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DENTON,H. Office of Nuclear Reactor Regulation, Director

SUBJECT: Responds to 850212 request for addl info re IE Bulletin 80-11, "Masonry Wall Design." Encl data & evaluation demonstrate that stress-strain test data representative of DUR-O-WAL samples.

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Iowa Electric Light and Power Company

April 19, 1985
NG-85-1712

Mr. Harold Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
IE Bulletin 80-11 Response -
Masonry Wall Design
Request for Additional Information
File: A-101a

Dear Mr. Denton:

This letter and its attachment provide a response to your staff's request for information resulting from a conference call of February 12, 1985. As the response to question No. 2 explains, the test wire data used to evaluate the performance of DUR-O-WAL masonry joint reinforcing was not obtained from DUR-O-WAL samples specifically. The data and evaluation enclosed, however, demonstrate that the stress-strain test data is representative of DUR-O-WAL, and that its performance is acceptable.

Please contact us if there are questions regarding this submittal.

Very truly yours,

Richard W. McGaughy

Richard W. McGaughy
Manager, Nuclear Division

RWM/SLS/ta*

Attachment: Response to the Request for Additional Information,
IE Bulletin 80-11: Masonry Wall Design

cc: S. Swails
L. Liu
S. Tuthill
M. Thadani
NRC Resident Office
Commitment Control No. 850069

IE11 1/1 Original To: Reg Files

RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION MADE BY THE NRC FOR IE BULLETIN 80-11: MASONRY WALL DESIGN DUANE ARNOLD ENERGY CENTER

QUESTION

1. For those walls in which the calculated stress exceeded 40 ksi, please provide the following information for each wall: calculated stress, wall's dimensions and thickness, type and spacing of reinforcement, and connection details at the boundary. Also, provide sample calculations (with necessary explanation to make them understandable) illustrating the analytical procedures used in obtaining the stress values.

RESPONSE

The calculated stresses in the horizontal reinforcement, the wall dimensions and thickness, the type and spacing of the vertical and horizontal reinforcement, and the boundary conditions assumed in the analysis for the walls with a calculated stress exceeding 40.0 ksi are listed in Table 1. Typical support details are shown in Figures 1 and 2.

Two sample calculations illustrating the analytical procedures used in obtaining the horizontal reinforcement stress values are contained in Appendix A.

QUESTION

2. Provide the stress-strain relationship of the type of joint reinforcement used in the plant. If test data from the manufacturer are not available, it is recommended that some simple tests be conducted to obtain this relationship.

RESPONSE

Figures 3 and 4 show stress-strain relationships (from References 1 and 2) for cold-drawn wire typical of that used in the manufacture of masonry joint reinforcing (DUR-O-WAL). The tests reported in References 1 and 2 were performed on wire utilized in the manufacture of welded wire fabric (WWF).

WWF is manufactured in accordance with the following ASTM specifications:

a. For WWF using plain wires:

- Manufacture

  ASTM A 185 Standard Specification for Welded Steel Wire Fabric for Concrete Reinforcement

- Wire properties

  ASTM A 82 Standard Specification for Cold-Drawn Steel Wire for Concrete Reinforcement

b. For WWF using deformed wires:

- Manufacture

  ASTM A 497 Standard Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement

- Wire properties

  ASTM A 496 Standard Specification for Deformed Steel Wire for Concrete Reinforcement

Joint reinforcing (such as DUR-O-WAL) is typically manufactured using ASTM A 82 cold-drawn plain or deformed wire. The joint reinforcing of DAEC consists of 3/16-inch (0.1875 inch) diameter longitudinal deformed wire with 9 gage (0.148 inch diameter) plain web, both conforming to ASTM A 82. Therefore, the stress-strain curves for plain and deformed wire (ASTM A 82 and ASTM A 496) shown in Figures 3 and 4 should be representative of DUR-O-WAL wire. These curves are based on stress-strain data selected from References 1 and 2 for wire sizes approximating the diameter of the longltudinal DUR-O-WAL wire (3/16 or 0.1875 inch). A comparison of the minimum required physical properties for ASTM A 82 and ASTM A 496 wire in this size range is shown in Table 2. As indicated in Table 2, the requirements are similar except for the bend tests, which are less restrictive for the deformed wire (ASTM A 496). A comparison of Figures 3 and 4, however, shows very little difference in stress-strain characteristics for deformed and plain wire. Both sets of curves reflect ductile behavior.

