1296   7.3.3 Selection of vehicle barriers can also be based on engineering analysis. Finite-element

1297   analysis and computer models specifically designed to analyze barrier impact, such as the Barrier

1298   Impact Response Model 3 Dimension, have been successfully used and correlated to actual test

1299   results. Using this method is much more cost-effective than full-scale testing. Before accepting

1300   the results of an engineering analysis from a manufacturer, have the calculations carefully

1301   checked by a qualified structural engineer.

1302   **8. Keywords**

1303   8.1 barrier system; vehicle barrier; vehicle counter-mobility barrier

1304
1305   **APPENDIXES**
1306   **(Nonmandatory Information)**
1307

1308   **X1. REFERENCES**

1309   **X1.1** Copies of many of the documents referenced in this practice can be obtained from the

1310   following websites:

1311   X1.1.1 Whole Building Design Guide website

1312   http://www.wbdg.org/references/padod.php (See service-specific information on the right

1313   hand side of the website.)

1314   X1.1.2 United States Army Corps of Engineers (USACE), Protective Design Center, Omaha

1315   District https:/pdc.usace.army.mil/library/drawings/acp

1316   AASHTO Geometric Design of Highways and Streets

1317   AASHTO Guide for Selecting, Locating and Designing Traffic Barriers

1318   AASHTO Roadside Design Guide

1319   Army Regulation (AR) 190-13, *Army Physical Security Program*

1320   DEPSECDEF Memorandum are located at http://www.accessboard.gov/ada%2daba/aba-

1321   standards-dod.cfm

1322   DOD 2000.12 *DOD Antiterrorism (AT) Program*

1323   DOD 2000.16 *DOD Antiterrorism Standards*

1324   DOD 5200.8-R *Physical Security Program*

1325 MCO P5530.14A *Marine Corps Physical Security Program Manual*

1326 Means, R. S., *Building Construction Cost Data,* 61st Edition, 2003, http://www.rsmeans.com

1327 PDC-TR90-2, *BIRM 3D–Barrier Impact Response Model 3 Dimension*

1328 Standard Definitive Designs; Access Control Points for U.S. Army Installations

1329 UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, Tri-Service Engineering

1330 Senior Executive Panel, http://dod.wbdg.org/

1331 UFC 4-010-02, *DoD Minimum Antiterrorism Standoff Distances for Buildings*, Tri-

1332 Service Engineering Senior Executive Panel, http://dod.wbdg.org/

1333 UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*, Tri-Service Engineering

1334 Senior Executive Panel, http://dod.wbdg.org/

1335 UFC 4-020-02, *Security Engineering Facilities Design Manual*

1336 UFC 4-020-02FA, *Security Engineering: Concept Design*, Tri-Service Engineering Senior

1337 Executive Panel, http://dod.wbdg.org/

1338 UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points*,

1339 Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/

1340 UFC 4-022-03, *Security Engineering: Fences, Gates and Guard Facilities*

1341 UFGS 34 71 13.19, *Unified Facilities Guide Specification, Active Vehicle Barriers,*

1342 http://dod.wbdg.org/

1343 UFGS 12 93 00, *Unified Facilities Guide Specification, Site Furnishings,* http://dod.wbdg.org/

1344 UG-2031-SHR *User's Guide: Protection Against Terrorist Vehicle Bombs*

1345 UFC 4- 022-03, *Security Engineering: Fences, Gates and Guard Facilities*

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1347

1348

X2. BARRIER COST DATA[8]

X2.1 Scope—This appendix presents rating and cost data for commercial vehicle barriers and cost data for passive barriers. The information contained herein is intended for informational purposes only.

X2.2 Nongovernment Publication

X2.2.1 Means, R. S., "Building Construction Cost Data", 65th Edition, 2007.

X2.3 Definitions—The definitions in section 3 of this practice apply to this appendix.

X2.4 Active Barriers

X2.4.1 *DoS Ratings for Active Barriers*—The ratings are explained in Table X2.1.

X2.4.2 Cost Data for Active Barriers—Table X2.2 contains cost data for active vehicles.

X2.3 **Cost Data for Passive Barriers**—Table X2.3 is a summary of cost data for selected passive vehicle barriers.

X3. PERFORMANCE DATA FOR PASSIVE VEHICLE BARRIERS

X3.1 Scope—This appendix presents performance data for commercial vehicle barriers and passive barriers. The information contained herein is intended for guidance only.

X3.2 Definitions—The definitions in Section 3 of this practice apply to this appendix.

X3.3 Passive Barriers—Table X3.1 is a summary of performance data for selected passive barriers.

X4. EXAMPLES FOR PROTECTION AGAINST TERRORIST VEHICLE BOMBS

X4.1 Scope—This appendix contains examples for determining the design of vehicle barrier systems. The information contained herein is intended for informational purposes only.

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[8] See U.S. Army Corps of Engineers (USACE), Protective Design Center, Omaha District (https://pdc.usace.army.mil/library/BarrierCertification) for latest versions of DoS and DoD certified/rated anti-ram vehicle barriers.

X4.2 Nongovernment Publications

X4.2.1 Means, R.S., "Building Construction Cost Data", 65th Edition, 2007.

X4.3 Definitions—The definitions in Section 3 of this practice apply to this appendix.

X4.4 Examples

X4.4.1 *Example 1*

X4.4.1.1 Administrative Building 827 (FIG X4.1) shall be protected against a terrorist vehicle bomb. The structure is a single-story, reinforced-concrete building. The following factors apply:

(*1*) A high threat level is considered. The design basis threat has been established as a moving vehicle with a gross weight of 15 000 lbs (6818 kg), including 1100 lbs (500 kg) of explosives, traveling at 50 mph (80 kph). This combination of vehicle size and speed will develop 1253 ft-lbf (173 kgf-m) of energy on impact (Table 2).

(*2*) Assume an asset value of 0.8 for Building 827. For a moving vehicle bomb as described X4.4.1.1, this corresponds to a medium level of protection, according to UFC 4-020-01. The damage to the building will be repairable. No permanent deformation will occur in primary structural members.

(*3*) For a medium level of protection, some injury from debris is anticipated, but serious injury or death is unlikely.

X4.4.1.2 Referring to FIG X4.1, the lines of approach are perimeter roads on the north and west sides of the building. Perimeter passive barriers and an active barrier on the west entrance to the facility will be required. A candidate active vehicle barrier system might be one of the example systems described in Table 4. For the perimeter fence, a candidate passive barrier could be the bollard system shown in FIG 8.

X4.4.1.3 Using UFC 4-020-01, the required standoff distance for a minimal level of damage to the building from 1100 lbs (500 kg) of explosives is 310 ft (95 m). Because there is about 320 ft

(97 m) available for standoff at the location closest to the perimeter (at Building 700), a medium level of protection can be secured. In this case, the asset value and high threat level indicate some injury is allowable, and minor damage to the structure is acceptable.

X4.4.1.4 Based on the performance characteristics of the example barrier system, the penetration distance of the design threat vehicle is 27 ft (8 m). Adding this distance to the distance required for mitigating the explosive effects, the total standoff distance between the barrier and the building should be at least 337 ft (103 m). Because this standoff distance is not available for Building 827 under current site conditions, the next step would be facility hardening or the acceptance of more damage to the structure.

X4.4.1.5 Passive barriers along the fence line should be designed to allow little or no penetration; the available standoff distance is already at the marginal level to protect personnel against death and injury. Selection of the concrete-filled bollard system (FIG 10) will provide adequate penetration resistance, because the approach is parallel to the barrier (77 % of the impact load from Table 1).

X4.4.2 *Example 2*

X4.4.2.1 Referring to FIG X4.1, the target buildings in this case are 796 and 798. Perimeter Road "B" has a 60-ft (18-m) offset (distance from the barrier to the restricting opposite curb). Using Table 1, a vehicle traveling at 50 mph (80 kph) can safely turn on a maximum 167-ft (51-m) radius curve without skidding. At this speed and angle of approach to the barrier, the vehicle will strike the barrier at an angle. Because of the angle of impact (Table 1), the speed directed at the barrier is 76.6 % of the 50-mph (80-kph) speed or 38 mph (61 m). Using Table 2 and rounding up to the next highest speed [40 mph (64 kph)], the kinetic energy transferred to the barrier will be 214 000 ft-lbf (29 kgf-m) if the design basis threat is a moving 4000-lb (1818-kg) vehicle and 919 200 ft-lbf (111 kgf-m) if the design basis threat is a moving 15 000-lb (6818-kg) vehicle.

NOTE X4.1—Incorporate reduction as a result of the angle of impact after calculation of kinetic energy.

X4.4.2.2 Once the kinetic energy has been calculated, refer to footnote 8 for a listing of passive barriers and penetration distances that can be used to select the most effective barrier. Anchored Jersey barriers could be used for the threat of a moving 4000-lb (1818-kg) vehicle, and a bollard system or concrete planter would be the only passive barriers that would be capable of stopping a 15 000-lb (6818-kg) vehicle. For the larger threat, it would be appropriate to install concrete blocks as shown in FIG 23 and space them in accordance with the information from Table 9 to reduce the vehicle speed to 30 mph (48 kph) or less.

X5. VEHICLE BARRIER DEBRIS MINIMIZATION AND EFFECTS ON COUNTER-MOBILITY

X5.1 GENERAL—Barriers are widely used in entry control facilities/access control points (ECF/ACP) and as perimeter boundaries to control traffic effectively. They can be successful in preventing entry of a suspected vehicle bomb into an installation; however, barriers may not prevent detonation of the bomb at the ECF/ACP. The barriers typically used in ECF/ACPs are designed to resist vehicle impact loads, not blast loads. The blast loading of a barrier wall can result in breakup of the barrier and subsequent throw of debris toward the facility being protected by the barrier. This debris has the potential of being thrown great distances depending on the explosive quantity in the vehicle bomb. The debris can range in size from small, penetrating pieces to whole barrier sections, presenting a significant hazard to personnel, and possibly structures, near the detonation site. Control of this debris, as well as control of traffic, should be considered when selecting and installing a barrier system.

X5.2 Barrier Response to Explosive Load Testing

X5.2.1 A large test program, Barrier Assessment for Safe Standoff (BASS), was conducted in 2001 for the USAF Force Protection Battlelab (FPB). Full-scale ECF/ACP vehicle barriers were subjected to detonations of bare explosives. The primary objectives of the effort were to analyze the secondary debris hazard for typical reinforced concrete ECF/ACP vehicle barriers and identify barrier modifications that would minimize or eliminate this debris hazard.

X5.2.2 Twelve barrier tests were conducted, with two barriers used per test. Various barrier, charge weight, and standoff distance configurations were tested. The tested barriers included:

X5.2.2.1 Jersey,

X5.2.2.2 Jersey with soil revetment,

X5.2.2.3 Bitburg,

X5.2.2.4 Bitburg with soil revetment,

X5.2.2.5 Jersey with polymer liner applied,

X5.2.2.6 Cellular Jersey with polymer liner applied,

X5.2.2.7 Jersey with rock/gravel fill revetment,

X5.2.2.8 Back-to-back Bitburgs,

X5.2.2.9 Texas, and

X5.2.2.10 Plastic, sand-filled barrier.

X5.2.3 Data collection included barrier debris pickup in designated areas behind each barrier, high-speed video of debris flight to aid in measuring debris velocities, documentation of the barrier response to the blast load, and free-field pressure measurements at specific locations in the debris fields.

X5.2.4 Based on the barrier debris collected and analyzed in this study, some barrier systems are more effective than others at reducing the potential secondary debris hazard from a vehicle

bomb detonating at an ECF/ACP. The addition of a soil revetment to common barrier

configurations significantly reduces debris hazards. Depending on the amount of explosives and

the standoff distance from the barrier to the charge, the barriers with a soil revetment either do not

break up or the debris is thrown considerably lesser distances than the same barrier configuration

without soil revetment. A rock/gravel revetment presents only a slightly worse hazard than a soil

revetment, if only the throw of the barrier debris is considered. Maximum debris distances

measured from tests with Jersey reinforced concrete barriers backed by a rock/gravel revetment

exceeded debris distances measured in tests of Jersey barriers backed by a soil revetment by less

than 20 %. Note, however, that debris from the rock/gravel revetment could also be thrown and

could cause damage (such as window breakage) to buildings within the installation.

X5.2.5 The polymer liner applied to a Jersey barrier does not offer any improvement to the

debris hazard from a Jersey barrier. Lightweight concrete and sand-filled plastic barriers produce

significantly reduced debris hazards. This may seem attractive in selecting a barrier system to

minimize barrier debris throw upon detonation of a vehicle bomb. However, subsequent counter-

mobility testing of these barriers showed failure in stopping the vehicle and preventing access

through an ECF/ACP, making them undesirable for use at an ECF/ACP.

X5.2.6 The tests also showed that the vehicle-to-barrier standoff used at an ECF/ACP is

equally important. Generally, using terminology from UFC 4-022-01, this standoff distance refers

to the distance between the access control zone (inspection site) and the final debris barriers in the

response zone. The larger 35-ft (10.7-m) standoff decreased debris hazards for all barrier systems

tested. It was recommended that the standoff distances be increased from 10 to 35 ft (3.05 to 10.7

m) at ECF/ACPs, where possible. It is recognized that a vehicle could potentially move through

the access control zone without stopping and through the response zone to impact a barrier. If the

vehicle bomb detonates while in direct contact with the barrier, the debris throw is obviously

1491 greater than if the bomb detonates 10 or 35 ft (3.05 or 10.7 m) away from the barrier. The use of

1492 low-debris barriers in this case is even more attractive.

1493 **X5.3 Low-Debris Barrier Counter-Mobility Evaluation**

1494 X5.3.1 Barriers qualified as low-debris-producing barriers when exposed to detonations of

1495 typical vehicle bombs do not necessarily meet counter-mobility criteria. Barriers that have been

1496 proven to minimize, or eliminate, debris hazards from an explosive threat shall still be validated

1497 for entry control capabilities. Both detonation response and counter-mobility issues should be

1498 addressed when selecting a barrier system for a particular base function, such as in an ECF/ACP.

1499 X5.3.2 For instance, the lightweight concrete and sand-filled plastic barriers proven to be low-

1500 debris barriers in the 2001 BASS tests did not perform well in subsequent crash tests. The Barriers

1501 for Reduced-debris and Counter-mobility Effects (BRACE) test program involved testing of these

1502 barrier types for counter-mobility. A baseline performance test was first conducted on a line of ten

1503 standard, reinforced concrete Jersey barriers tied together with steel cables. A 15 000-lb (6820-kg)

1504 truck impacted the center of the line of barriers at 30 mph (48 kph). While the line of Jersey

1505 barriers successfully stopped the vehicle, neither the lightweight concrete nor the sand-filled

1506 plastic barrier was able to stop the vehicle. Two new low-debris vehicle barrier concepts were

1507 later devised and tested in another FPB-funded test series, Vehicle Impact Performance

1508 Evaluation of Reduced-debris, Counter-mobility Barriers (VIPER-CB).

1509 X5.3.3 The low-debris barriers tested in the later program were Hesco bastion concertainers

1510 (typically used as perimeter barriers and to provide ballistic and fragment protection) and a

1511 modification of the lightweight concrete Jersey barrier with polymer coating. The lightweight

1512 concrete, polymer-coated barriers and the steel gate successfully defeated the threat of a 15 000-lb

1513 (6820-kg) truck traveling at 30 mph (48 kph). The depth of penetration of the truck was 16 ft (4.9

1514 m) for the lightweight concrete, polymer-coated barriers. The Hesco bastion concertainers were

tested with a 15 000-lb (6820-kg) truck traveling at 50 mph (80 kph). The concertainers

successfully stopped the truck in approximately 5 ft (1.5 m), with no penetration of the payload.

Contact Hesco for proper configuration tested as indicated above.

X5.3.4 The recommendations from the tests described in this section are to use both low-debris, counter-mobility barriers (Hesco bastion and lightweight concrete, polymer-coated barriers). The low-debris systems adequately protect against the standard threat of a 15 000-lb (6820-kg) vehicle impacting at 30 mph (48 kph). The Hesco bastion barriers do not require any anchoring. They are simply stacked in layers. To defeat the standard threat above, two rows of barriers on the bottom with a staggered row of barriers on top are sufficient, as shown in FIG X5.1. Concrete anchors to existing thick roadways or specially placed foundations should be used with the polymer-coated, lightweight concrete barrier system.

