Headquarters U.S. Air Force

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UFC 4-023-02 Retrofit of Existing Buildings to Resist Explosive Effects

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Overview

- **UFC 4-023-02 *Security Engineering: Structural Design to Resist Explosive Effects for Existing Buildings***
  - **Design and analysis of various retrofit approaches**
  - **Covers mostly wall retrofits; some information on columns, roofs**
  - **Windows will be covered in UFC 4-013-04**
  - **Summarizes the published results of DoD-sponsored research into blast mitigation**
    - Often retrofit techniques based on **very limited** data, and therefore conservative

Philosophy of Retrofit for Blast

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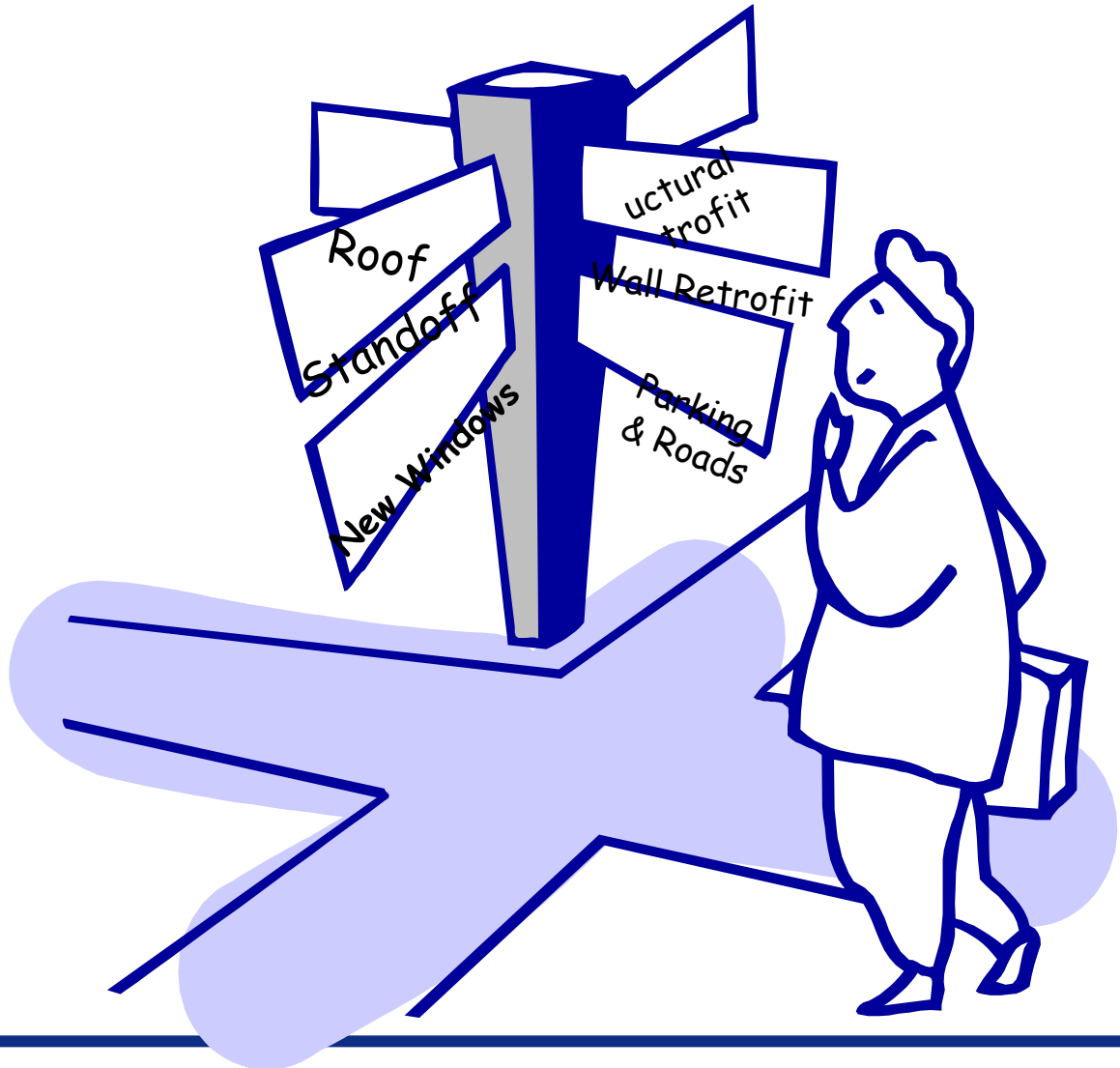

Balanced Design

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- Goal of blast protection retrofits = Increased Level of Protection (LOP)
  - #1 Objective = Prevent structural collapse
  - #2 Objective = Prevent injury from flying debris
- Design should be “balanced” among various building elements

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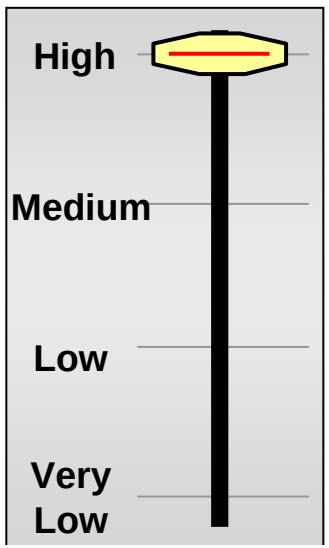
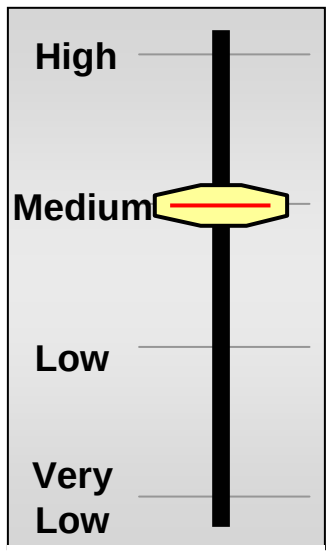
Balanced Design, continued