REFERENCES

1. Investigation of Stress-Strain Characteristics of Plain Wire, Wire Reinforcement Institute, Wiss, Janney, Elstner & Associates (September 1969)

2. Investigation of Stress-Strain Characteristics of Plain Wire, Wire Reinforcement Institute, Wiss, Janney, Elstner & Associates (October 1969)

TABLE I

BLOCK WALL DESIGN SUMMARY - WALLS WITH CALCULATED HORIZONTAL REINFORCING STRESS EQUAL TO OR GREATER THAN 40 KSI

Wall No.	Calculated Stress in Horizontal Reinforcement (ksi)	Wall Dimensions: Width (ft)	Wall Dimensions: Height (ft)	Wall Dimensions: Thickness (in.)	Boundary Conditions[1] Side-Side-Top-Bottom	Horizontal Reinforcement: Bond Beam Reinforcement[2]	Horizontal Reinforcement: Joint Reinforcement Spacing[3] (in.)	Vertical Reinforcement	Grouted Cell Spacing[4] (in.)
205-1	49.1	8.0	10.0	12.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
205-7	42.1	3.5	13.3	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
205-8	42.1	6.0	13.3	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
205-12	42.1	3.5	13.3	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
205-14	42.1	7.0	6.0	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
405-12	40.1	46.7	25.0	30.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#6 @ 16"	F
406-2	46.0	11.7	26.5	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
412-3	48.9	7.2	7.9	24.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#6 @ 16"	F
412-3A	43.3	14.0	12.3	24.0	S-S-S-S	4-#6 @ 4'-0"	16.0	#5 @ 16"	F
412-8	43.3	16.2	22.3	24.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	F
412-9	54.0	21.3	22.7	12.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	F
412-10	43.3	3.5	23.5	24.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	F
412-11	43.3	9.3	23.5	24.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	F
412-13	54.0	12.0	24.0	18.0	S-FX-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
412-14	47.2	4.0	25.3	12.0	S-FR-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
412-17A	48.9	32.2	21.9	27.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#6 @ 16"	F
412-18	52.2	22.7	21.9	12.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
417-16	44.4	58.8	18.3	12.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	F
418-8	43.9	12.1	19.6	8.0	S-S-S-S	4-#4 @ 4'-0"	16.0	#5 @ 16"	16
423-3	40.9	5.3	20.1	12.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
423-4	40.9	8.2	22.2	12.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	F
664-1	40.6	6.0	12.3	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
664-2	40.6	4.0	12.0	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16
664-3	40.6	9.8	12.3	8.0	S-S-S-S	4-#4 @ 4'-0"	8.0	#5 @ 16"	16

Notes:

1. Boundary Conditions

   S = Simple
   FR = Free
   FX = Fixed

2. For multi-wythe walls, the bond beam reinforcement is applicable to each outer wythe of the wall.

3. Joint reinforcement consist of extra heavy DUR-O-WAL joint reinforcement spaced vertically as noted in the table above. For multi-wythe walls, the joint reinforcement is placed in the outer wythes only.

4. F indicates fully grouted.

TABLE 2

COMPARISON OF MINIMUM REQUIRED PHYSICAL PROPERTIES FOR ASTM A 82 AND ASTM A 496 WIRE

	Plain Wire ASTM A 82	Deformed Wire ASTM A 496
Minimum Strength (ksi)		
General		
Yield	70	75
Ultimate	80	85
Welded Wire Fabric		
Yield	65(1)	70
Ultimate	75(1)	80
Bend Test Requirements		
Bend Angle	180 degrees	90 degrees
Pin diameter diameter(2)	One wire diameters(3)	Two wire

(1)Wire size W1.2 (0.124 inch diameter) and larger
(2)Wire size W7 (0.299 inch diameter) and smaller
(3)Wire size D-6 (0.276 inch diameter) and smaller