X5.3.5 In FIG X5.2, the cabling and anchor system used to test this system are shown. For the test, the polymer-coated, lightweight concrete Jersey barriers were placed in a line and connected with three 1-in. (2.5-cm) steel cables, as shown in FIG X5.2. The cable was 1-in. (2.5-cm) diameter, 6×36 extra improved plow steel, with independent wire rope center. A 4-ft (1-m) long loop was created in the cables at the right end of the line of barriers. The purpose of this loop is to allow some slack in the cable; this reduces the peak tensile force but allows additional penetration of the truck. Steel shackles were used to connect the cables to the anchor plate and 1-in. (2.5-cm) cable clips at a 6-in. (15-cm) spacing were used to tie the ends of the cables. For this example, the barrier anchoring system was designed to meet a load of 75 000 lb (34 020 kg) of force in each cable. Anchoring for a similar barrier system should at least meet the same anchoring requirement.

X5.4 Restoration of Damaged Barriers

X5.4.1 Another critical consideration in selection of vehicle barriers for use in an ECF/ACP or other perimeter protection is the amount of time required to restore the barrier system to 100 % capability after it has been damaged by exposure to a vehicle bomb detonation. Some barriers can be fully restored to their original protection capability within minutes after the removal of the vehicle debris. Other barrier types may take months to repair and restore to 100 %.

X5.4.2 Restoration time depends on the type of barrier, whether or not it has a revetment, the size of the vehicle bomb, and the standoff distance between the bomb and the barrier at the time of detonation. Concrete barriers exposed to low design basis threats will have minimal breakup and may just topple over or be slightly displaced. In such a case, the barriers could be reused and re-anchored back into the barrier system. Other barrier types may need to be completely replaced with new barriers. If a revetment was being used, it will have to be rebuilt when the barriers are replaced. Estimates of time required to restore the barrier system to 100 % capability is critical information to consider in vehicle barrier selection.

TABLE 1 Speed Correction Factor for a Vehicle Traveling Parallel to Barrier (Based on Friction Coefficient = 1.0)

Speed of Vehicle in mph (kph) →	20 (32)	30 (48)	40 (64)	50 (80)	60 (97)	70 (113)	80 (129)
Max. Radius of Curve at f = 1.0 ft (m)→	27 (8)	60 (18)	107 (33)	167 (51)	240 (73)	327 (100)	427 (56)
Offset Distance in ft (m) ↓							
10 (3.1)	0.616	0.559	0.438	0.342	0.292	0.242	0.208
20 (6.2)	0.966	0.743	0.588	0.470	0.407	0.342	0.309
30 (9.3)	1.0	0.866	0.707	0.547	0.485	0.423	0.375
40 (12.4)	1.0	0.946	0.788	0.656	0.559	0.470	0.423
50 (15.3)	1.0	0.988	0.848	0.707	0.616	0.545	0.470
60 (18.3)	1.0	1.0	0.899	0.766	0.656	0.588	0.515
70 (21.4)	1.0	1.0	0.940	0.809	0.707	0.629	0.545
80 (24.4)	1.0	1.0	0.966	0.867	0.743	0.656	0.574

TABLE 2 Kinetic Energy Developed by Vehicle, ft-lbf (kgf-m) × 1000

Vehicle Weight in lbs (kg) ↓	Speed of Vehicle in mph (kph)						
	10 (16)	20 (32)	30 (48)	40 (64)	50 (80)	60 (97)	70 (113)
4000-lb (1818 kg) Vehicle	13 (2)	53 (7)	120 (17)	214 (29)	334 (46)	481 (66)	655 (90)
15 000-lb (6818 kg) Vehicle	50 (7)	200 (28)	451 (62)	802 (111)	1253 (173)	1804 (249)	2455 (339)

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TABLE 3 Performance Data for Portable Vehicle Barriers

	Example 1[A]	Example 2[A]	Example 3[A]	Example 4[A]
Height, in. (cm)	30 (76)			31 (78.7)
Width, in. (cm)	96 (244)		144 (366)	144 (366)
Normal operating cycle (seconds)	3	10 - 15	15	3 - 5
Emergency operating cycle (seconds)	1			
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	1.2 (0.16)			1.2 (0.16)

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1575   [A] DoS certified.

1576

1577   **TABLE 4 Performance Data for Example High-Security Barricade System**

	Example System[A]	Example Flush-Mounted System[A]
Height, in. (cm)	38 (96)	36 (91)
Width, in. (cm)	84 to 144 (213 to 366)	144 (366)
Normal operating cycle (seconds)	3 to 15	3 to 15
Emergency operating cycle (seconds)	<1.5	<1.5
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	0.12 (0.16)	0.12 (0.16)
Kinetic energy rating by engineering analysis, ft-lbf(kgf-m) × 1 000 000 (destruction of vehicle with some damage to barrier)	0.40 (0.55)	0.32 (0.44)

1578

1579   [A] DoS certified.

1580

1581

TABLE 5 Performance Data for Example Bollard System

	Example [A]
Height, in. (cm)	30 (76)
Width, in. (cm)	10 (25) at 2 ft (0.6 m) on center
Normal operating cycle (seconds)	3 to 15
Emergency operating cycle (seconds)	<1.5
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	0.445 (0.06)
Kinetic energy rating by engineering analysis, ft-lbf(kgf-m) × 1 000 000 (destruction of vehicle with some damage to barrier)	1.9 (0.26)

1582

1583   [A] DoS certified.

1584

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1586   **TABLE 6 Performance Data for Cable-Reinforced Crash Beams**

	Example Model
Height, in. (cm)	30 (76) to 36 (91)
Length, in. (cm)	120 (305) to 240 (610) Note 1
Normal operating cycle (seconds)	8 to 15
Emergency operating cycle (seconds)	Not available
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	0.0965 (0.013)
1. Contact vendor to verify length and performance of barrier tested.	

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TABLE 7 Performance Data for Example Linear Crash Gate

	Example System [A]
Height, in. (cm)	108 (274)
Length, in. (cm)	144 (365) to 300 (762)
Normal operating cycle [ft (m) per minute]	30 (9) to 100 (30)
Emergency operating cycle (seconds)	Not applicable
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	1.2 (0.16)

1592

1593 [A] DoS certified.

1594

1595

TABLE 8 Performance Data for MSB Vehicle Barriers

	Example 1 [A]	Example 2 [A]
Height, in. (cm)	31 (79)	33 (84)
Width, in. (cm)	168 (427) 10 ft (3 m) clear	168 (427) 10 ft (3 m) clear
Normal operating cycle (seconds)	3 to 5	3 to 5
Emergency operating cycle (seconds)	1	1
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) × 1 000 000	1.2 (0.16)	1.2 (0.16)

1596

1597 [A] Not DoS certified.

1598

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1601

TABLE 9 Separation Distance (D)[A] for Barriers to Reduce Speed on a Straight Path in Ft (m)

Achievable Speed of Vehicle on a Curve in mph (kph)	20 (32)	30 (48)	40 (64)	50 (80)	60 (97)
Road Width in ft (m)					
20 (6.1)	28 (8.5)	43 (13.1)	58 (17.7)	73 (22.2)	87 (26.5)
30 (9.1)	40 (12.2)	63 (19.2)	86 (26.2)	108 (32.9)	130 (39.6)
40 (12.2)	47 (14.3)	77 (23.5)	106 (32.3)	134 (40.8)	161 (49.1)
50 (15.2)	51 (15.5)	87 (26.5)	122 (37.2)	155 (47.2)	187 (57.0)
60 (18.3)	54 (16.5)	96 (29.3)	135 (41.1)	172 (52.4)	209 (63.7)

[A] Based on $f = 1.0$.

TABLE 10 Maximum Vehicle Approach Angles and Side Slope Angles

Vehicle	Maximum Approach Angle (degrees)	Maximum Side Slope Angle (degrees)
Jeep Liberty	38.1	
Jeep Commander	34	
Hummer H3	39.4	
Hummer H1	72	40
Hummer H2	41	40
Land Rover LR3	37	35
Toyota FJ Cruiser	34	41
Land Rover Range Rover	34	
Jeep Grand Cherokee	34	
Mercedes G-Class	36	28.4
Toyota 4 Runner	31	

TABLE 11 Performance of Cable Restraint Systems

Cable Barrier with 200-ft (61-m) Anchorage Spacing	Kinetic Energy in ft-lbf × 1000 (kgf-m)	Penetration in ft (m)
1 Cable at 3/4-in. (2–cm) dia.	10 (13.8)	4 (12.2)
2 Cables at 3/4-in. (2–cm) dia.	20 (27.6)	4 (12.2)
3 Cables at 3/4-in. (2–cm) dia.	33 (46.7)	4 (12.2)
4 Cables at 3/4-in. (2–cm) dia.	41 (57.8)	4 (12.2)
1 Cable at 1-in. (2.5-cm) dia.	15 (20.7)	4 (12.2)
2 Cables at 1-in. (2.5-cm) dia.	34 (47.0)	4 (12.2)
3 Cables at 1-in. (2.5-cm) dia.	50 (70.0)	4 (12.2)
4 Cables at 1-in. (2.5-cm) dia.	70 6 (97.6)	4 0 (12.2)

1609

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TABLE X2.1 DoS Ratings[A]

DoS Rating	Speed of Vehicle At Impact in mph (kph)	Kinetic Energy	Max. Allowable Penetration of Vehicle
K12	50 mph (81 kph)	1 250 000 ft-lbf (178 812 kgf-m)	
K8	40 mph (64 kph)	800 000 ft-lbf (110 600 kgf-m)	
K4	30 mph (48 kph)	450 000 ft-lbf (62 212 kgf-m)	
L3			3 ft (0.91 m)
L2			3 to 20 ft (0.91 to 6.1 m)
L1			20 to 50 ft (6.1 to 15.2 m)

1612

1613   [A] Based on 15 000-lb (6818-kg) vehicle weight.

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TABLE X2.2 Manufacturer's Data and Cost for Certified Active Barriers

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($ × 1000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (s)	Emergency Cycle (s)
SLIDING GATE Active, Fixed, Gate	K4 – K12	***	***	12	108	10 to 15	7 to 10
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	36	2 to 15	1
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	39	4 to 5	1
SLIDING GATE Active, Fixed, Gate	K12	35 to 45	125	12	108	27 to 48 FPM	
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	39	3 to 15	2
RETRACTABLE BOLLARDS Active, Bollard	K8	27 to 37	125	1.06 dia.	39	3 to 15	1.5
RETRACTABLE BOLLARDS Active, Bollard	K12	29 to 39	118	1.06 dia.	35	3 to 15	1.5
RETRACTABLE BOLLARDS Active, Bollard	K4	25 to 35	133	0.55 dia.	30	3 to 15	1.5

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1621

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($ × 1000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (s)	Emergency Cycle (s)
SHALLOW MOUNT HYDRAULIC WEDGE Active, Fixed, Barricade	K12	20 to 40	70	#	44	4 to 6	1
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	20 to 40	75	#	32	4 to 6	1
RETRACTABLE BOLLARDS Active, Bollard	K4	15 to 20	75	#	30	4 to 6	1
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	13	60	14	31	3	1
SURFACE MOUNTED HYDRAULIC WEDGE SINGLE BUTTRESS Active, Fixed, Barricade	K12	24	35	14	33	3	1
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	18	60	14	31	3	1
RETRACTABLE BOLLARD Active, Fixed, Bollard	K12	43.2	50-75	# (3 bollards)			
HYDRAULIC DROP ARM Active, Fixed, Barricade	K4	22.7	40	#	39	3	

1622

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($ × 1000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (s)	Emergency Cycle (s)
NET BASED NON-HYDRAULIC SINGLE LANE Active, Fixed, Barricade	K8	47.9	Included in cost	#	55-58	2	1.5
NET BASED NON-HYRAULIC MULTIPLE LANE Active, Fixed, Barricade	K8	59.4	Included in cost	36	55-58	2	1.5
NET BASED NON-HYRAULIC MULTIPLE LANE Active, Fixed, Barricade	K12	95.5	Included in cost	36	55-58	2	1.5
RETRACTABLE BOLLARDS Active, Fixed, Bollard	K12	~100	20 to 30	4 bollards			
DEEP FOUNDATION CRASH BEAM Active, Fixed, Barricade	K12	***	***	25	24 to 30	3 to 5	1
SHALLOW FOUNDATION CRASH BEAM Active, Fixed, Barricade	K4	***	***	25	24 to 30	3 to 5	1
WEDGE BARRIER Active, Fixed Barricade	K8	***	***			2 to 4	

* Cost figures are estimates from various manufacturers of vehicle barrier systems.

*** Cost information not publicly available

*# No data currently available

1628   # Various widths were tested.

1629   **TABLE X2.3 Cost for Passive Barriers**

Barrier	Cost/Unit [A]
Anchored concrete Jersey barrier, non-reinforced (2007 Means double face, precast concrete median barrier; 34 71 13.26.2200)	$65/ft ($213.25/m)
Buried tires, 36-ply, 8-ft (2.4-m) diameter, weighing 2000 lb (909 kg) each	$25.00/tire
Eight-in. (20.3-cm) diameter bollard system at 3 ft (0.9 m) on center with 12-in. (30.5-cm) channel rail (2007 Means 8-in (0.2-m) bollard 34 71 13.17.2700, corrugated steel rail, 3 ft (0.9 m), 34 71 13.260012.)	$629/each
Standard chain link fence [7 ft (2.1 m), 9 ga w/ outrigger] and two 3/4-in. (1.9-cm) diameter cables (2007 Means 7-ft (2.1-m) chain link 32 31 13.53.0100 with cable guide rail assuming a 3/4-in. (1.9-cm) cable 34 71 13.26.0600)	$61.30/ft ($201/m) (including fence)
Eight-in. (20.3-cm) diameter concrete-filled pipe (2007 Means 8-in. concrete-filled pipe bollards 34 71 13.17.2700)	$515.00/each
Concrete planter barrier (2007 Means for 48-in. (1.2-m) dia., 3-ft (0.9-m) high 34 71 13.17.0200)	$955/each
Cable barrier (2007 Means 34 71 13.26.0600 guide rail with steel posts; wire rope [6 × 19] adjusted per 05 15 16.50.0830 series rope costs)	
One cable at 3/4-in. (1.9-cm) dia.	$12.90/ft ($42.32/m)
Two cables at 3/4-in. (1.9-cm) dia.	$16.95/ft ($55.61/m)
Three cables at 3/4-in. (1.9-cm) dia.	$21.05/ft ($69.06/m)
Four cables at 3/4-in. (1.9-cm) dia.	$25.10/ft ($82.35/m)
One cable at 1-in. (2.5-cm) dia.	$18.50/ft ($60.70/m)
Two cables at 1-in. (2.5-cm) dia.	$26.75/ft ($87.76/m)
Three cables at 1-in. (2.5-cm) dia.	$34.00/ft ($111.55/m)
Four cables at 1-in. (2.5-cm) dia.	$43.25/ft ($141.90/m)
Reinforced concrete retaining or knee wall [2007 Means 03 30 53.40.6200 for cast-in-place concrete retaining walls, 4-ft (1.2-m) high]	$340/ yd^3 ($445/m^3)

1630

1631   [A] Based on *Building Construction Cost Data*, 65th Annual Edition, Reed construction Data, 2007.
1632   Average cost for continental United States. All costs including overhead and profit.