Primary Structure
(Collapse Hazard)



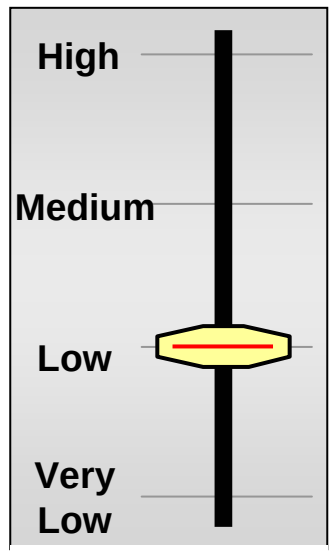
Columns, beams, roof, slabs and bearing walls

Secondary Structure
(Debris Hazard)



Non-load bearing walls and supports

Openings
(Debris Hazard)



Doors, windows and vents

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Levels of Protection (LOPs)

Level of Protection	Potential Wall Damage	Potential Injury
Below AT Standards	**Collapse of primary structural elements**	**Fatalities near 100%**
Very Low	**Collapse of secondary structural elements**	**Fatalities 10 – 25% Majority seriously injured**
Low	**Damaged – unrepairable; major deformation of secondary structure**	**Fatalities < 10% Majority injured**
Medium	**Damaged – repairable; minor deformation of secondary structure**	**Some minor injuries**
High	**Superficial damage**	**Superficial injuries**

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Retrofit Design Approach

- Determining the Need for a Retrofit
  - General Design Procedures
  - DoD Minimum Construction Standards
  - Reference Structures and Range-to-Effect

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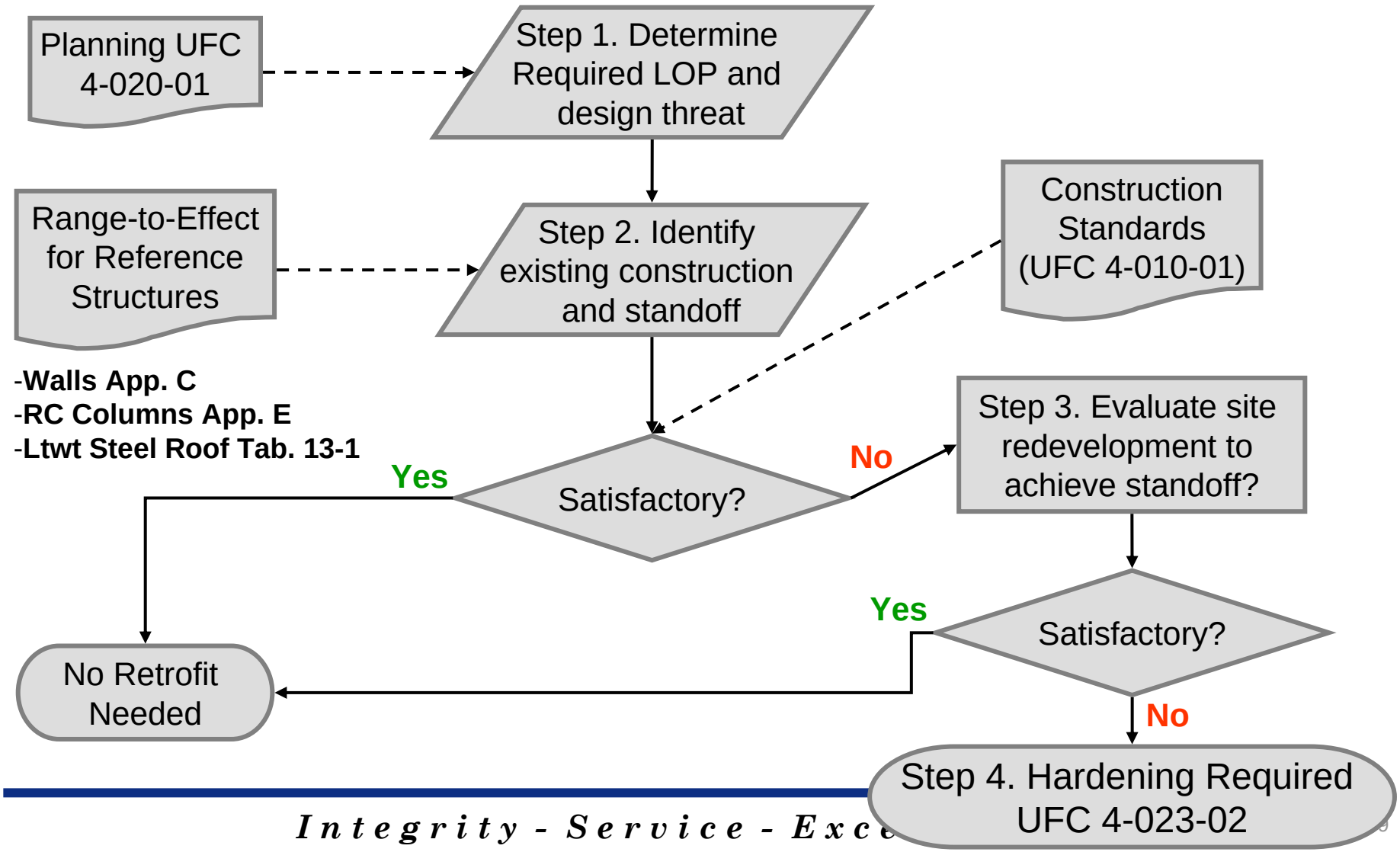
General Design Procedures