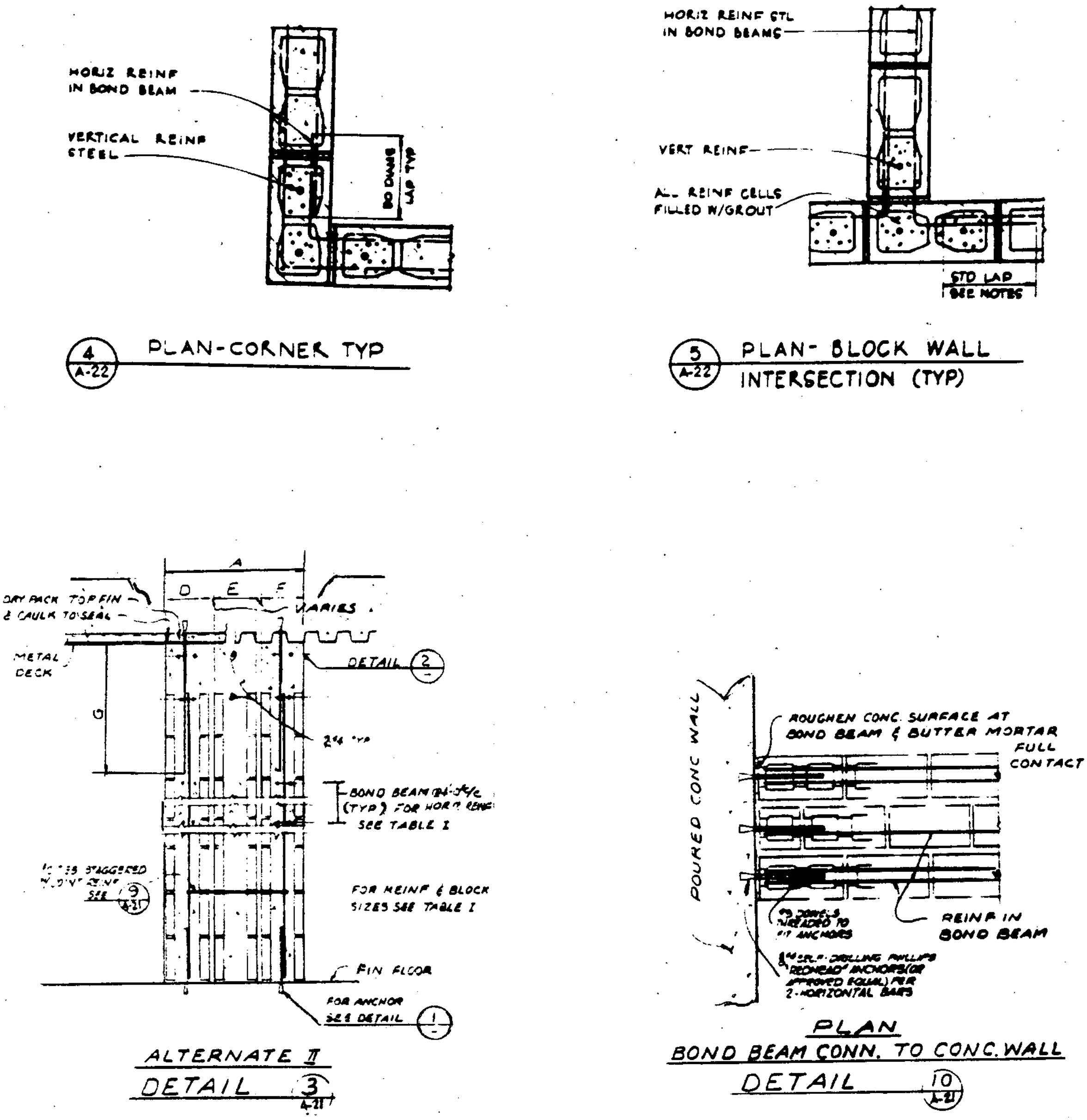
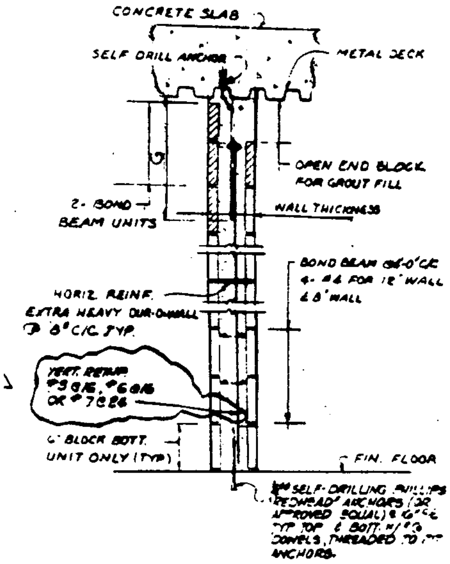
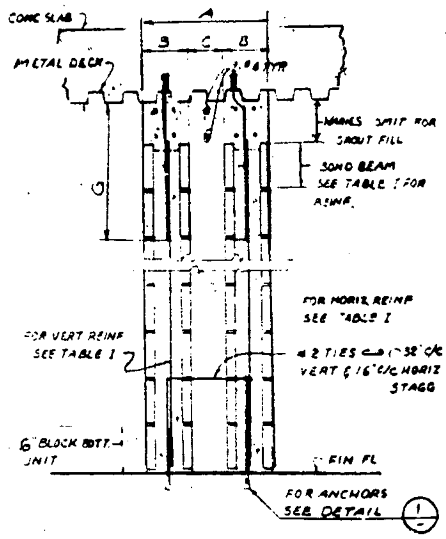