1633

1634 **TABLE X3.1 Performance for Passive Barriers**

Barrier	Kinetic Energy ft-lbf (kgf-m) × 1 000 000	Penetration ft (m)
Anchored concrete Jersey barrier, non-reinforced	0.3 (0.04)	20 (6.1)
Buried tires, 36-ply, 8-ft (2.4-m) diameter, weighing 2000 lb (909 kg) each	0.3 (0.04)	1 (3.05)
Eight-in. (20.3-cm) diameter bollard system at 3 ft (0.9 m) on center with 12-in. (30.5-cm) channel rail	1.1 (0.15)	None
12.75-in. (32.4-cm) to 13.25-in. (33.7-cm) diameter bollard system at 3 ft (0.9 m) on center	0.8 (0.11) 1.2 (0.17)	3 (0.9) 3 (0.9)
Standard chain link fence [7 ft (2.1 m), 9 ga w/ outrigger] and one 3/4-in. (1.9-cm) diameter cable	0.06 (0.008) 0.35 (0.048)	7 (2.1) 26 (7.9)
Eight-in. (20.3-cm) diameter concrete-filled pipe	0.135 (0.019)	1.5 (0.46)
Concrete planter barrier	1.08 (0.15)	31.2 (9.5)
Cable barrier [200-ft (60.9-m) anchorage spacing] [A]		
One cable at 3/4-in. (1.9-cm) dia.	0.1 (0.014)	40 (12)
Two cables at 3/4-in. (1.9-cm) dia.	0.2 (0.028)	40 (12)
Three cables at 3/4-in. (1.9-cm) dia.	0.338 (0.047)	40 (12)
Four cables at 3/4-in. (1.9-cm) dia.	0.418 (0.058)	40 (12)
One cable at 1-in. (2.5-cm) dia.	0.15 (0.021)	40 (12)
Two cables at 1-in. (2.5-cm) dia.	0.34 (0.047)	40 (12)
Three cables at 1-in. (2.5-cm) dia.	0.506 (0.07)	40 (12)
Four cables at 1-in. (2.5-cm) dia.	0.706 (0.098)	40 (12)
Reinforced-concrete retaining wall [B] 10 in. (25.4 cm) thick 21 in. (53.3 cm) thick 3.28 ft (1 m) wall	0.157 (0.022)	None
Cable barrier – two 3/4-in. (1.9-cm)	0.36 (0.05)	13 (3.96)

1635

1636 [A] Based on analytical modeling, using BIRM 3D (PDC-TR90-2) or other

1637 finite element analysis process.

1638 [B] Of the wall designs, the shorter and thinner section 3-ft (1-m) wall is the most efficient, based on K
1639 rating.[7]

1640
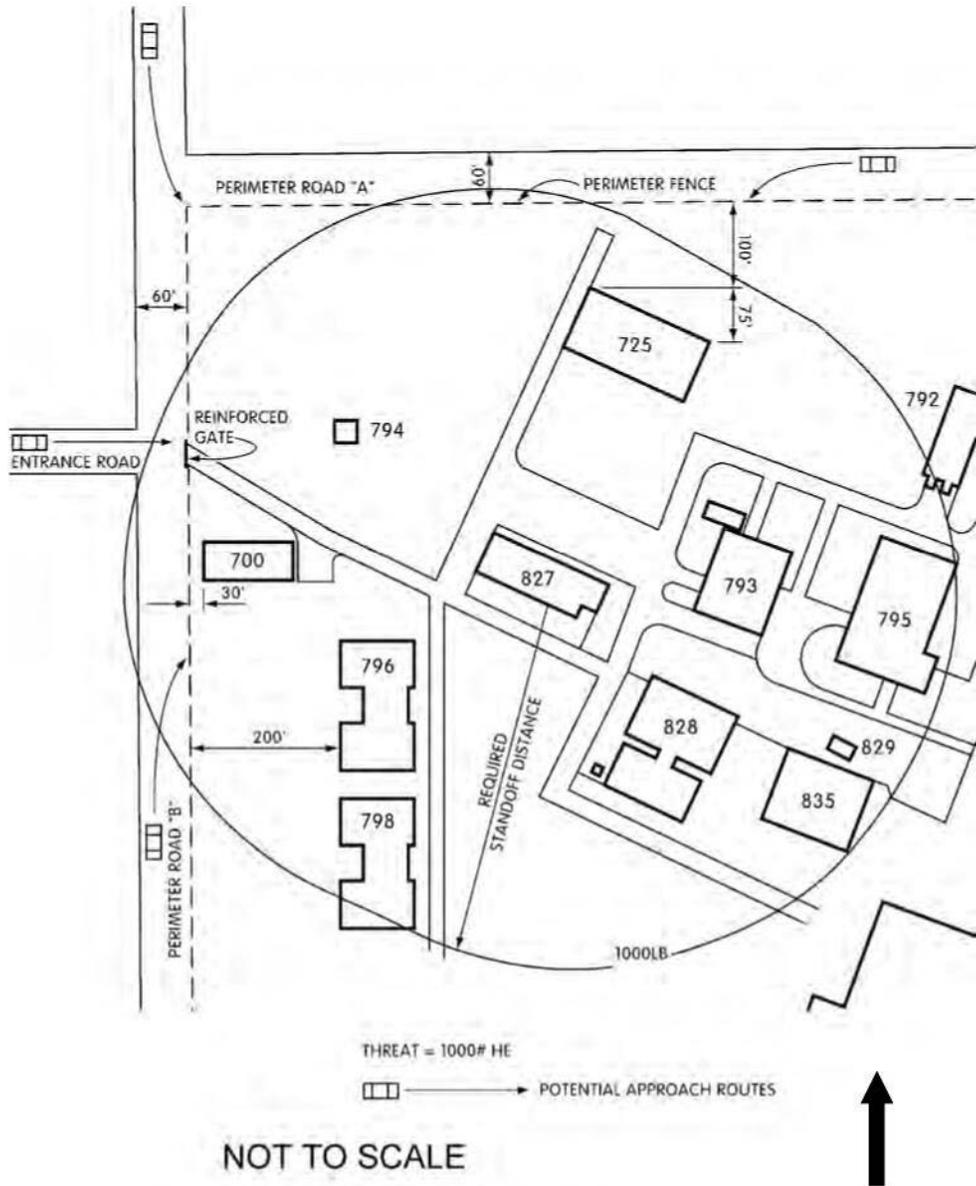
1641
1642 **FIG 1 Example Site Layout**
1643
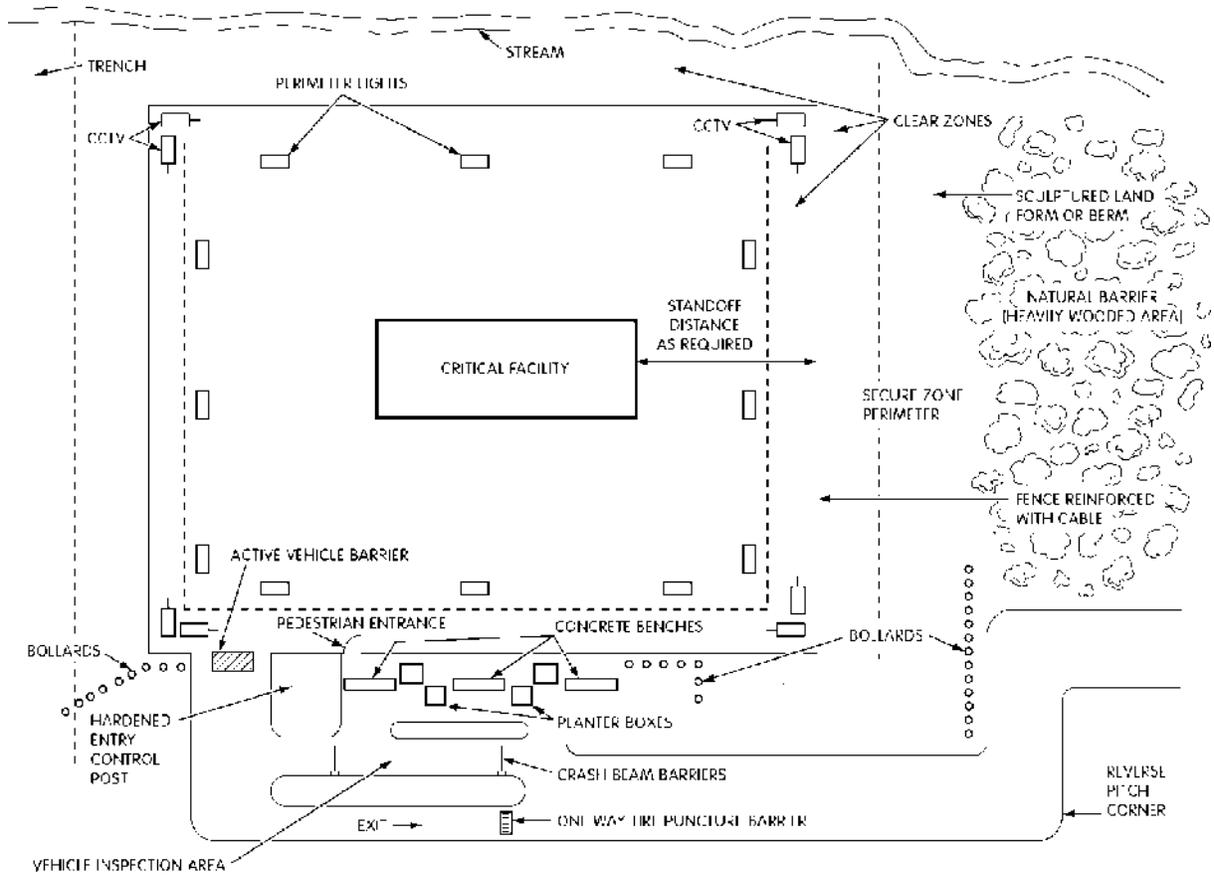
FIG 2 Integrated Physical Security System
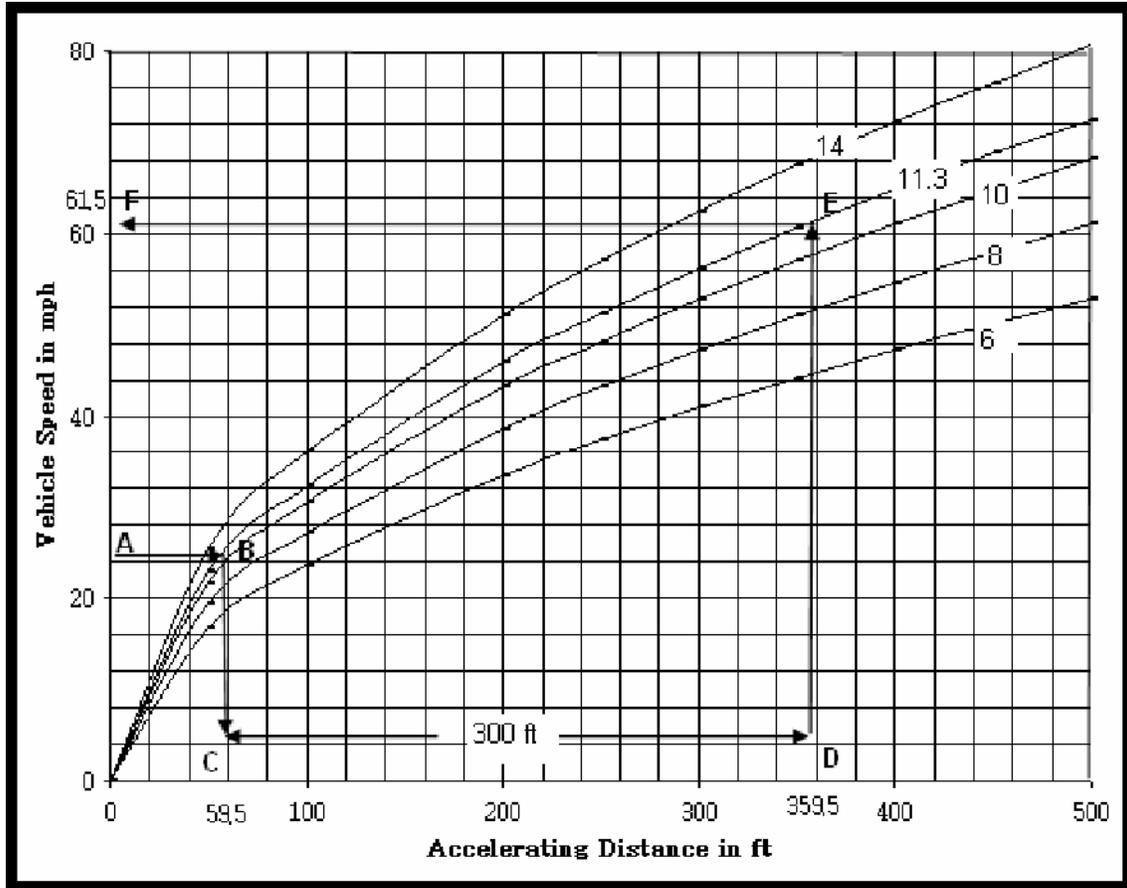
FIG 3 Vehicle Speed Versus Acceleration Distance
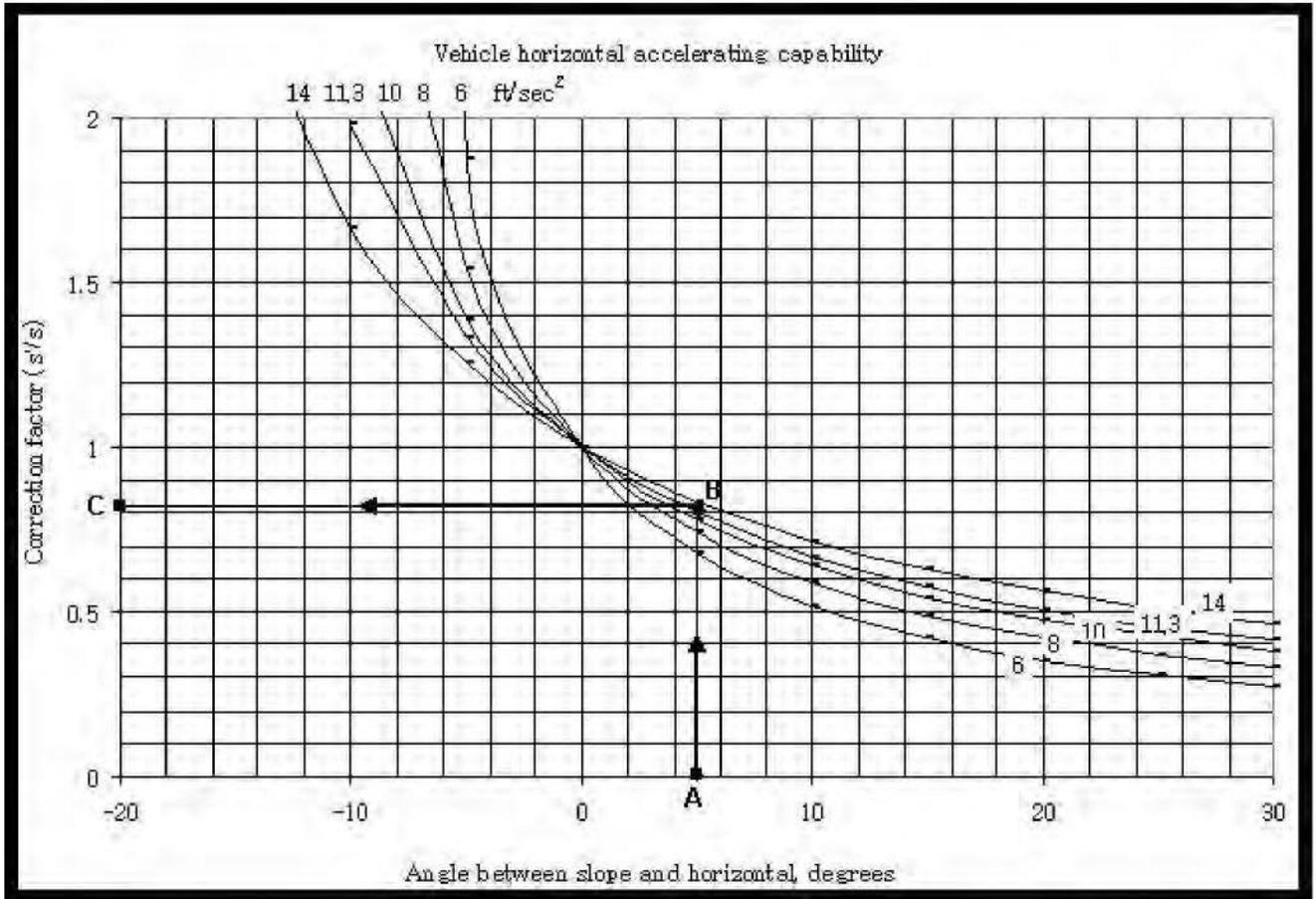
FIG 4 Speed Correction Factor for Vehicles Driving on a Sloped Path
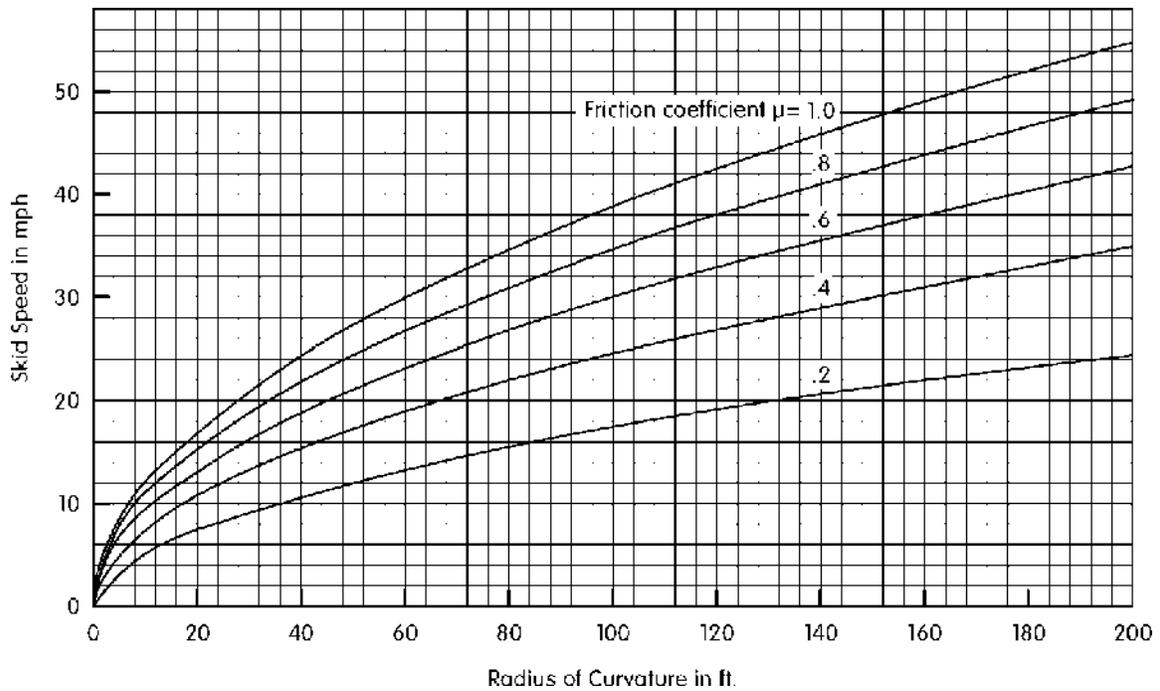
1655   **FIG 5 Skid Speed Versus Radius of Curvature**