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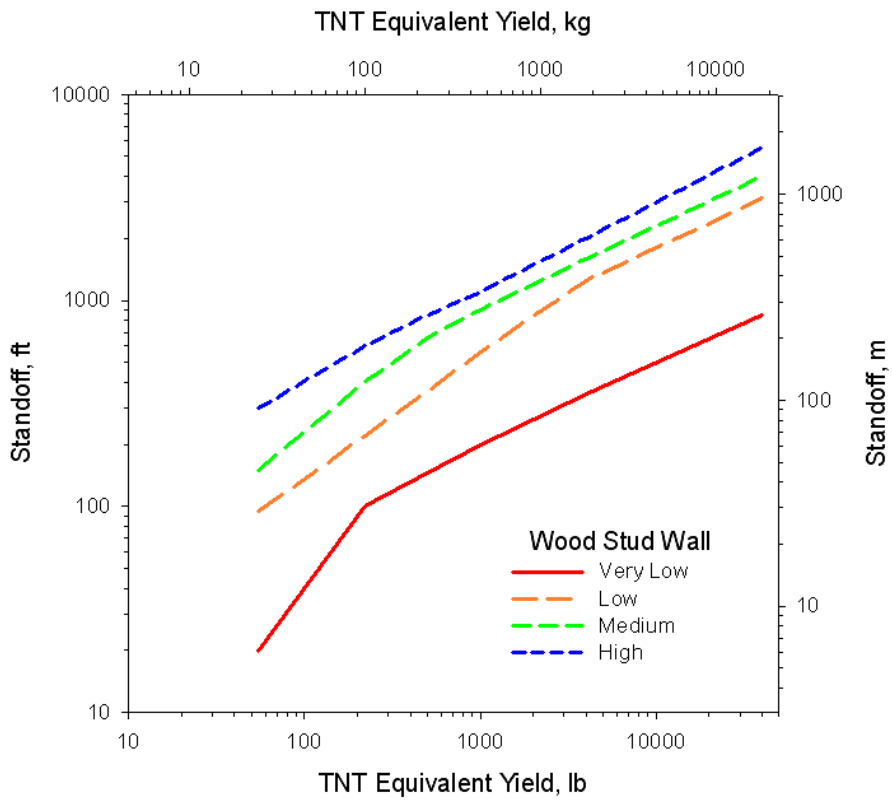
Reference Structures

- UFC includes range-to-effect charts for 14 reference structure types
  - Table 2-1 describes structures, with emphasis on exterior wall construction
  - Appendix C contains wall range-to-effect charts
- User must "best fit" actual structures to one of these types

Figure C-1. Range-to-Effect Chart for Wood Stud Wall.



Wood Stud

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- One-story, wood stud walls, plywood sheathing (Fig. C-1)
- Two-story, wood stud load-bearing walls, plank sheathe siding (Fig. C-2)

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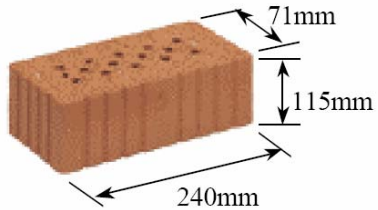
Unreinforced Masonry

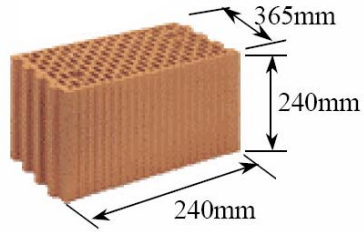
- One-story, unreinforced concrete masonry unit (CMU) infill walls (Fig. C-3)
- One-story, unreinforced CMU infill walls with all cells fully grouted (Fig. C-6)

Unreinforced European Brick

- **Two-story, unreinforced large format clay brick walls, load bearing (Fig. C-4)**
- **Two-story unreinforced standard format clay brick walls, load bearing (Fig. C-5)**



Standard Format



Large Format

Large Format Brick Wall

Reinforced Masonry

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- One-story, reinforced concrete moment frame, lightly reinforced CMU infill walls (Fig. C-7)
- Two-story, steel frame, lightly reinforced CMU infill walls (Fig. C-8)

Reinforced Concrete

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- One-story, 150-mm (6-in) thick reinforced concrete load bearing walls (Fig. C-9)
- Two-story, 200-mm (8-in) thick reinforced concrete load bearing walls (Fig. C-10)

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Other Construction Types

- One-story, pre-engineered building, steel frame, sheet metal walls (Fig. C-11)
- Multi-story, steel frame, glazed curtain walls (Fig. C-12)

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Expeditionary Structures

- One-story, expeditionary building, wood stud walls, plywood sheathing

  (Fig. C-13)
- One-story, expeditionary tent building, canvas duck walls, aluminum framing (Fig. C-14)

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Organization of Wall Retrofit Techniques

- Eleven wall retrofit approaches (Chps. 3-13)
  - Description
  - Applicability
  - Testing
  - Level of Protection
  - Construction Details
- Table 2-2 summarizes key aspects
  - Organized roughly by wall type [all (2) – masonry (6) – stud (3)]
  - "Difficulty to Install" is subjective and relative indicator to help compare the eleven approaches

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Thin Steel Plate Catcher System (Chap. 3)

- Steel plate anchored into frame with optional foam layer
- Applicable to all wall types
- Resulting LOP: Medium
- Installation Difficulty: Medium to High
- Load Bearing: No
- Windows: No