Figure 1 Typical Block Wall Support Details



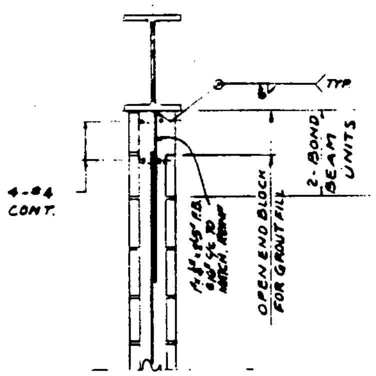
DETAIL 1 A-21

TYP. FOR 8" & 12" WALLS



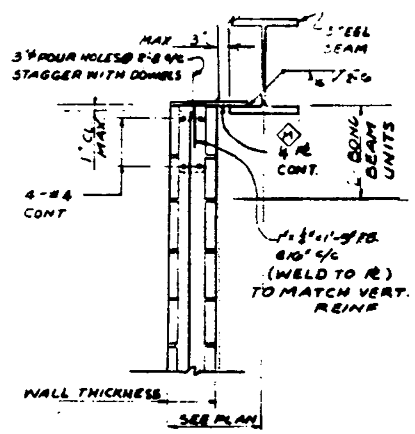
ALTERNATE I

DETAIL 2 A-21



SECTION AT STEEL BEAM

DETAIL 7 A-21



DETAIL 8 A-21

Figure 2 Typical Block Wall Support Details

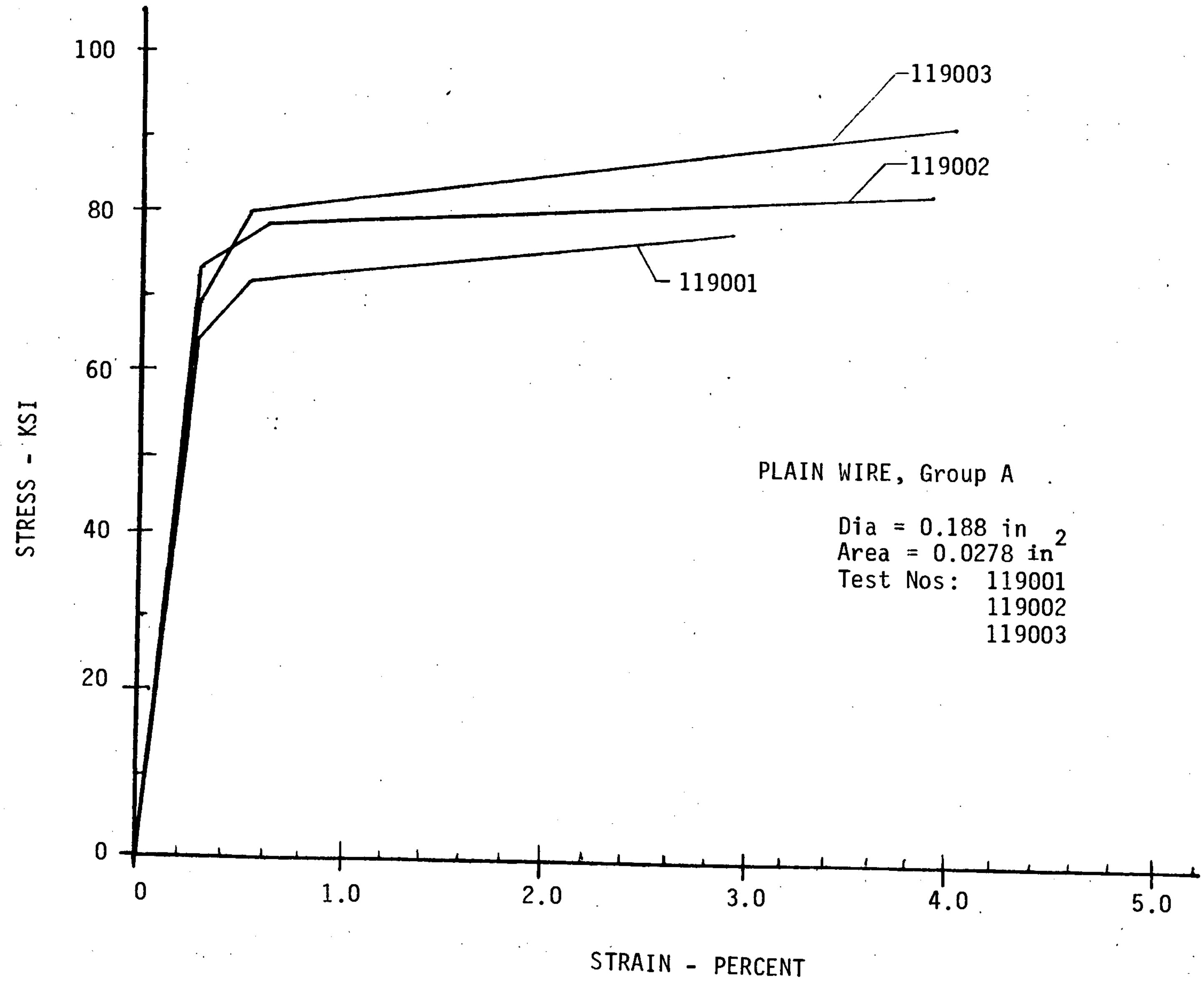


Figure 3 Typical Stress - Strain Curves for Plain Wire, (Reference 1)