1656
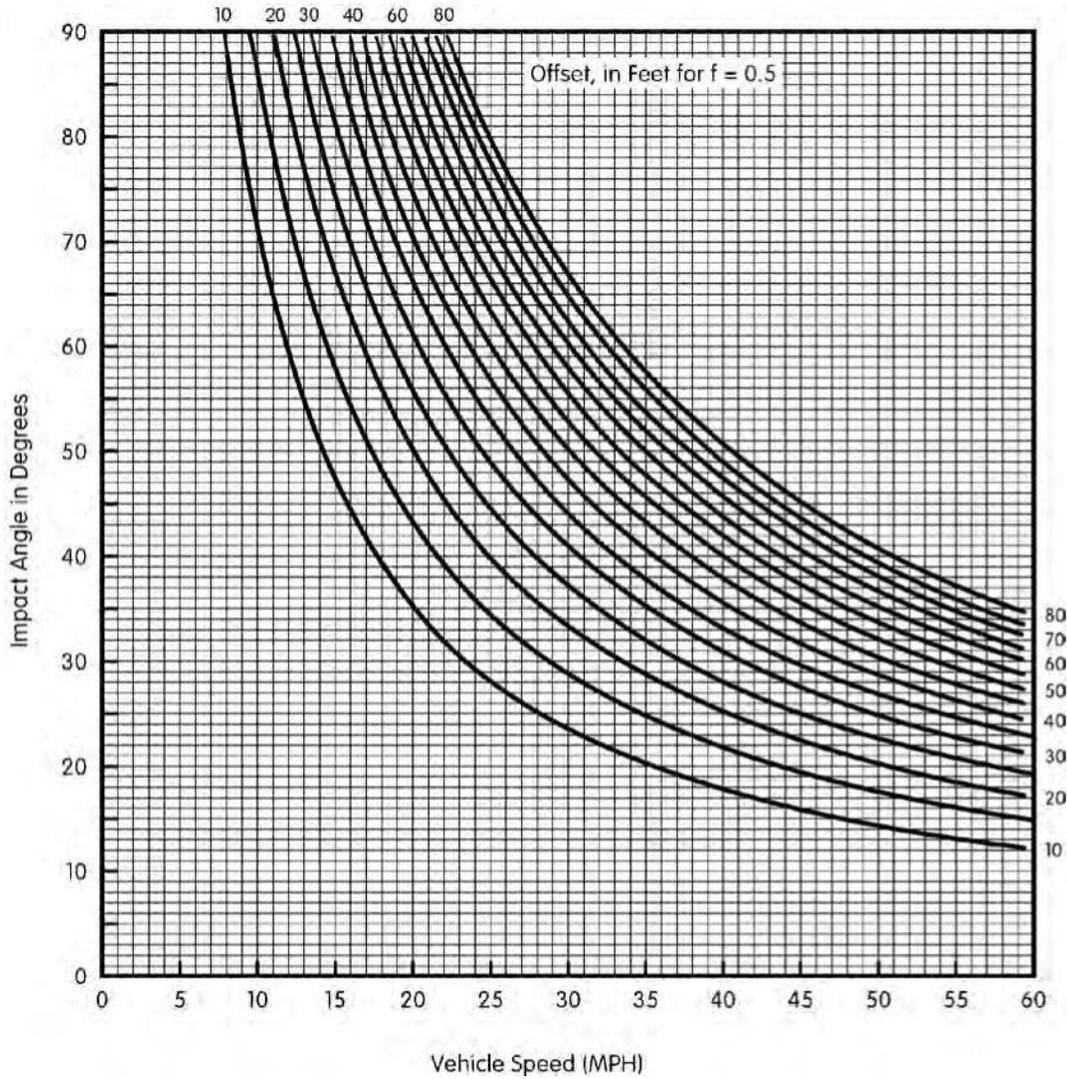
1657

1658   **FIG 6 Correction Factor for Vehicle Traveling Parallel to Barrier (Based on**
1659   **Coefficient of Friction, $f = 0.5$)**

1660
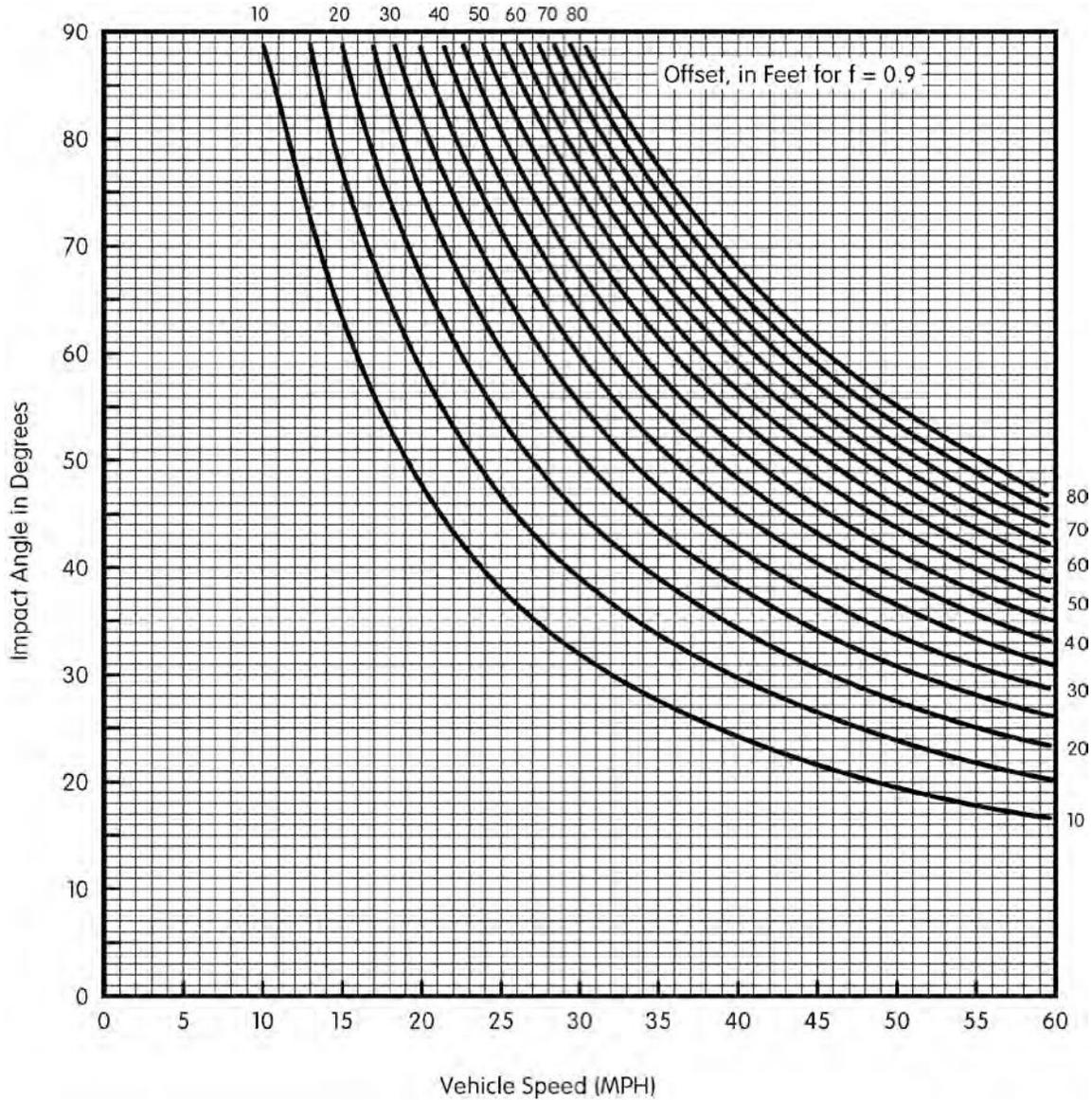
FIG 7 Correction Factor for Vehicle Traveling Parallel to Barrier (Based on Coefficient of Friction, f **= 0.9)**
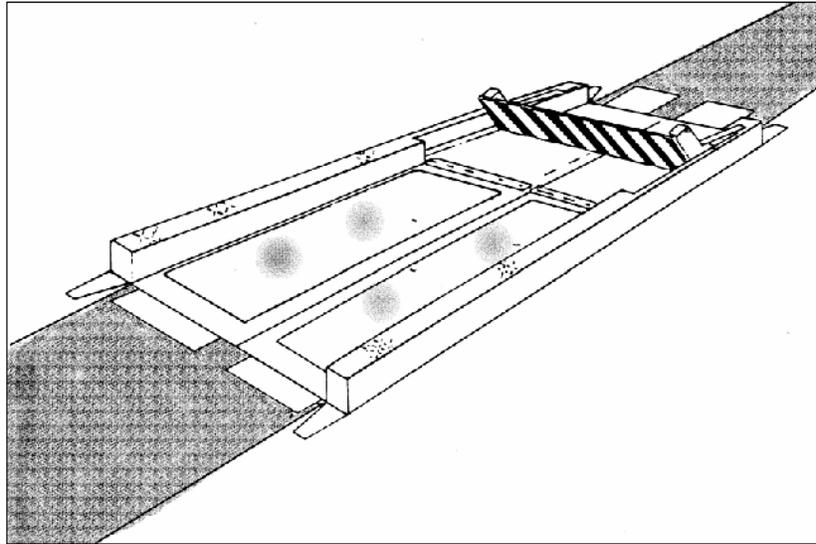
1665
1666 **FIG 8 Vehicle Surface Barrier (Example 1)**
1667

1668
1669 **FIG 9 Portable High-Security Anti-Terrorist Vehicle Crash Barrier (Example 2)**
1670

1671
1672 **FIG 10 Portable Barrier (Example 3)**
1673

1674
1675 **FIG 11 Maximum Security Vehicle Arrest Barrier (Example 4)**
1676
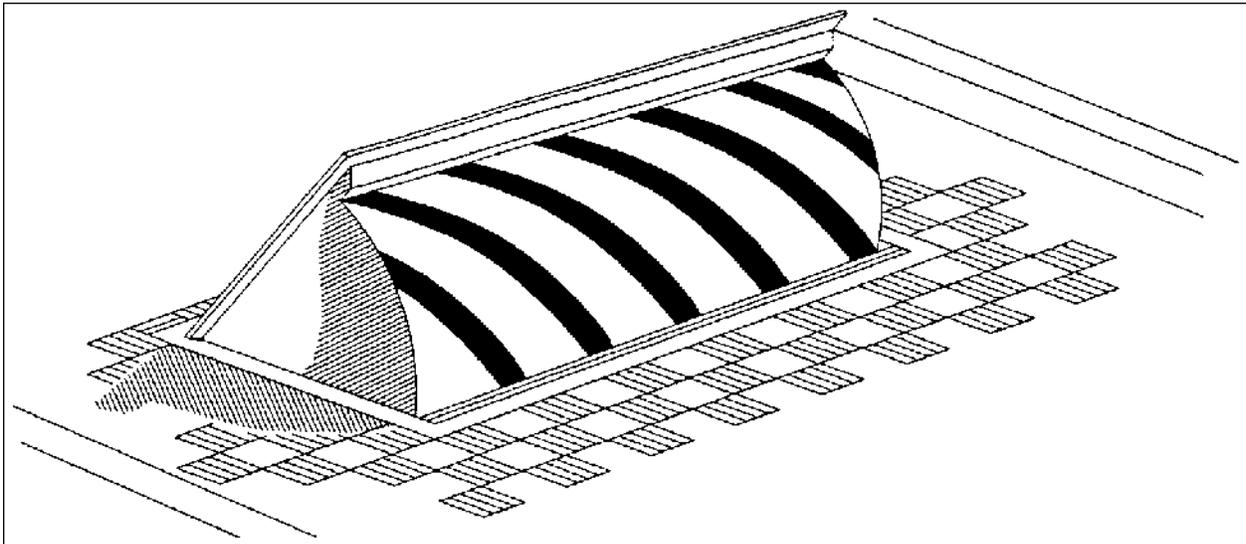
1677
1678 **FIG 12 Example High-Security Barricade System (Wedge Type)**
1679
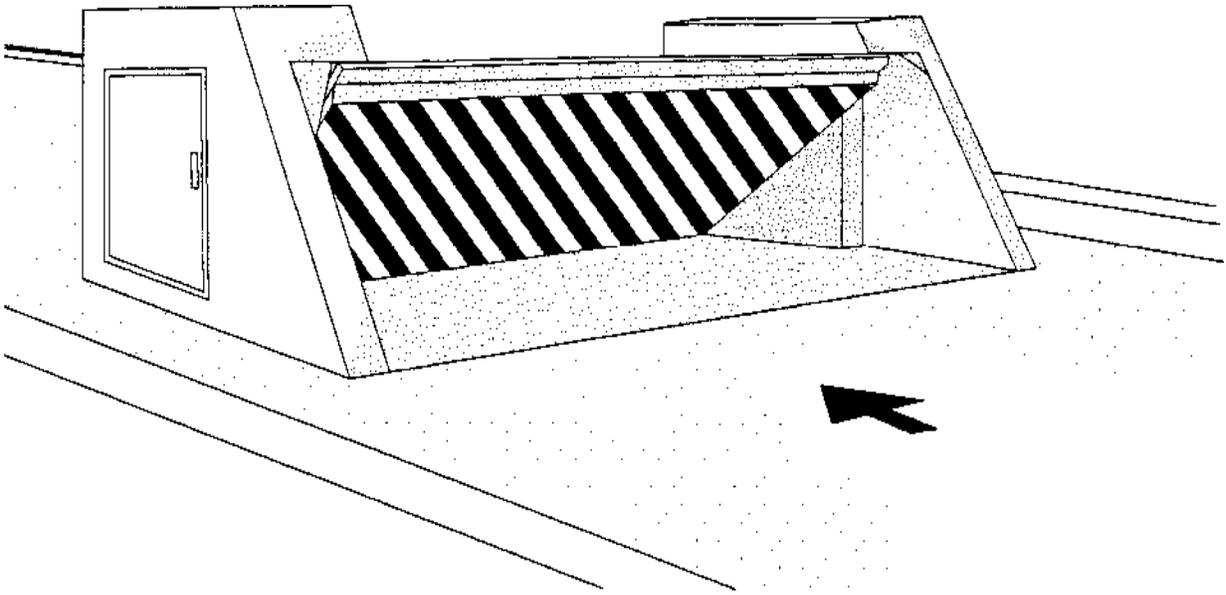
1680