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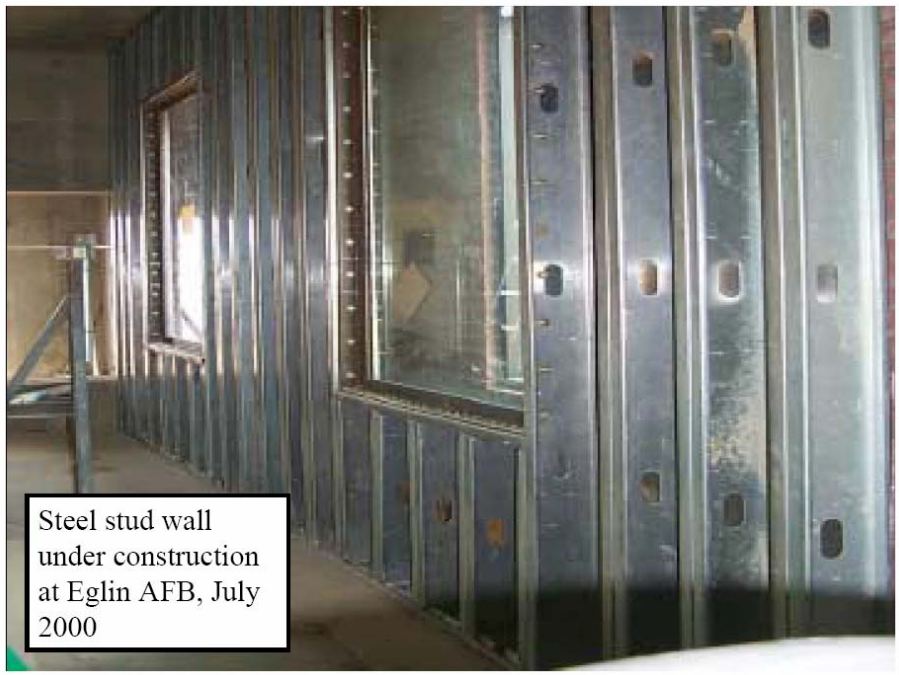
Steel Stud Wall / Window Retrofit (Chap. 4)

- Steel stud wall erected inside existing wall
- Applicable to all wall types with reinforced concrete frames
- Resulting LOP: Medium
- Installation Difficulty: Medium to High
- Load Bearing: Yes
- Windows: Yes



Steel stud wall under construction at Eglin AFB, July 2000

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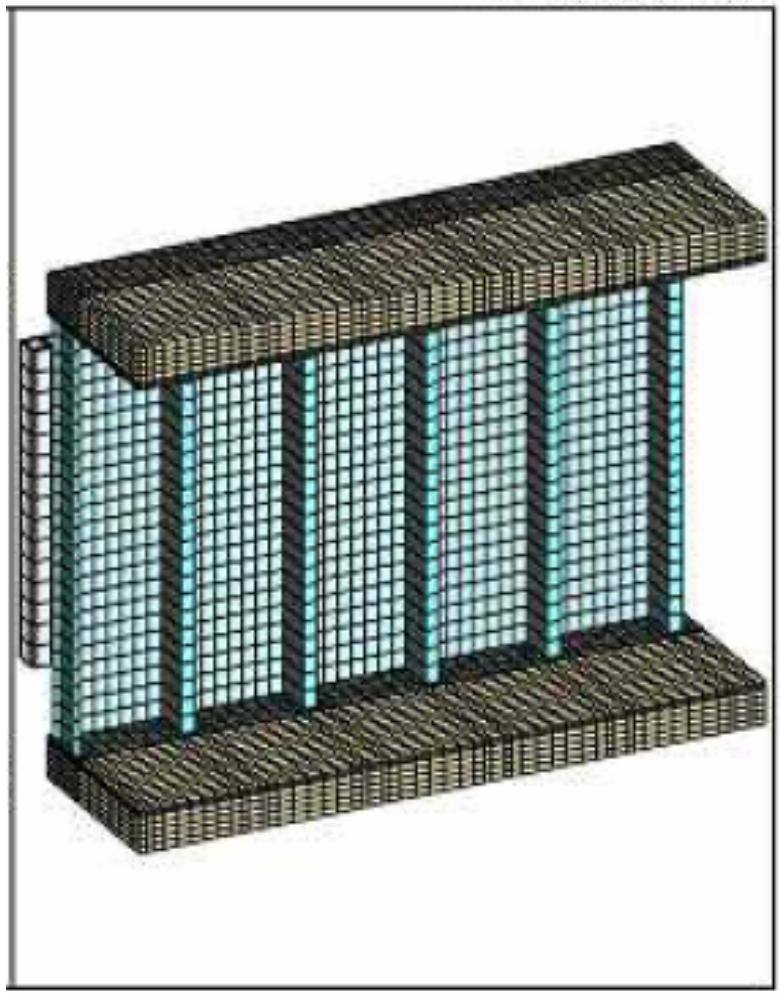
Stiffened Steel Plate Wall Retrofit (Chap. 5)

- Thin steel plate stiffened with structural steel tubes that are anchored into floor diaphragms
- Applicable to load-bearing masonry
- Resulting LOP: Medium
- Installation Difficulty: Medium to High
- Load Bearing: Yes
- Windows: No