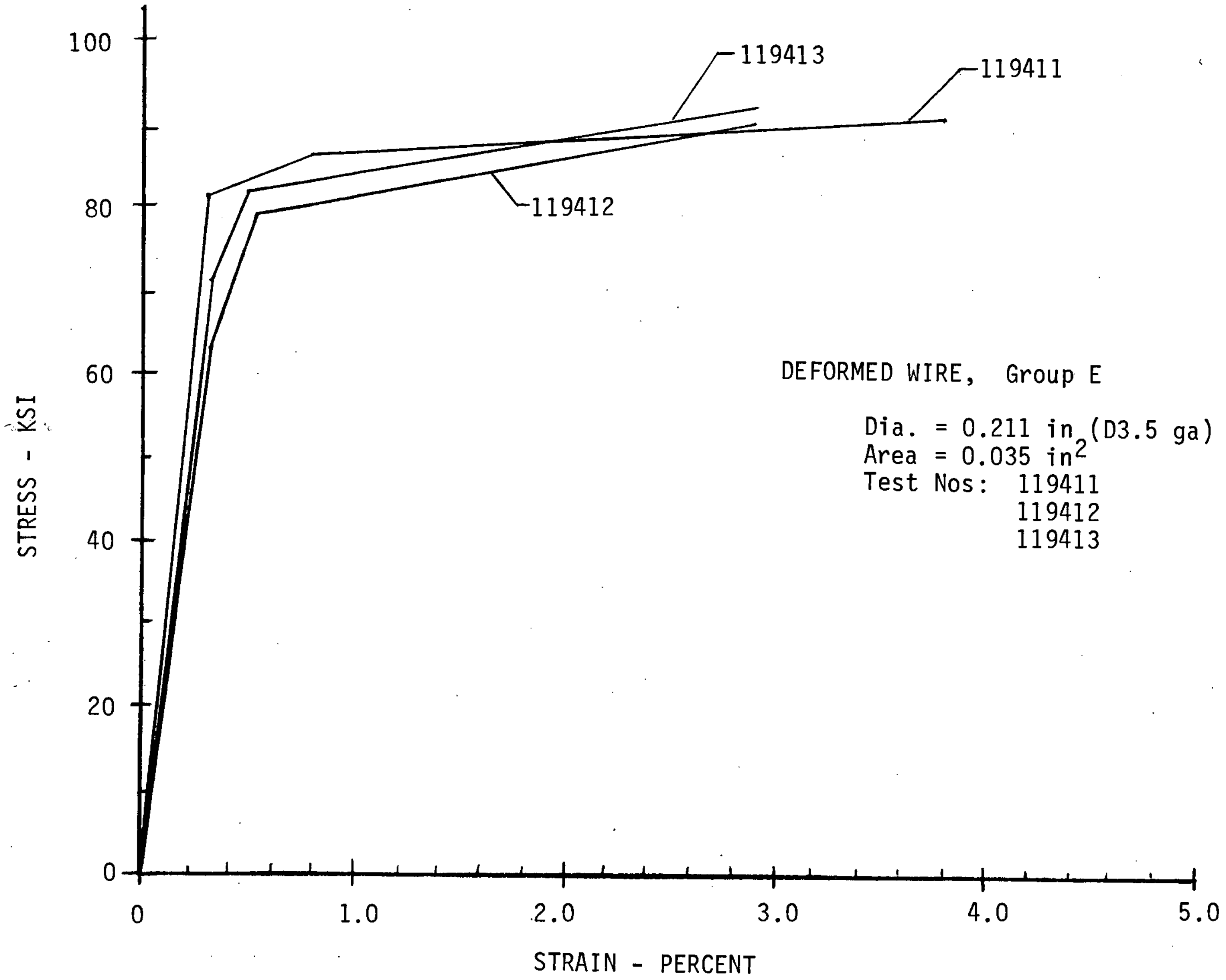


Figure 4 Typical Stress - Strain Curves for Deformed Wires (Reference 2)

APPENDIX A

SAMPLE CALCULATIONS OF MASONRY WALL ANALYSES

Two sample calculations are presented to illustrate the analytical procedures used in calculating stresses in the horizontal reinforcement of the masonry walls at the Duane Arnold nuclear plant. Sample Calculation A-1 illustrates the analysis of a wall assumed to span both horizontally and vertically. Sample Calculation A-2 illustrates the analysis of a wall assumed to span in the horizontal direction only. The sample calculations are not analyses of actual walls, but represent the typical procedures used for analyzing masonry walls at Duane Arnold for the response to IE Bulletin 80-11.

SAMPLE CALCULATION A-1: TWO-WAY SPAN

A. Wall Data

Wall location: In reactor building with base at El 786'-0"
Width (a) = 16'-0" = 192 inches
Height (b) = 10'-8" = 128 inches
Thickness (t) = 12 inches
Number of wythes = 1
f'_m = 2,000 psi
M_o = 2,000 psi
$E_m = 2 \times 10^6$ psi
Poisson's ratio = 0.2
Unit weight (γ) = 150 lb/ft²
Unit mass (ρ) = 0.0027 lb-sec²/in.³
Cracked section moment of inertia (I_{CR}) = 81.78 in.⁴/ft
Reinforcement yield stress (F_y) = 60.0 ksi
DUR-O-WAL yield stress (F_y') = 70.0 ksi
Horizontal reinforcement = Bond beams with four No. 4 bars at 4'-0" spacing; plus extra-heavy DUR-O-WAL at 8 inches
Vertical reinforcement = No. 5 bars at 16 inch spacing

B. Assumptions

1. Wall will be treated as a plate spanning both vertically and horizontally for the frequency calculation and moment calculations.
2. All four boundaries (top, bottom, and two sides) are assumed simply supported.