1681 **FIG 13 Example High-Security Barricade System (Flush-Mounted)**

1682
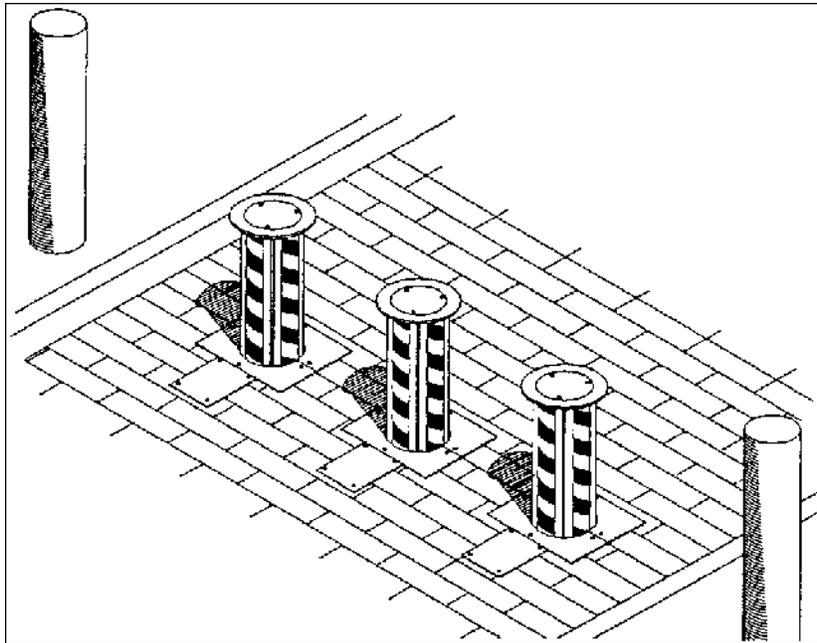
1683

1684 **FIG 14 Example Bollard System**

1685
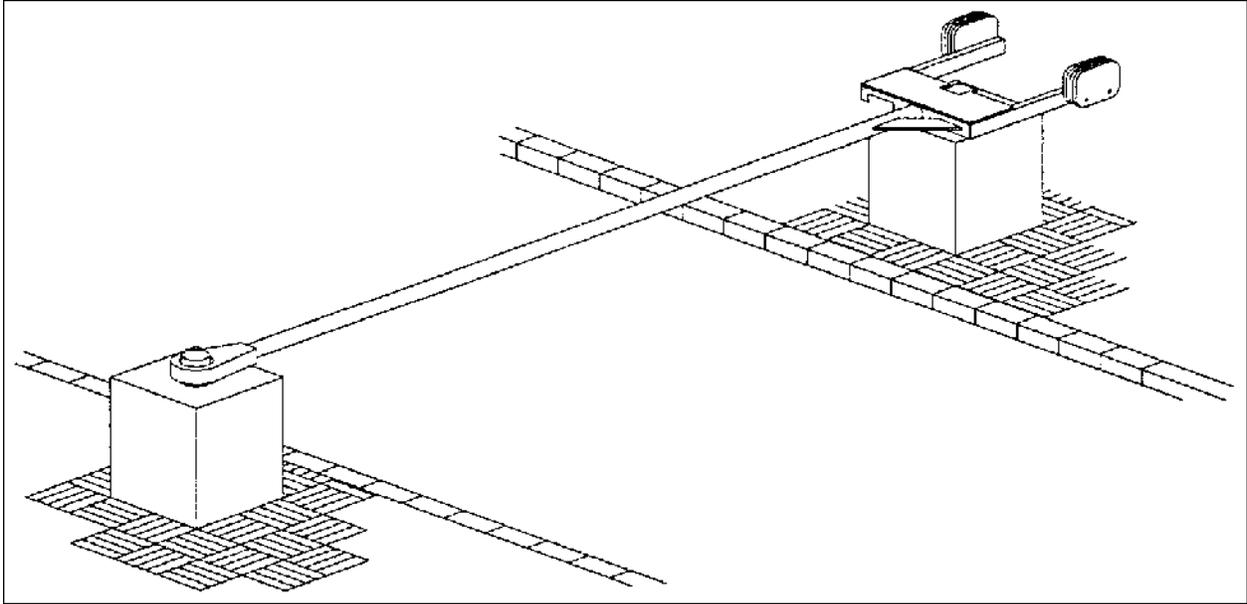
1686

1687 **FIG 15 Cable-Reinforced Crash Beams**

1688
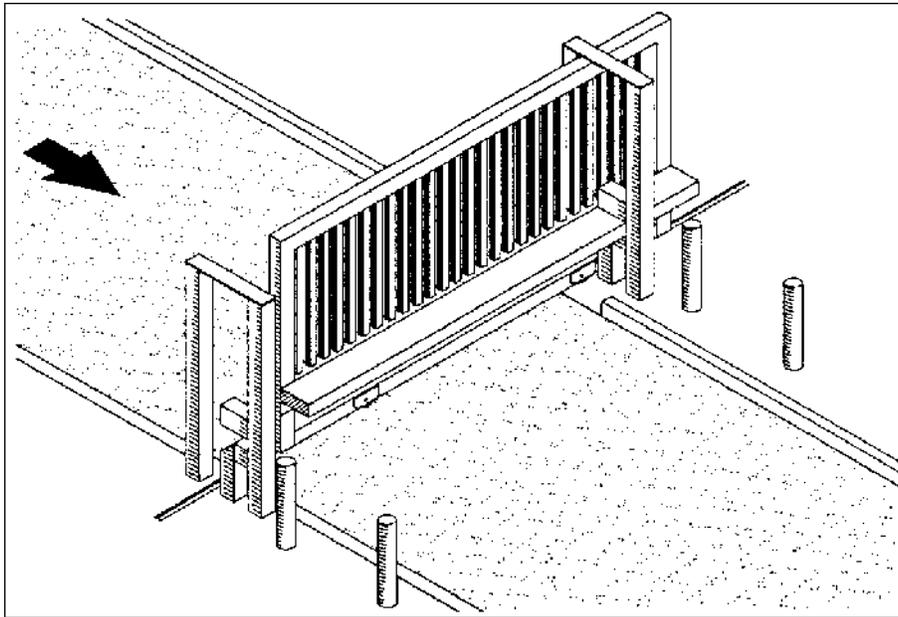
1689

1690 **FIG 16 Example Linear Crash Gate**

1691
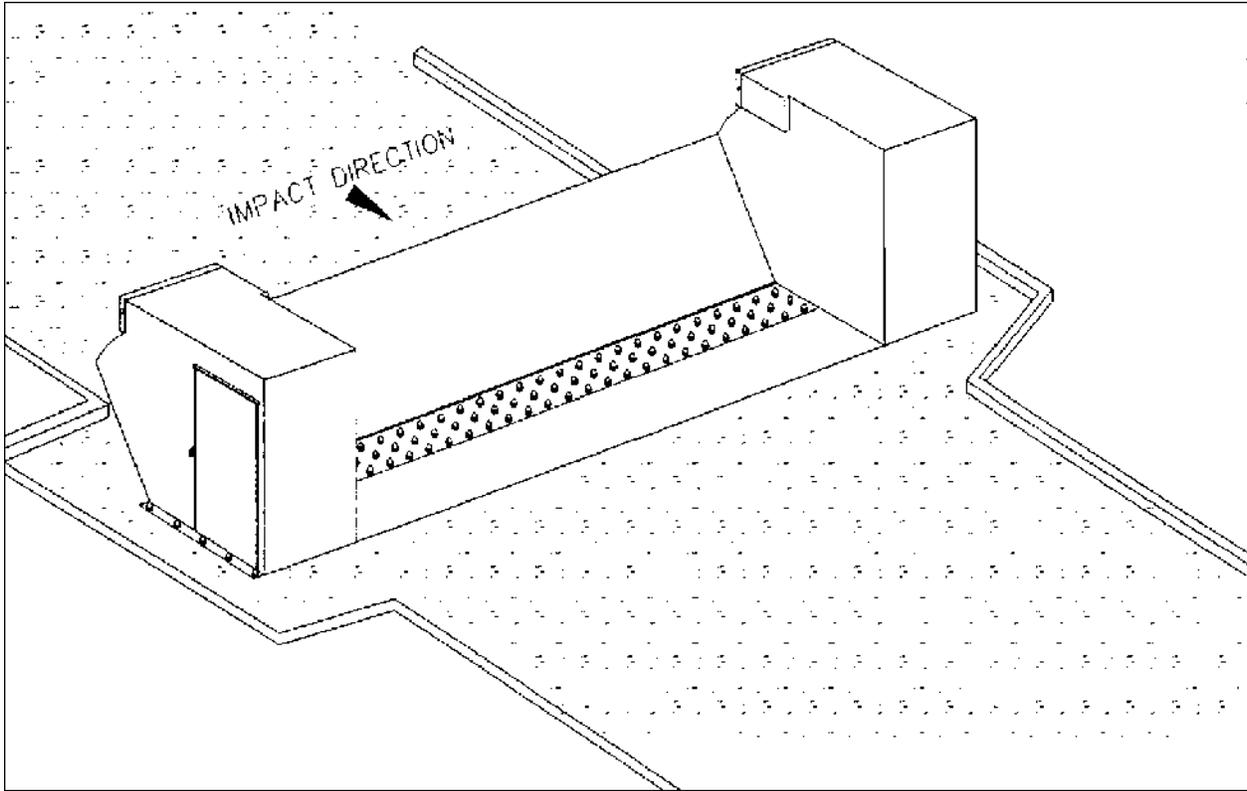
FIG 17 Example MSB Vehicle Barrier (Lift Plate Barricade System)
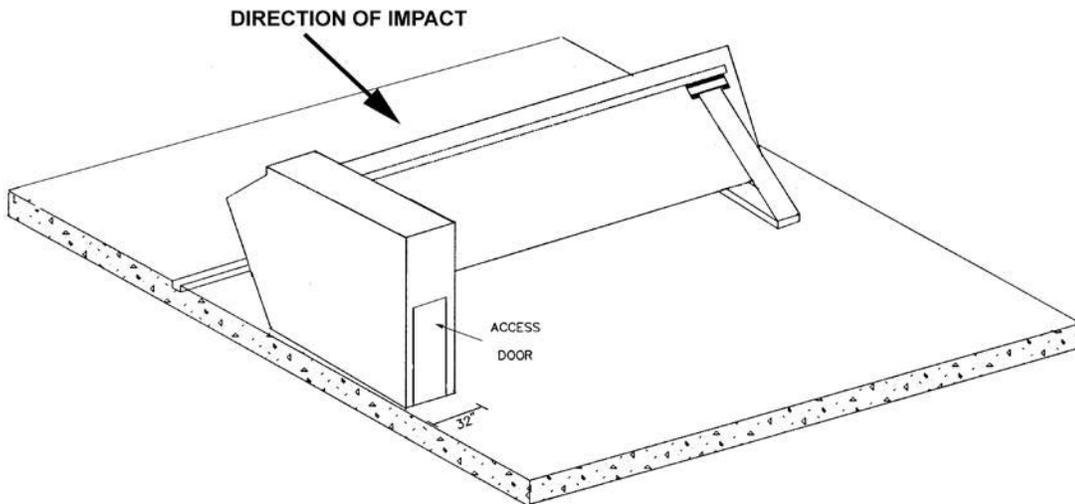
FIG 18 Second Example MSB Vehicle Barrier

PROTECTED SIDE

GROUT FILL
AND WASH

SPACE BOLLARD
@ 900 (MAX.)

200DIA. (12 WALL THK)
STEEL PIPE W/
CONCRETE FILL
(PIPE Fy=MIN 250MPa)

FINISH GRADE

14DIA. TIES @ 100
(Fy=275MPa MIN, TYP)

6-20DIA. @ 150

CONTINUOUS CONCRETE
RECTANGULAR FOOTING
(F'c=20.5 MPa @ 28 DAYS)

OPTIONAL 250x30 CHANNEL
W/ 2-20DIA. ANCHOR BOLTS
AND NUTS WELDED ONTO EACH
CHANNEL AFTER INSTALLATION.
(CHANNEL Fy= MIN 250MPa)

150

ATTACK SIDE

0.50 (MIN) CORROSION
SHRINK SLEEVE

750

300

300

MIN 50 CLEAR,
SIDES AND TOP

1 200

1-12DIA. TOP &
BOTTOM

70 CLEAR

600
MIN.

1 — BOLLARD SECTION
SCALE = 1:20

NOTE: ALL DIMENSIONS IN MILLIMETERS.

FIG 19 DoS Passive Anti-Ram Bollard Example

1698
1699
1700
1701
1702
1703

89

DOS DESIGN # DS — 10

SYMMETRICAL ABOUT ℄

TYP 1/4

200 DIA X—STRONG, STEEL PIPES FILL WITH CONRETE, TYPICAL

80 DIA STANDARD STEEL PIPE

910

610

GRADE LINE ℄

TOP OF CONCRETE

1220

6—20 DIA EACH SIDE
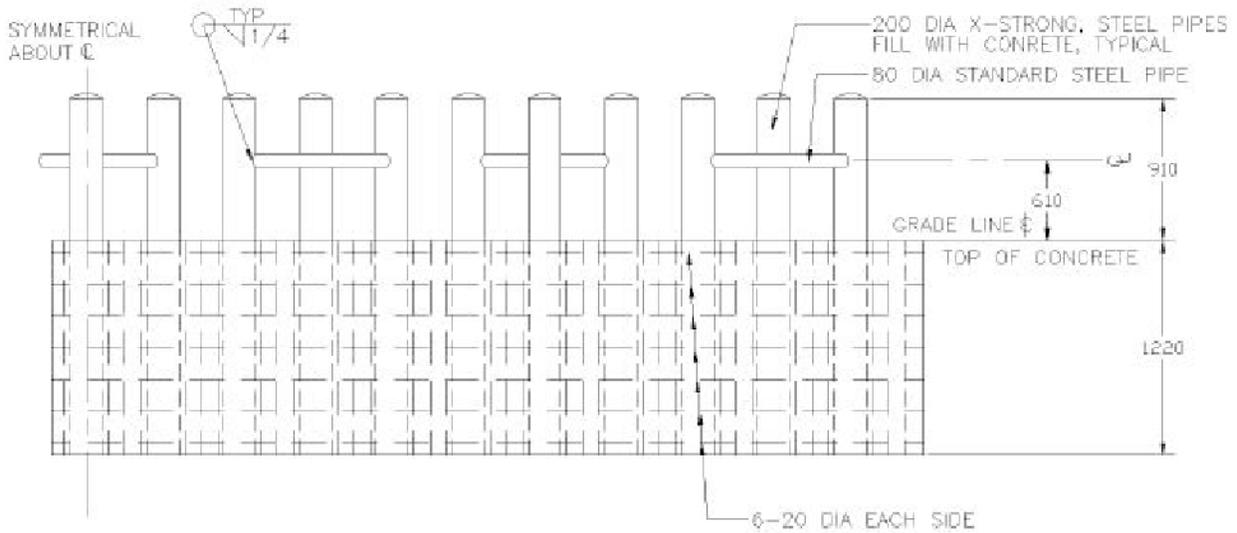
1704
1705 **FIG 20 Example Bollard Design Section**

1706

1707 DOS DESIGN #DS — 10

SOLID BARRIER

SOLID BARRIER
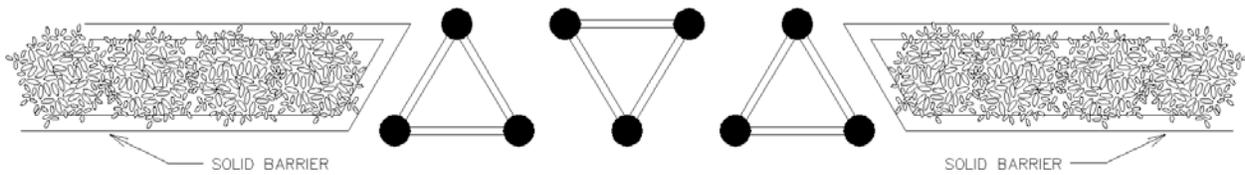
1708

EXAMPLE:
ACCEPTABLE FOR USE IN WIDE SIDEWALK AREAS WHERE
PEDESTRIAN FLOW MUST BE MAINTAINED.