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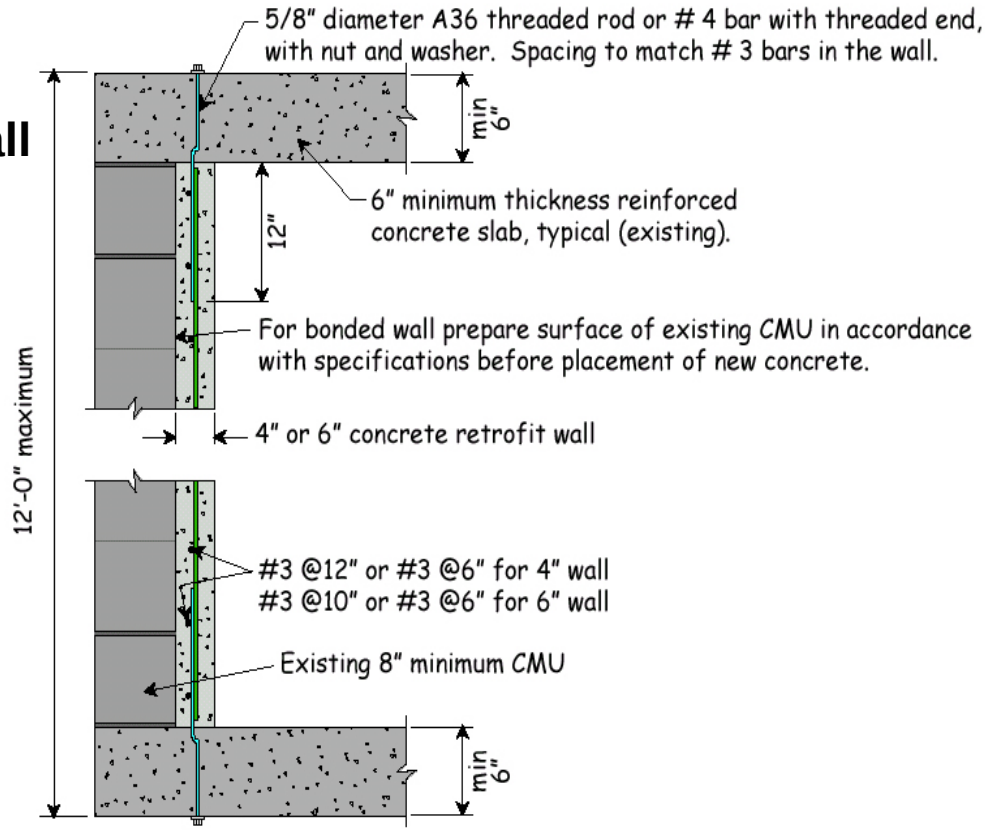
Reinforced Concrete Backing System (Chap. 6)

- Reinforced concrete backing wall placed inside existing wall
- Applicable to reinforced and unreinforced masonry
- Resulting LOP: High
- Installation Difficulty: High
- Load Bearing: Yes
- Windows: Yes



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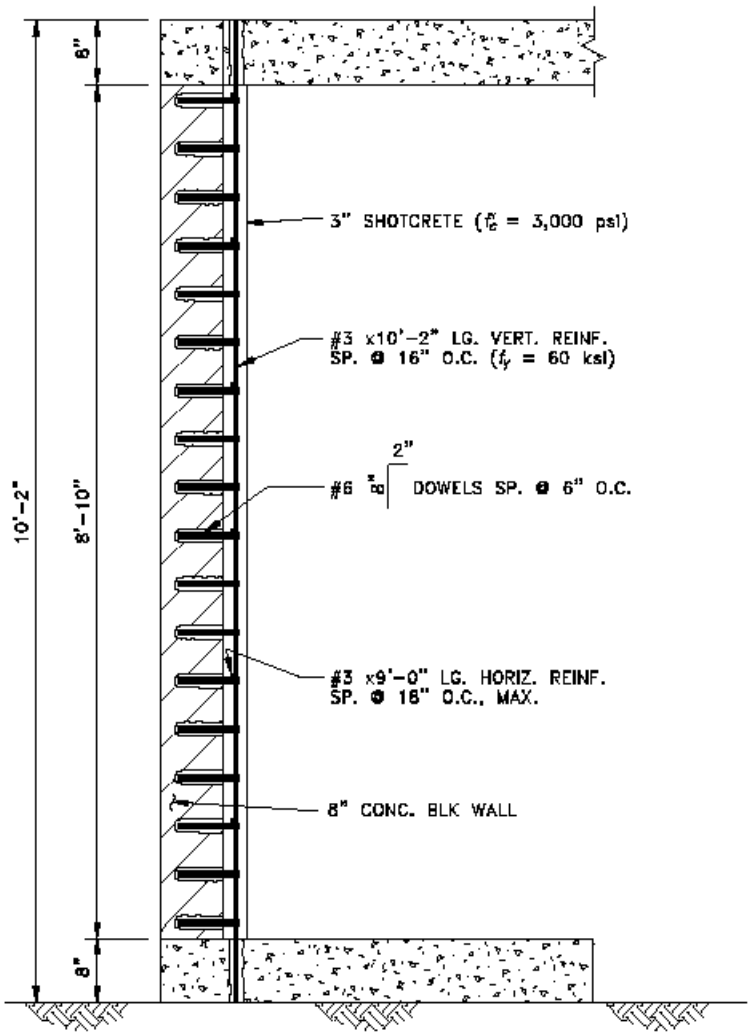
Shotcrete Retrofit for Walls (Chap. 7)

- Reinforced shotcrete doweled into existing masonry
- Applicable to reinforced masonry walls
- Resulting LOP: High
- Installation Difficulty: High
- Load Bearing: Yes
- Windows: Yes



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Geotextile Fabric Catcher System (Chap. 8)

- Geotextile curtain anchored behind existing wall
- Applicable to unreinforced masonry
- Resulting LOP: Medium
- Installation Difficulty: Low
- Load Bearing: No
- Windows: No

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Polymer Retrofit for Masonry (Chap. 9)