C. Calculate the Fundamental Frequency of the Wall

$$f_n = \frac{\pi}{2}\left[\frac{D}{\rho}\right]^{1/2}\left[\frac{1}{a^2}+\frac{1}{b^2}\right]$$

Reference A-1
Table A1

where

f_n = frequency of the wall (cps)
a = wall width (inches)
b = wall height (inches)

$$D = \frac{E_m I_{CR}}{b' (1 - \mu^2)} = \frac{2.0 \times 10^6 \ (81.78)}{12 \ (1 - 0.2^2)} = 1.4 \times 10^7 \text{ lb/in.}$$

μ = Poisson's ratio
b' = width of section being analyzed - inches
ρ = unit mass

Therefore

$$f_n = \frac{\pi}{2} \left[\frac{1.4 \times 10^7}{0.0027}\right]^{1/2} \left[\frac{1}{(192)^2} + \frac{1}{(128)^2}\right] = 10.0 \text{ cps}$$

and

$$\text{period} = \frac{1}{f_n} = \frac{1}{10.0} = 0.1 \text{ sec}$$

D. Load Combinations

Note: Loads to be considered for the analysis

D = dead load = 0
L = live load = 0
W = wind load = 0
E_o = operating basis earthquake (OBE) load
E_{ss} = safe shutdown or design basis (SSE or DBE) earthquake
W_t = tornado load = 0
Y_p = pipe break = 8.0 kips - jet impingement load
P_A = room pressurization due to pipe break = 1.2 psi

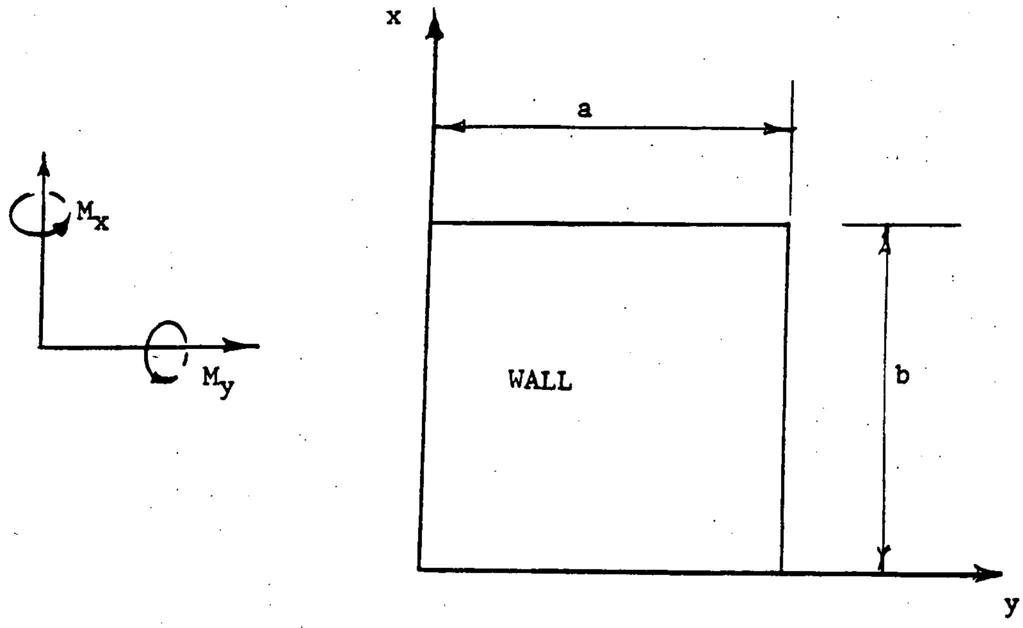
Load Combinations Considered

Normal $D + L + E_o$

Abnormal $D + L + E_{ss} + Y + P_a$

Note: Abnormal load case will govern because D = 0 and L = 0. The governing load combination = $E_{ss} + Y_p + P_a$.

E. Calculate Applied Moments



1. Calculate moments due to seismic loads

From Reference A-1, Table B.3a:

$M_x = qa^2C_x$

$M_y = qb^2C_y$

where

M_x = horizontal span moment
M_y = vertical span moment
C_x = horizontal moment coefficient (Reference A-1)
C_y = vertical moment coefficient (Reference A-1)
a = wall width - inches
b = wall height - inches
q = seismic equivalent unit pressure = γA_e
= 150 (0.64)

where

γ = unit weight
A_e = horizontal acceleration corresponding to a wall frequency of 10 cps (period = 0.1 sec) as obtained from the response spectrum at El 812'-0" (next highest floor level) in the reactor building for 5% damping. (Reference A-3, Figure C-3.)
A_e = 2 (0.20 g's) = 0.40 g's (DBE conditions)

Therefore

$$q = (150)(0.40) = 60 \text{ lb/ft}^2$$
$$\gamma = \frac{a}{b} = \frac{192}{128} = 1.50$$

Therefore, from Reference A-1, Table B.3a:

$$C_x = 0.0173$$
$$C_y = 0.0772$$

Therefore

$$M_{xe} = 60(192)^2 (0.0173)/144 = 267 \text{ ft-lb/ft}$$
$$M_{ye} = 60(128)^2 (0.0772)/144 = 527 \text{ ft-lb/ft}$$

2. Calculate moment due to room pressurization from pipe break

Note: Use same procedure as above.