1709
1710 **FIG 21 Bollard Design Example Layout in Plan View**

1711
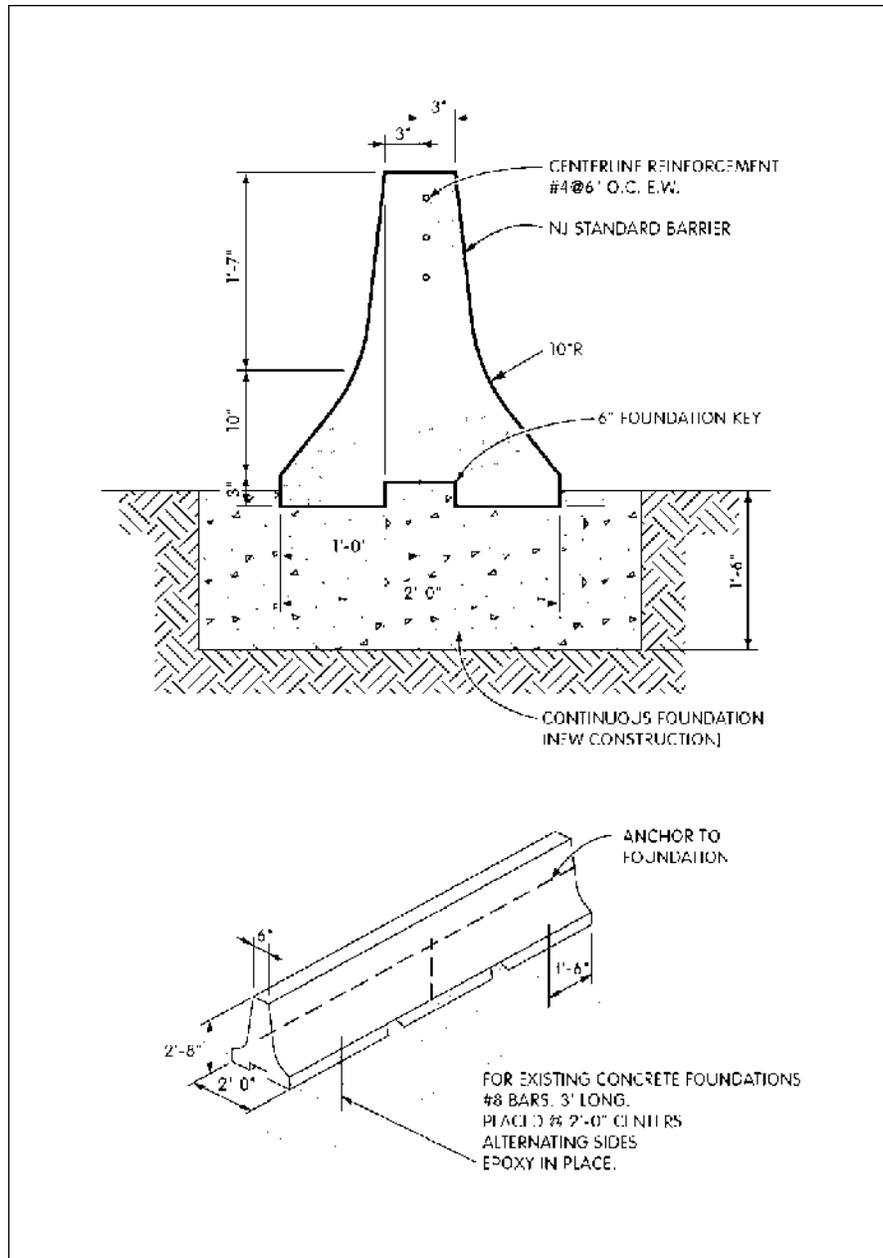
FIG 22 Precast Nonreinforced Concrete Median
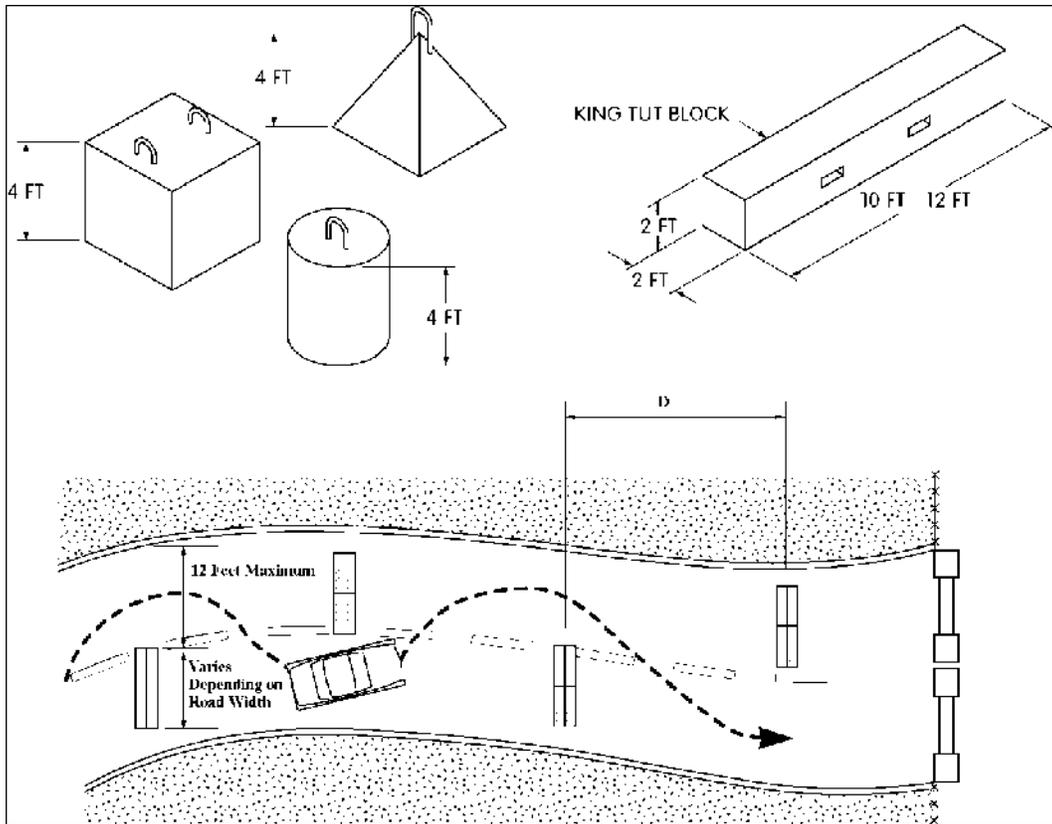
FIG 23 Concrete Blocks

PLAN

SECTION
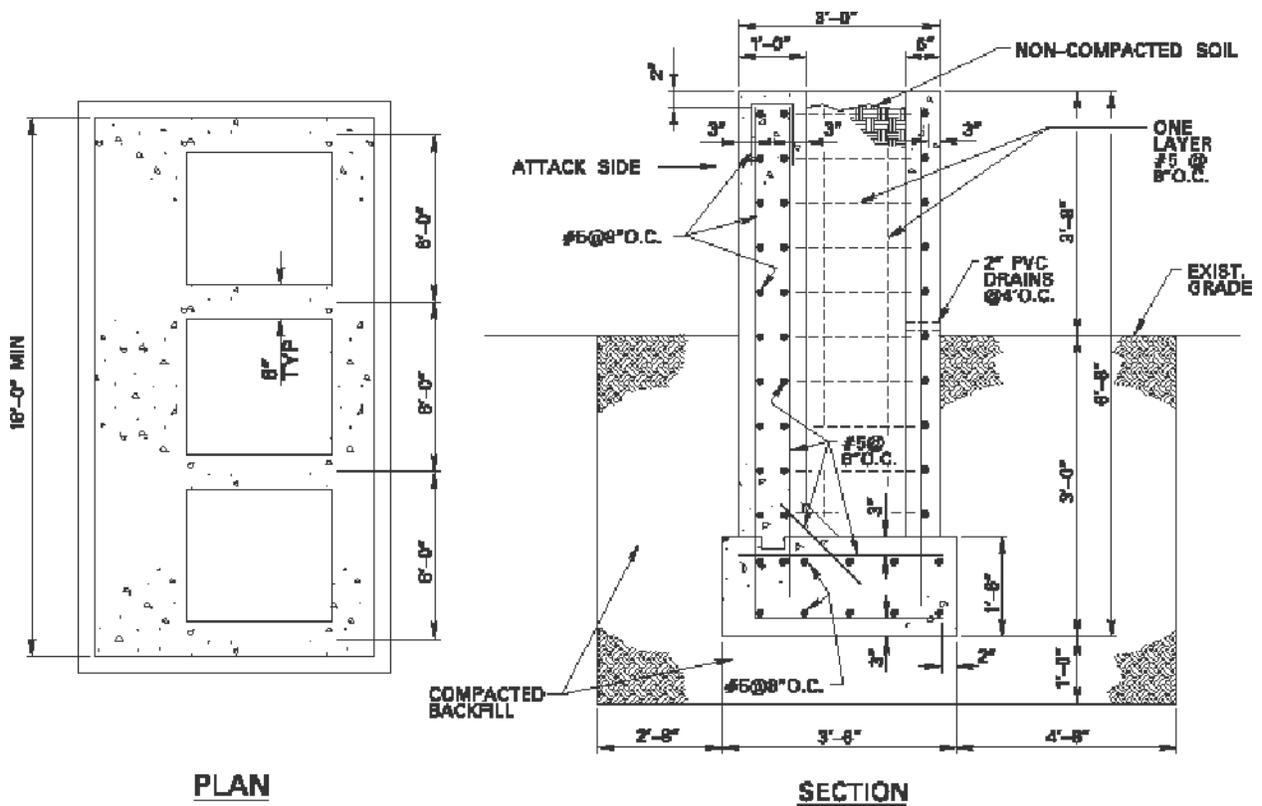
1719

FIG 24 Reinforced Concrete Planter

1720

1721
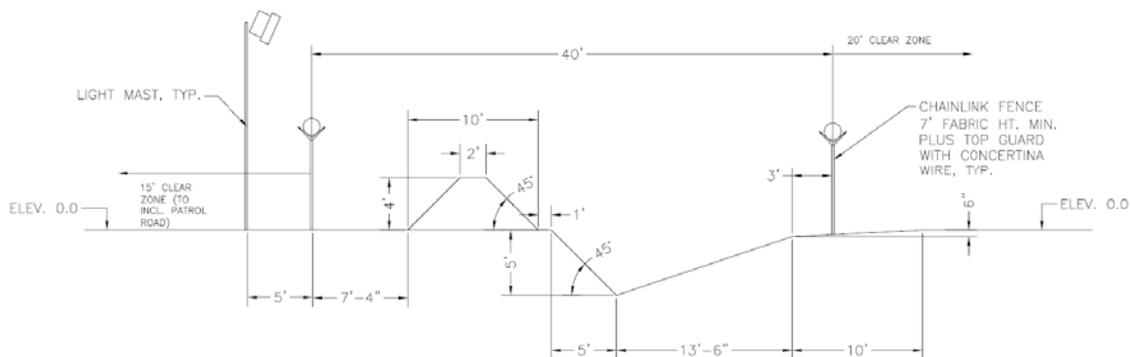
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FIG 25 Anti-Vehicular Ditch Profile with Incline Slope Requiring Stabilization