- Spray-on polymer coating applied to interior wall surface
- Applicable to unreinforced masonry
- Resulting LOP: Medium
- Installation Difficulty: Medium
- Load Bearing: No
- Windows: Yes

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Geotextile Fabric Catcher System (Chap. 8)

- Geotextile curtain anchored behind existing wall
- Applicable to unreinforced masonry
- Resulting LOP: Medium
- Installation Difficulty: Low
- Load Bearing: No
- Windows: No

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Polymer Retrofit for Masonry (Chap. 9)

- Spray-on polymer coating applied to interior wall surface
- Applicable to unreinforced masonry
- Resulting LOP: Medium
- Installation Difficulty: Medium
- Load Bearing: No
- Windows: Yes

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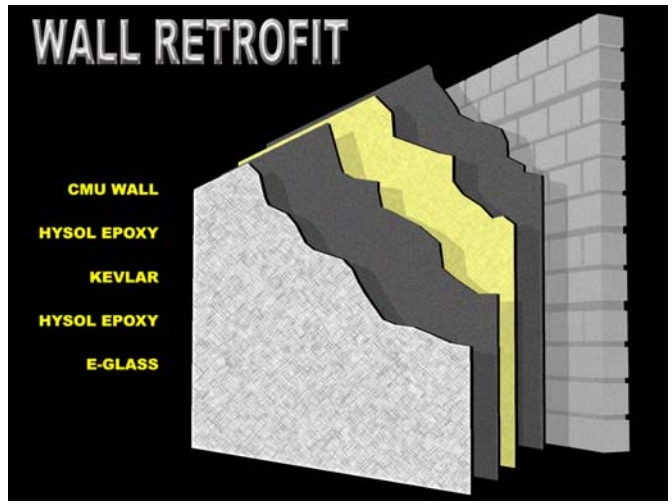
Composite Backing System for Masonry (Chap. 10)

- Fiberglass or aramid fabric in epoxy matrix and bonded to wall
- Applicable to unreinforced masonry
- Resulting LOP: Medium
- Installation Difficulty: Low to Medium
- Load Bearing: No
- Windows: No



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Metal Stud Wall System (Chap. 11)

- 20 gauge steel sheet supported by steel studs anchored into existing frame
- Applicable to infill stud walls
- Resulting LOP: Medium
- Installation Difficulty: Low to Medium
- Load Bearing: No
- Windows: No

Polymer Retrofit for Wood Construction (Chap. 12)

- Spray-on polymer coating applied to interior wall surface
- Applicable to wood stud
- Resulting LOP: Low to High
- Installation Difficulty: Medium
- Load Bearing: No
- Windows: Yes

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Additional Reinforcing Materials Retrofit for Expeditionary Wood Structures (Chap. 13)

- **Additional plywood and dimension lumber attached to structure**
- **Applicable to expeditionary wood structures (SEA Huts)**
- **Resulting LOP: Low to High**
- **Installation Difficulty: Low**
- **Load Bearing: N/A**
- **Windows: Yes**

Selection of Candidate Wall Retrofit Approaches

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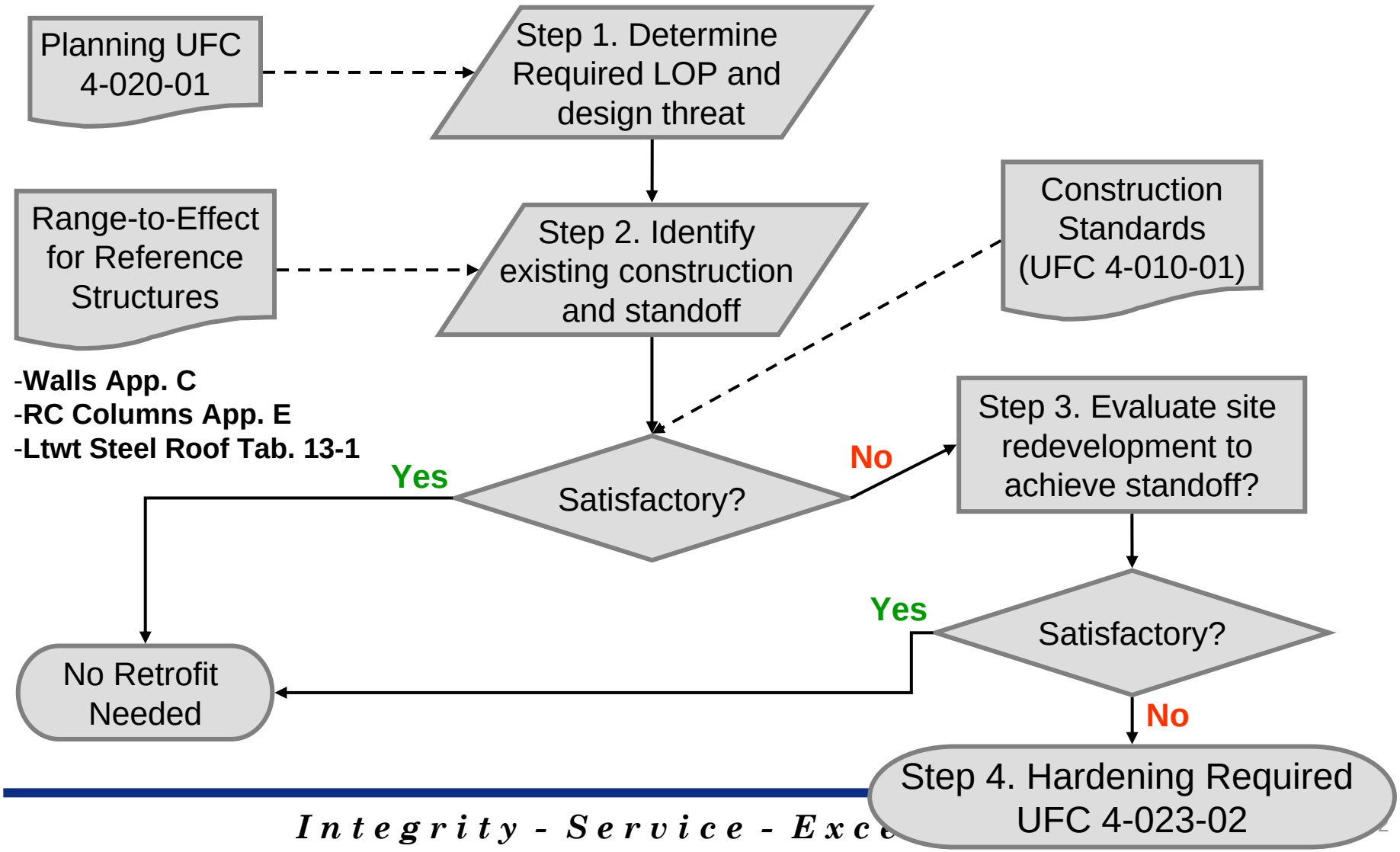