Room Pressurization = 1.2 psi

$$M_{xp} = qa^2C_x = 1.2(192)^2(0.0173) = 765 \text{ ft-lb/ft}$$
$$M_{yp} = qb^2C_y = 1.2(128)^2(0.0772) = 1{,}518 \text{ ft-lb/ft}$$

3. Calculate moment due to pipe break jet impingement

Jet impingement load = 8.0 kips

Note: Assume jet impingement load acts at the center of the wall.

From Reference A-1:

$$M_x = C_xQ$$

$$M_y = C_yQ$$

where

Q = concentrated load = 8.0(1.2) = 9.6 kips
Note: The 1.2 increase factor for jet impingement loads is in accordance with Reference A-2, Attachment 3, Section 5.2.2.e. This factor (resistance-to-force ratio) limits the ductility ratio to a maximum value of 3 with an available resistance margin of 20%.

$$\gamma = \frac{a}{b} = \frac{192}{128} = 1.50$$
$$\frac{x}{b} = \frac{0.5(192)}{128} = 0.75$$
$$\frac{y}{b} = 0.5$$

Therefore; from Reference A-1; Table B.3.1

$$C_x = 0.305$$
$$C_y = 0.351$$

Therefore

$$M_{xj} = 0.305(9,600) = 2,928 \text{ ft-lb/ft}$$
$$M_{yj} = 0.351(9,600) = 3,370 \text{ ft-lb/ft}$$

4. Calculate minimum required moment capacities to resist combined loads.

Load combination = $E_{ss} + P_a + Y_p$

Therefore

$$\text{Total } M_x = 267 + 765 + 2,928 = 3,960 \text{ ft-lb/ft}$$
$$\text{Total } M_y = 527 + 1,518 + 3,370 = 5,415 \text{ ft-lb/ft}$$

F. Calculate Moment Capacities of the Wall

Note: The moment capacity of the wall will be determined for a 12-inch wide beam strip using the "working stress" method.

1. Calculate moment capacity in the vertical direction

$$M_{yc} = A_s F_s \left[d - \frac{kd}{3}\right]$$

where

A_s = 0.233 in²
b = 12 inches
d = 6 inches
F_s = 0.9 F_y; Reference A-2; Section 5.2.1 for extreme environmental/abnormal loads
= 0.9(60,000) = 54,000 psi

$$k = \sqrt{(pn)^2 + 2pn} - pn = 0.263$$

$$n = \frac{E_s}{E_m} = \frac{29 \times 10^6}{2.0 \times 10^6} = 14.5$$

$$p = \frac{A_s}{db} = \frac{0.233}{(6)(12)} = 0.0032$$

Therefore

$$M_{yc} = 0.233(54,000)\left[6 - \frac{(0.263)(6)}{3}\right]$$
$$= 68,847 \text{ in.-lb/ft}$$
$$= 5,739 \text{ ft-lb/ft}$$

2. Calculate moment capacity in the horizontal direction

$$M_{xc} = A_s F_s \left[d - \frac{kd}{3}\right]$$

where

A_s = 0.15 in²
b = 12 inches
d = 10 inches
$F_s = 0.9\ F_y$ = 54,000 psi

$$k = \sqrt{(pn)^2 + 2pn} - pn = 0.173$$
$$n = 14.5$$
$$p = \frac{A_s}{db} = \frac{0.15}{(10)(12)} = 0.00125$$

Therefore

$$M_{xc} = 0.15(54{,}000)\left[10 - \frac{0.173(10)}{3}\right]$$
$$= 76{,}329 \text{ in-lb/ft}$$
$$= 6{,}361 \text{ ft-lb/ft}$$

G. Compare Required with Available Moment Capacity

	Moment Required (ft-lb/ft)	Moment Available (ft-lb/ft)
M_x	3,960	6,361
M_y	5,415	5,739

Available M_x and M_y > Required M_x and M_y

<u>Wall is okay</u>

Note:

$$M_{ye} + M_{yp} + 2\,\frac{M_{yi}}{1.2} > M_{ye}$$

Therefore, wall responds inelastic

F_{sy} = 54 ksi

SAMPLE CALCULATION A-2: ONE-WAY SPAN

A. Wall Data

Wall location: In reactor building with base at El 812'-0"
Width (a) = 12'-0" = 144 inches
Height (b) = 20'-0" = 240 inches
Thickness (t) = 8 inches
Number of wythes = 1
f'_m = 2,000 psi
M_O = 2,000 psi
$E_m = 2 \times 10^6$ psi
Poisson's ratio (μ)= 0.2
Unit weight (γ), wall + attachments = 80 + 10 = 90 lb/ft^2
Unit mass (ρ) = 0.0016 $lb\text{-}sec^2/inches^3$
Reinforcement yield stress (F_y) = 60.0 ksi
DUR-O-WAL yield stress (F_y') = 70.0 ksi
Horizontal reinforcement = Bond beams with four No. 4 bars at 4'-0" spacing; plus extra-heavy DUR-O-WAL at 8 inches
Vertical reinforcement = No. 5 bars at 16 inch spacing