1723

1724
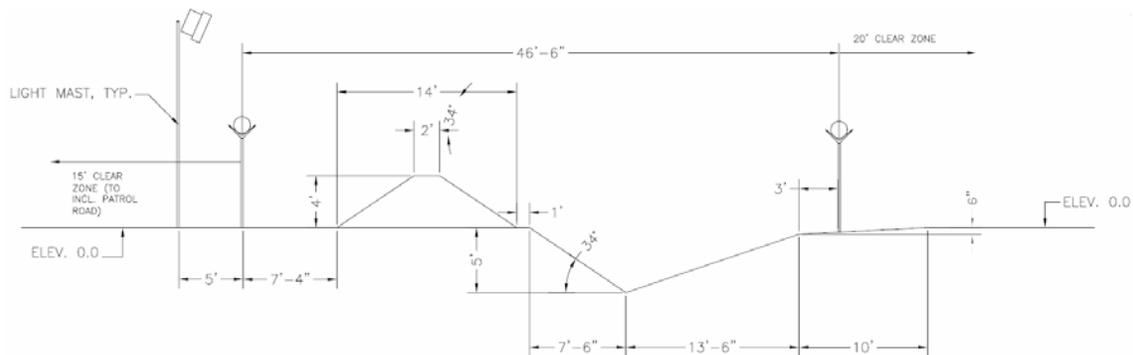
1725

**FIG 26 Anti-Vehicular Ditch Profile with Maximum Incline Slope Not
Requiring Stabilization**

1726

1727

1728
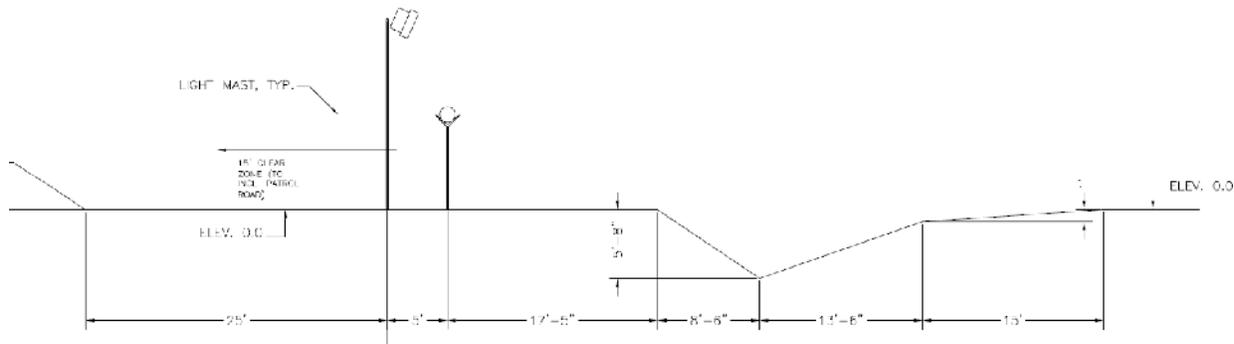
1729

**FIG 27 Anti-Vehicular Ditch Profile with Maximum Incline Slope Not
Requiring Stabilization or Berm**

1730

1731

1732
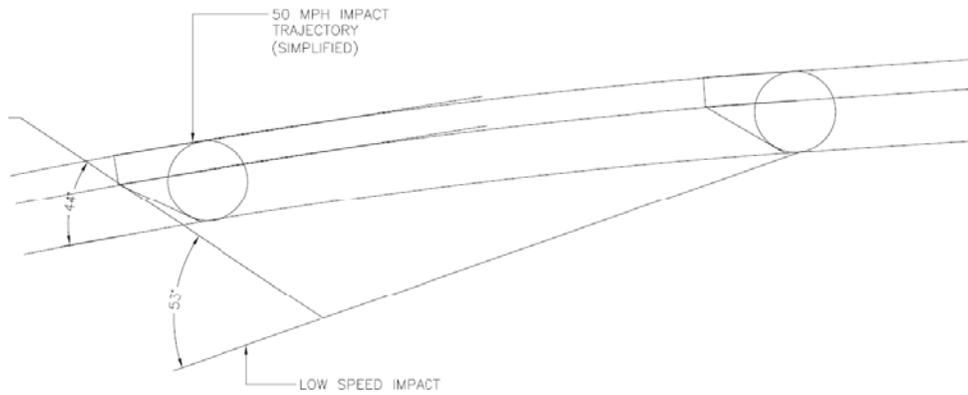
FIG 28 Simulated Trajectory Path and Impact Angle with Ditch Incline Slope for Vehicle at Two Speeds
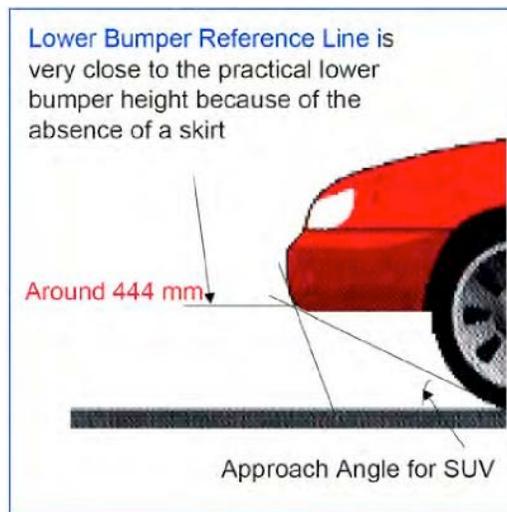
FIG 29 Lower Bumper Reference Line and Vehicle Approach Angle
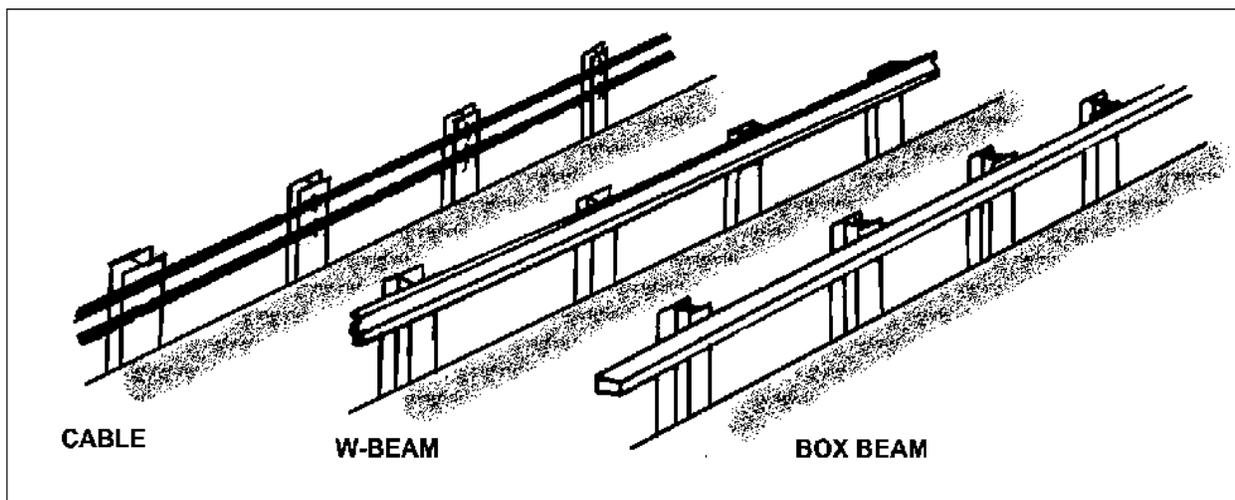
1741 **FIG 30 Guardrails**

1742
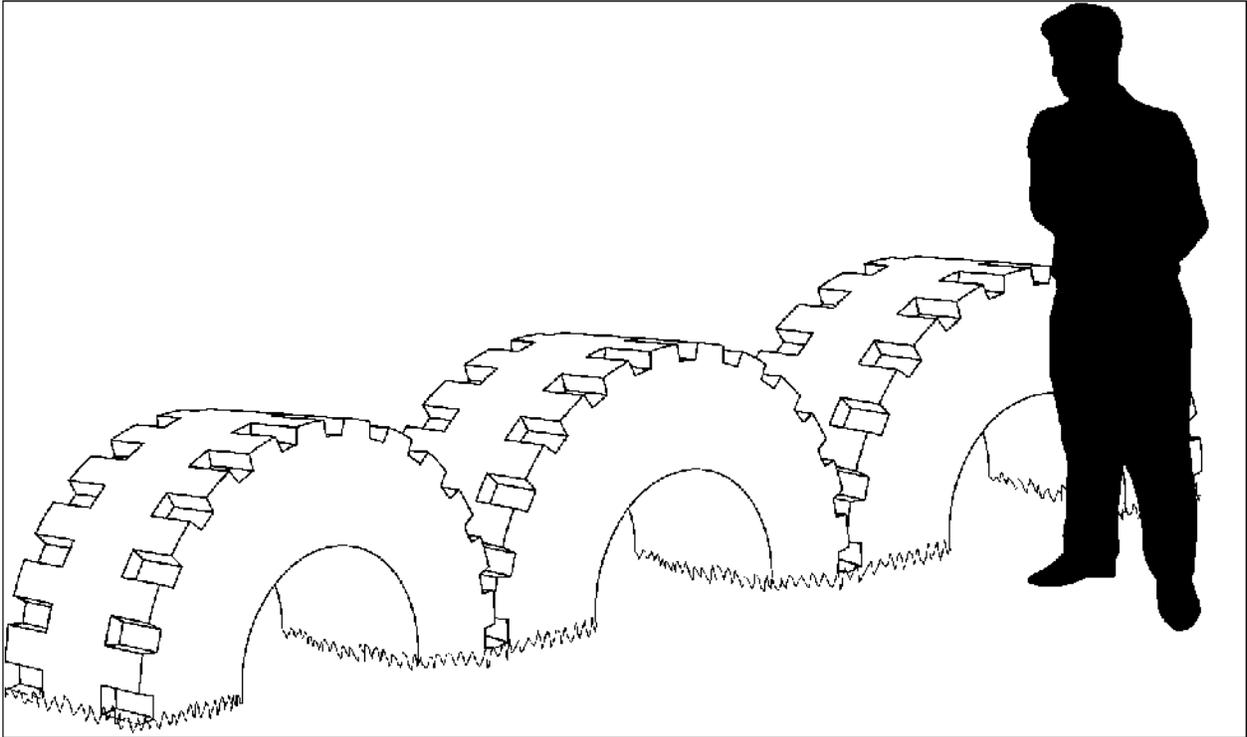
1743

1744 **FIG 31 Heavy Equipment Tire Barrier**

1745
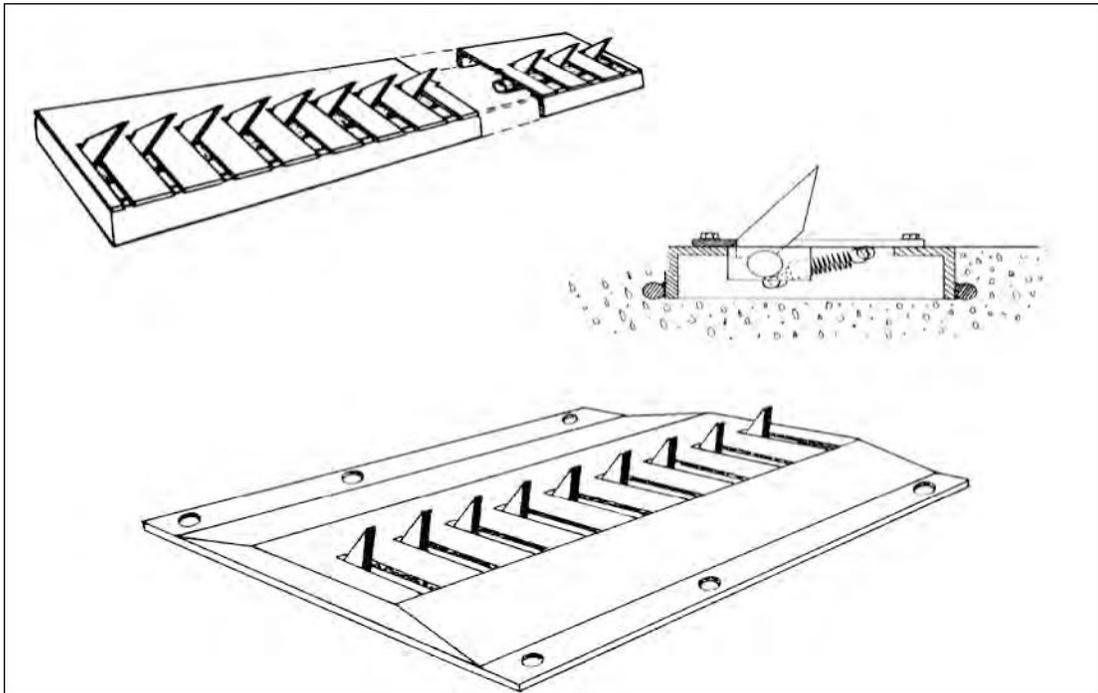
1746

1747

1748 **FIG 32 Tire Shredders**

PULL POST

SWAGED EYE END

1.25" TURNBUCKLE WITH JAW END PULL

U-BOLT

1.25" THREADED ROD (GALVANIZED)

4" x 4" x 0.25" ANCHOR PLATES
(WELDED THEN GALVANIZED)

CABLE (WIRE ROPE)

3'-0"

3' x 3' x 1'-6" CONCRETE DEADMAN

UNDISTURBED SOIL

3'-0"
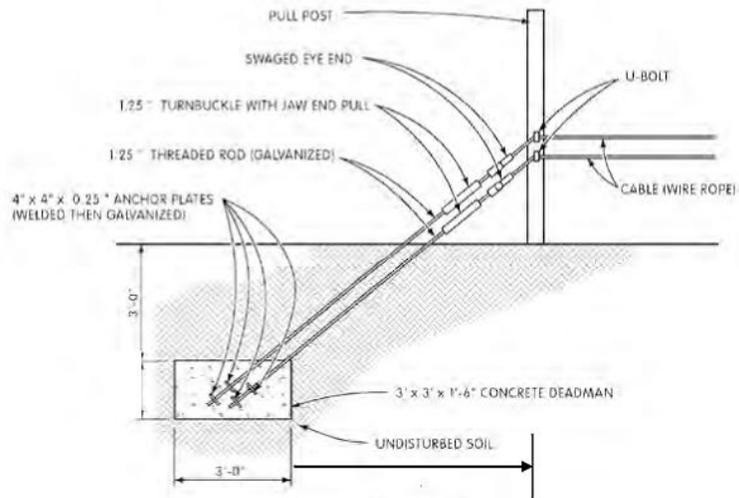
DEADMAN DETAIL

NO SCALE

1749

2'-8"

CENTERLINE OF CABLE (WIRE ROPE) GROUP.
TOP AND BOTTOM CABLES SHOULD BE NO
MORE THAN 8" FROM THE CENTERLINE.

DEADMAN SPACING
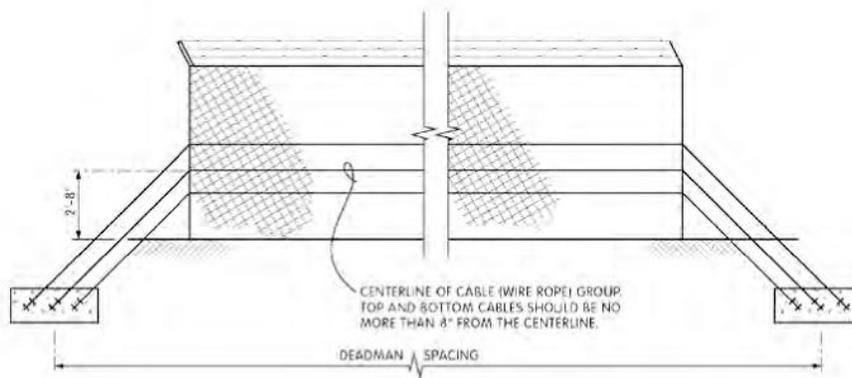
TYPICAL CABLE-RUN CABLE RESTRAINT SYSTEM

1750

1751 **FIG 33 Steel Cable Barriers**

1752
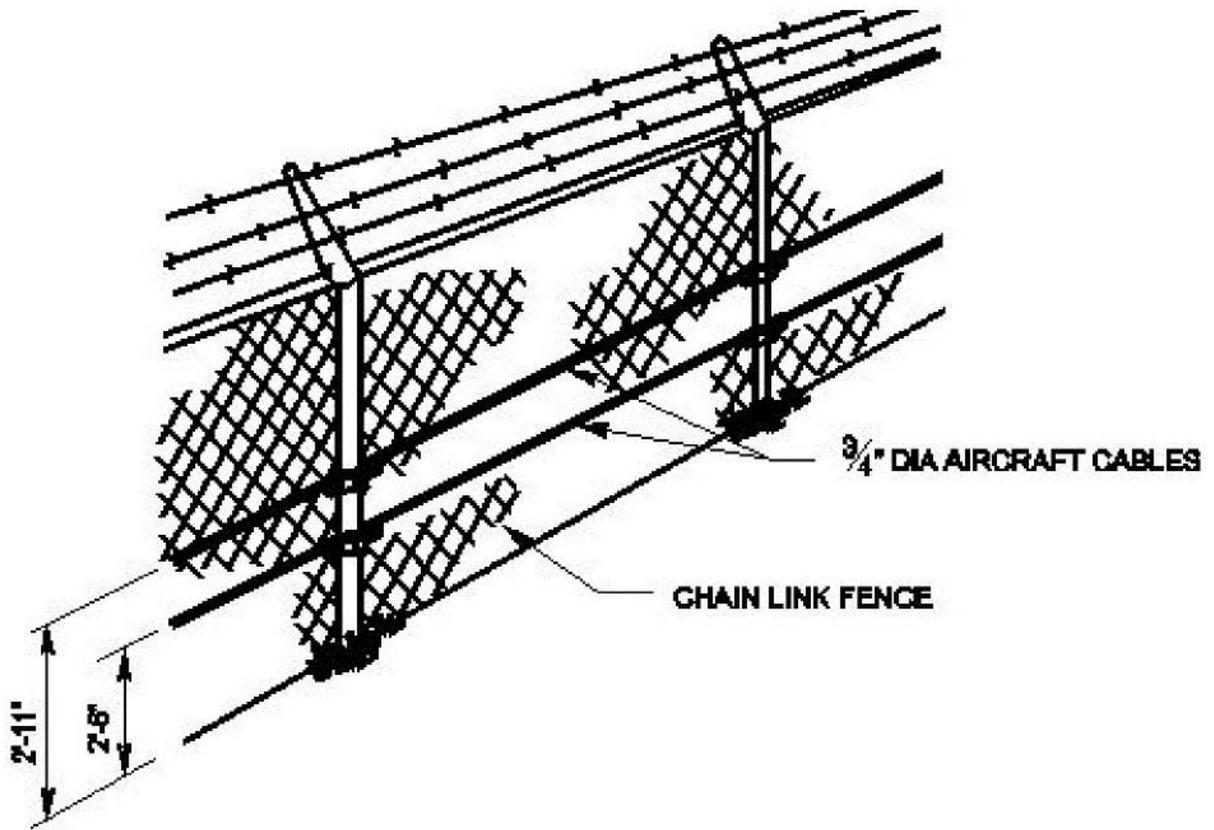
FIG 34 Typical Steel Cable Reinforced Chain-Link Fencing