Selection of Candidate Wall Retrofit Approaches, continued

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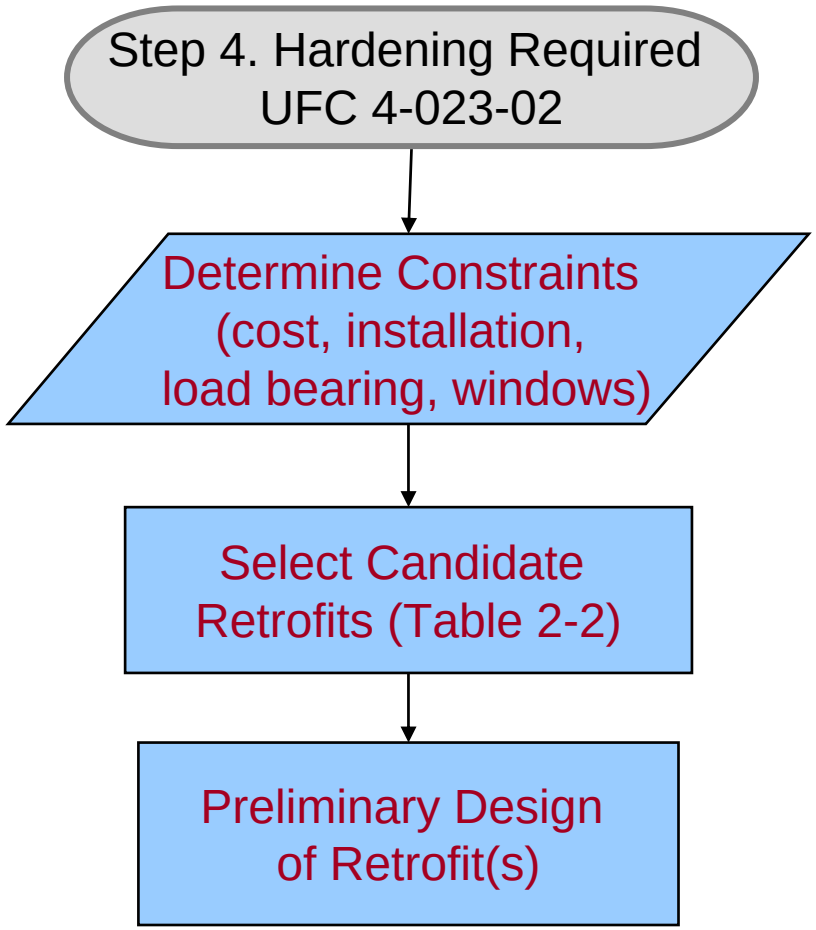
NO



Selection of Candidate Wall Retrofit Approaches, continued

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Table 2-2. Wall Retrofit Systems

Retrofit System (Chapter)	Brief Description	Applicable Wall Type(s)	Resulting Injury LOP	Difficulty to Install	Load Bearing Walls?	Walls with Windows?
Thin Steel Plate Catcher System (3)	Thin steel plate anchored into existing frame with optional foam layer	All	Medium	Medium to High	No	No
Steel Stud Wall / Window Retrofit (4)	16 gauge, six-inch deep steel stud wall built inside existing wall	All with Reinf Concrete Frames	Medium	Medium to High	Yes	Yes
Stiffened Steel Plate Wall Retrofit (5)	Thin steel plate stiffened with structural steel tubes anchored into floor diaphragms	Load Bearing Unreinforced and Reinforced Masonry	Medium	Medium to High	Yes	No
Reinforced Concrete Backing (6)	4-inch or 6-inch reinforced concrete backing wall placed against inside wall face	Unreinforced and Reinforced Masonry	High	High	Yes	Yes
Shotcrete (7)	3-inch reinforced shotcrete doweled into existing masonry	Reinforced Masonry	High	High	Yes	Yes
Geotextile (8)	A curtain of geotextile fabric anchored behind existing wall	Unreinforced Masonry	Medium	Low	No	No
Polymer Retrofit for Masonry (9)	Spray-on polymer coating applied to interior wall surface	Unreinforced Masonry	Medium	Medium	No	Yes
High Strength Composite Backing (10)	Field-made composite of fiberglass or aramid fabric in epoxy matrix and bonded to wall	Unreinforced Masonry	Medium	Low to Medium	No	No
Metal Stud Wall System (11)	20 gauge steel sheet supported by steel studs anchored into existing frame	Infill Stud Walls	Medium	Low to Medium	No	No
Polymer Retrofit for Lightweight Structures (12)	Spray-on polymer coating applied to interior wall surface	Wood Stud	Low to High	Medium	No	Yes
Additional Reinforcing Materials (13)	Plywood attached to interior stud walls, floor; dimension lumber to reinforce frame, trusses	Expeditionary Wood Structures (SEA Huts)	Low to High	Low	N/A	Yes

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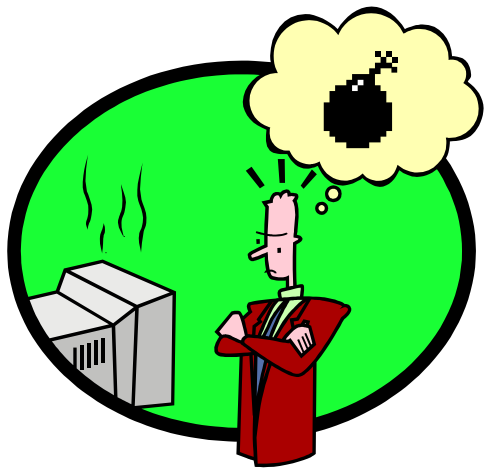
Example Problem: Selection of Candidate Wall Retrofit Approaches

- **Given: 1-story wood barracks,**
  2.4 m (8-ft) walls,
  45 m (150 ft) perimeter standoff
  Required LOP = Low
  Required DBT = 225 kg (500 lb)
- **Find: Evaluate existing structure and select candidate retrofits if needed**



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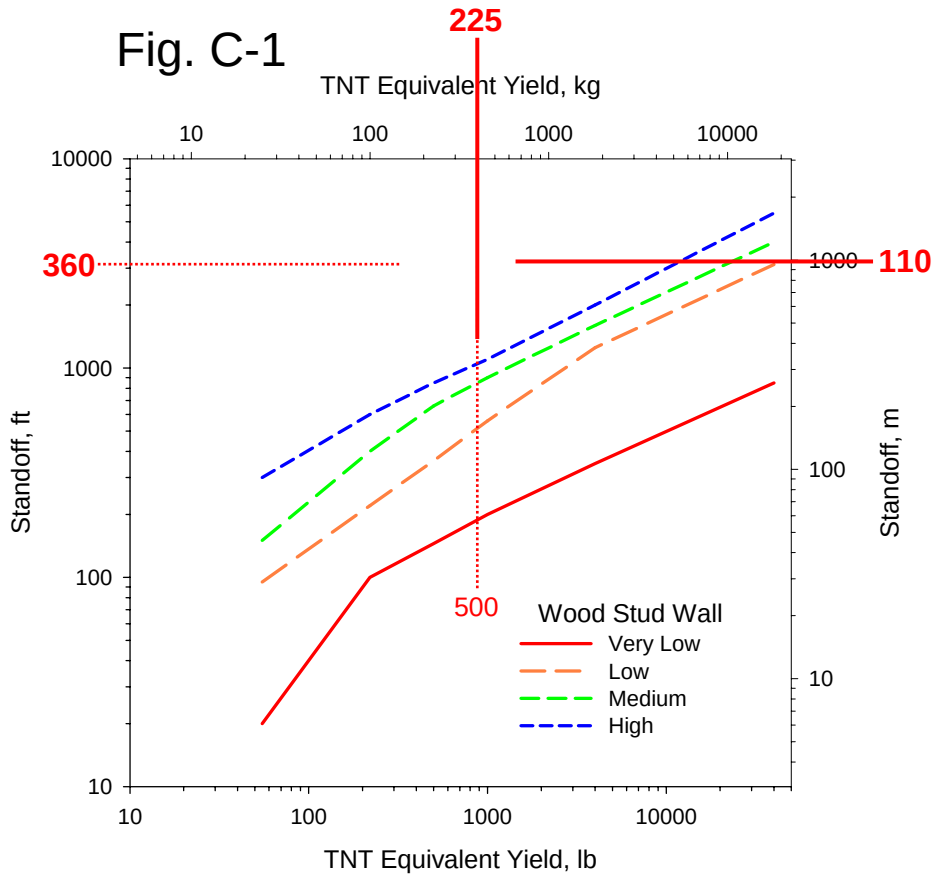
Example Problem, continued

Solution:

- **Step 1 (Given):**
  LOP = Low
  DBT = 225 kg (500 lb)
- **Step 2:**
  From App. C, select
  Wood Stud Wall (Fig. C-1)
  ➔ Required standoff = 110 m

Fig. C-1



45 m (150 ft) < 110 m (360 ft) ➔ **Must Mitigate**

Example Problem, continued

- **Solution:**
  - **Step 3:**
    Assume site layout is fixed and additional standoff is not available
  - **Step 4:**
    Table 2-2 Options:
    Thin Steel Plate Catcher System
    Metal Stud Wall System
    Polymer Retrofit for Wood Construction
    Additional Reinforcing Materials

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Example Problem, continued

Inputs from Table 2-2 and Applicable Range-to-Effect Charts

Retrofit System	LOP	Difficult to Install	Load Bearing Walls?	Walls with Windows?	Low LOP Standoff
Thin Steel Plate Catcher System	**Medium**	**Medium to High**	**No**	**No**	**2.4 m (8 ft) (Medium LOP)**
Metal Stud Wall System	**Medium**	**Low to Medium**	**No**	**No**	**27.6 m (90 ft) (Rebuild wall)**
Polymer Retrofit	**Low to High**	**Medium**	**No**	**Yes**	**48.8 m (160 ft)**
Additional Reinforcing Materials	**Low to High**	**Low**	**N/A**	**Yes**	**39.6 m (130 ft)**

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Questions?