1753

1754

1755

MATERIAL SPECIFICATIONS

CONCRETE: f'c = 20.0 MPa (MIN)
REINFORCING STEEL: fy = 275 MPa (M

NOTE: ALL DIMENSIONS WITH A DECIMAL IN METE
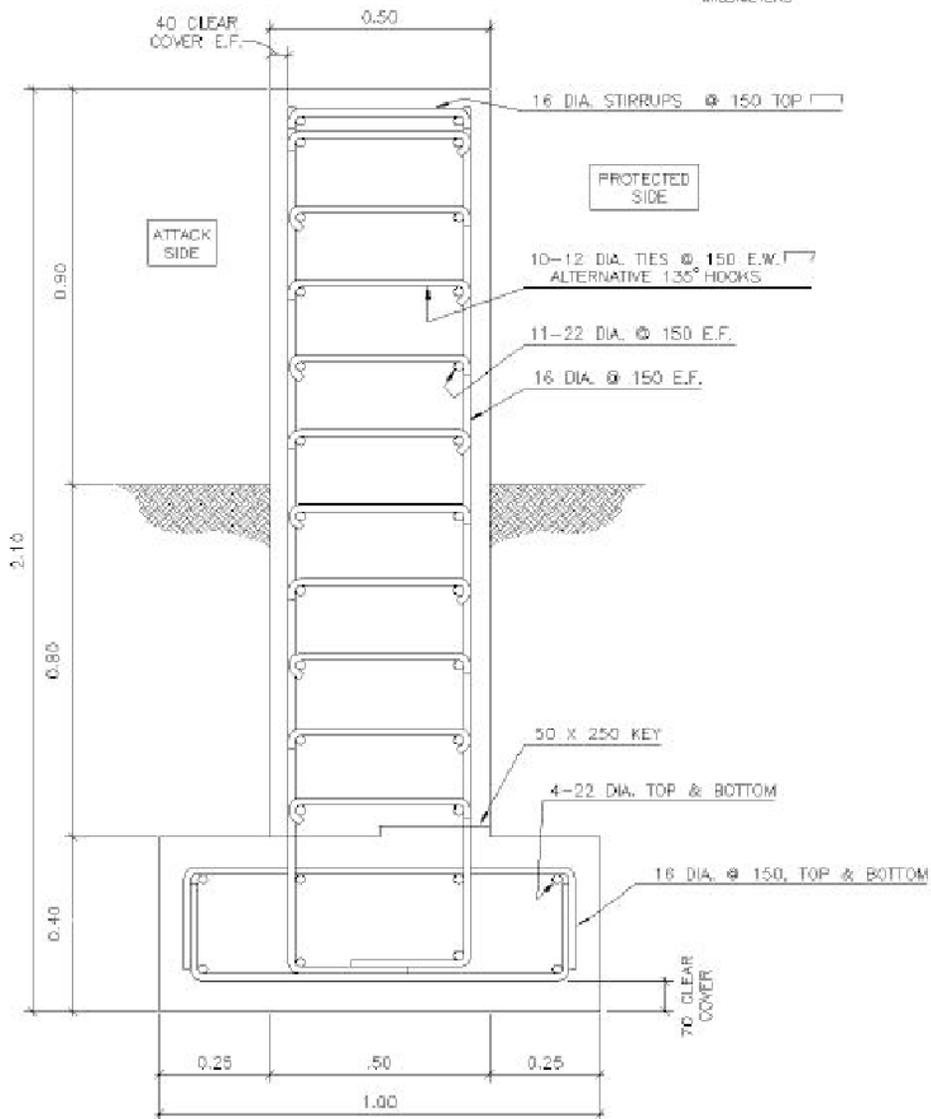ALL DIMENSIONS WITHOUT DECIMAL IN
MILLIMETERS

40 CLEAR
COVER E.F.

0.50

16 DIA. STIRRUPS @ 150 TOP

PROTECTED
SIDE

ATTACK
SIDE

10-12 DIA. TIES @ 150 E.W.
ALTERNATIVE 135° HOOKS

11-22 DIA. @ 150 E.F.

16 DIA. @ 150 E.F.

0.90

2.10

0.80

50 X 250 KEY

4-22 DIA. TOP & BOTTOM

0.40

16 DIA. @ 150, TOP & BOTTOM

70 CLEAR
COVER

0.25   .50   0.25

1.00

FIG 35 Anti-Ramming Foundation Wall
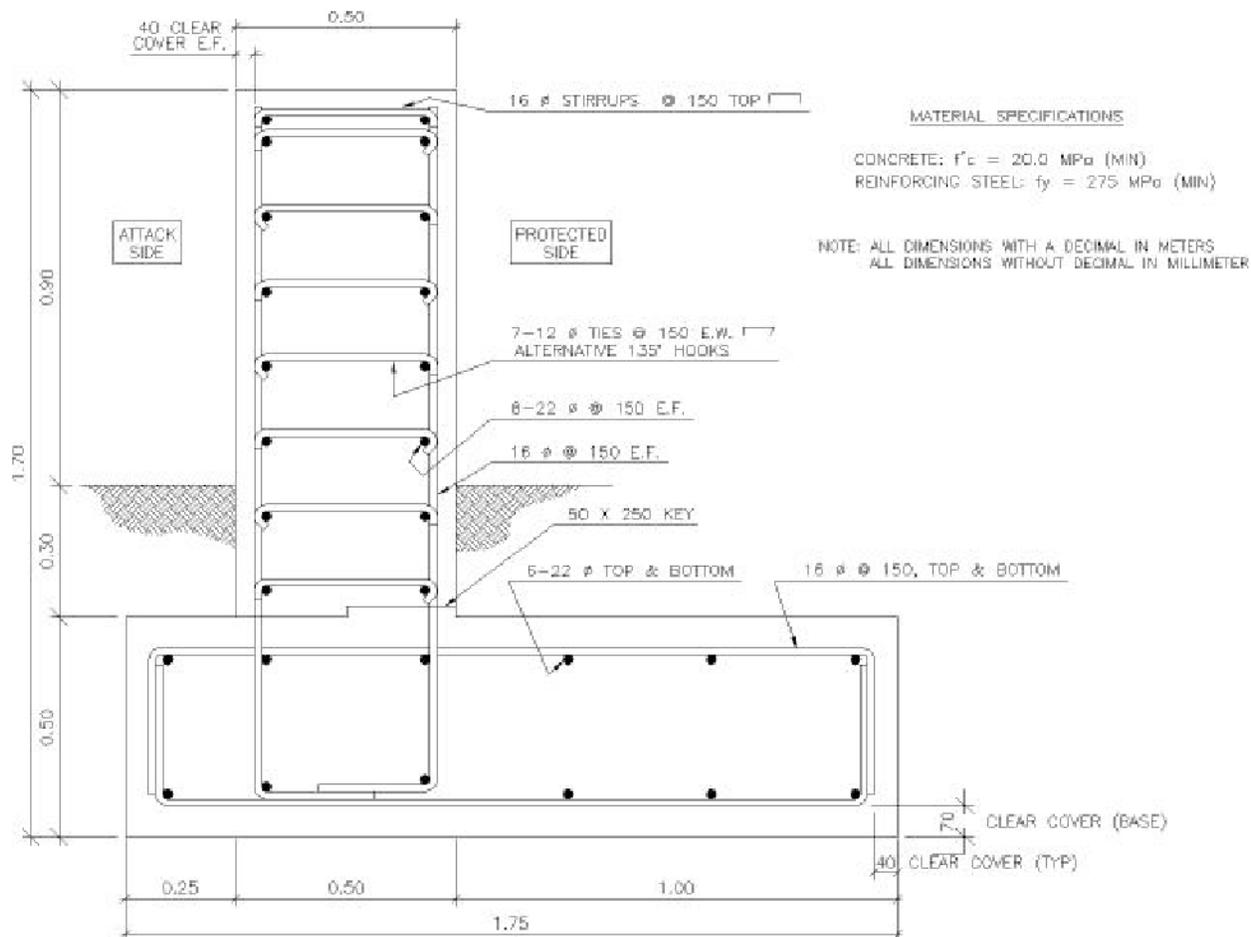
FIG 36 Anti-Ramming Knee Wall Section
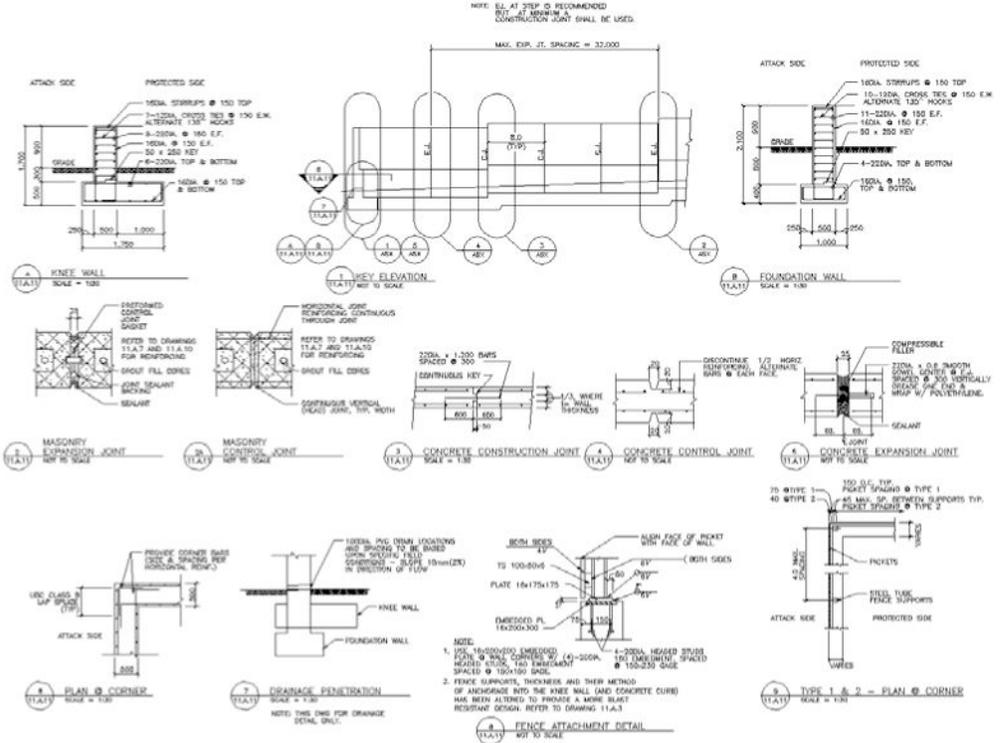
FIG 37 Reinforced Concrete Knee Wall Details
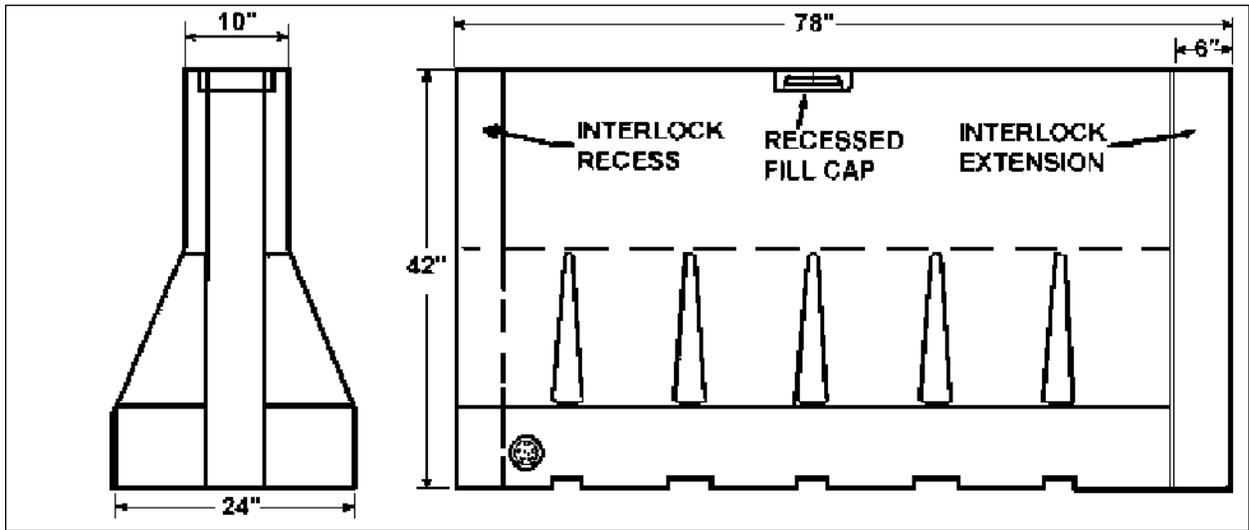
FIG 38 Commercially Available Plastic Barrier System

THREAT = 1000# HE

POTENTIAL APPROACH ROUTES
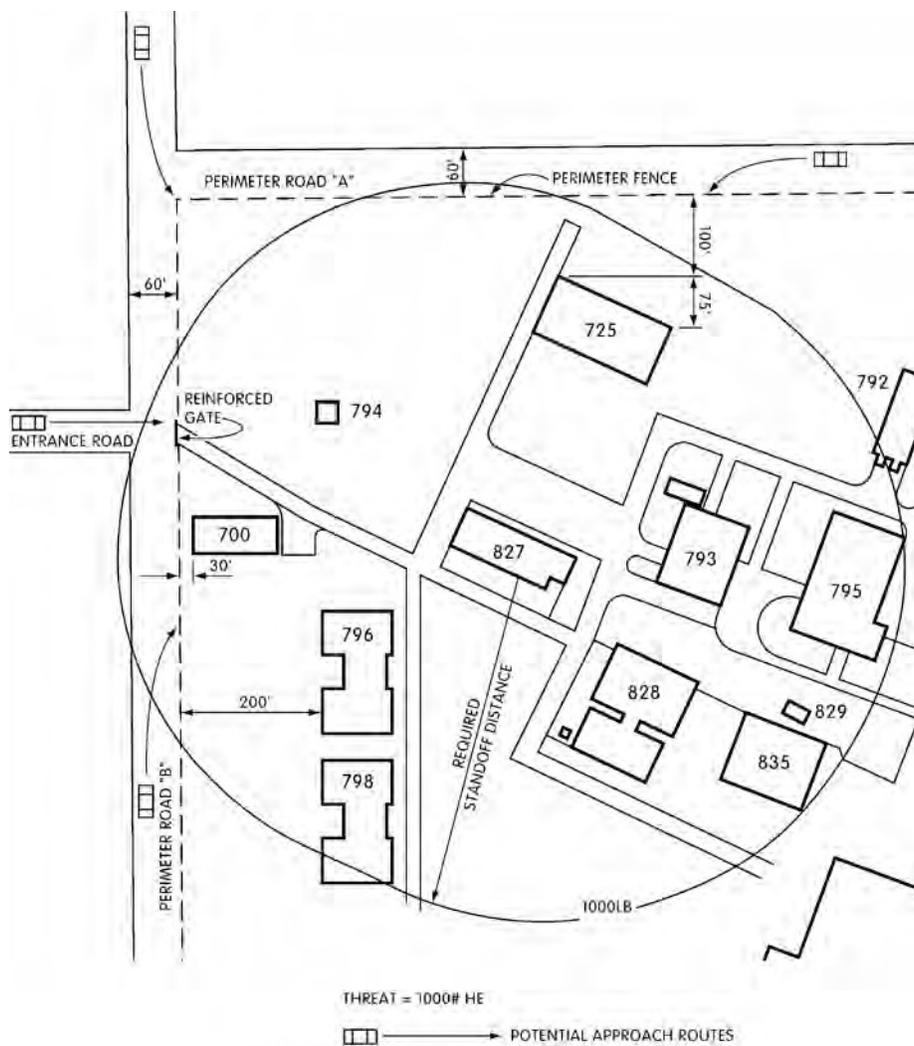
NOT TO SCALE

FIG X4.1 Site Planfor Examples

1771
1772 **FIG X5.1 Hesco Bastion Concertainer Barrier, Oblique View**
1773

1774
1775 **FIG X5.2 Polyer-Coated, Lightweight Concrete Barrier System**