B. Assumptions

1. A one-way horizontal beam strip analysis will be used for calculating applied moments.

2. All four boundaries (top, bottom, and two sides) are assumed simply supported.

3. The seismic accelerations will be obtained from the peak of response spectrum. Therefore, the frequency of the wall need not be calculated.

C. Load Combination

Note: Loads to be considered for the analysis

D = dead load = 0
L = live load = 0
W = wind load = 0
E_o = operating basis earthquake (OBE) load
E_{ss} = safe shutdown or design basis (SSE or DBE) earthquake
W_t = tornado load = 100 lb/ft^2

Loading Combination Cases to be Determined

Normal D + L + E_o

Abnormal

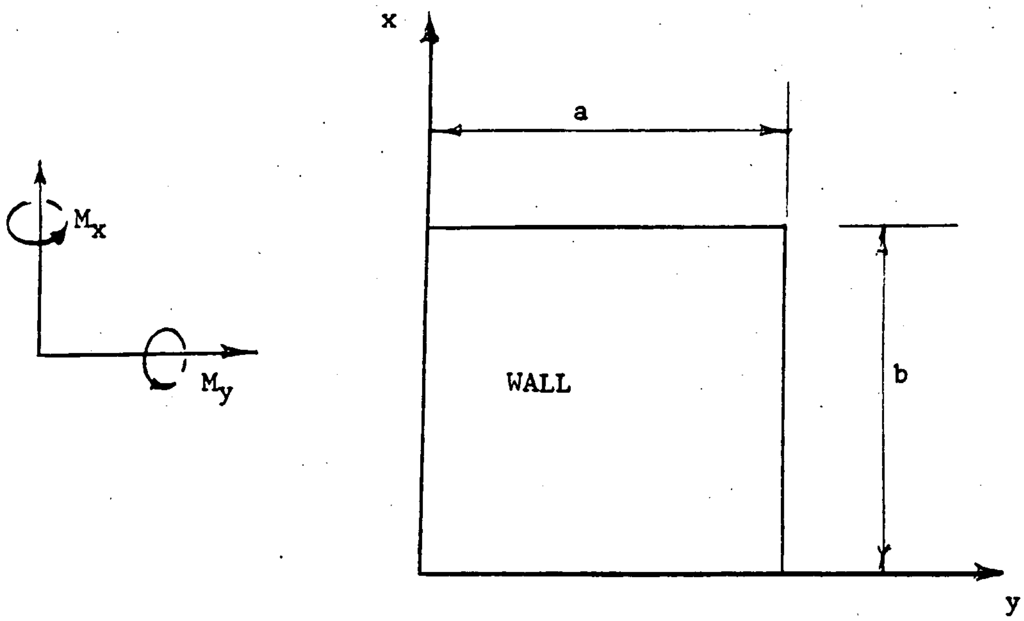
a) D + L + E_{ss}

b) $D + L + W_t$

c) $W_t = 100$ psf

Note: Abnormal loading controls.

D. Calculate Applied Moments



1. Load Combination 1 = $D + L + E_{ss}$

a. Moment due to uniform seismic wall load

$$M_x = \frac{qa^2}{8}$$

where

$q = \gamma A_e = 90(1.52$ g's) = 137 lb/ft²
γ = weight of wall and attachments per square foot
A_e = horizontal wall acceleration corresponding to response spectrum peak acceleration at El 833'-6" (next highest floor level) for 5% damping in reactor building (Reference A-3, Figure C-2).
$A_e = 2(0.76) = 1.52$ g's (DBE conditions)

Therefore

$$M_{xe} = \frac{137(12.0)^2}{8} = 2,460 \text{ ft-lb/ft}$$

2. Load Combination 2 = D + L + W_t

W_t = 100 lb/ft² < 137 lb/ft²

Therefore, the seismic load combination (D + L + E_{ss}) controls.

E. Calculate the Moment Capacity of the Wall

Note: The moment capacity of the wall will be determined for a 12-inch wide horizontal beam strip using the "working stress" method.

$$M_{xc} = A_s F_s \left[d - \frac{kd}{3}\right]$$

where

A_s = 0.15 in²
d = 6 inches
b = 12 inches
F_s = 1.67 (24,000 psi) = 40.000 psi
Note: The 1.67 stress increase factor is from Reference A-2, Attachment 3, Section 5.2.1 for extreme environmental/abnormal loads. The allowable stress of 24,000 psi for Grade 60 reinforcement is from Reference A-4, Section 10.2.1.1.

$$k = \sqrt{(pn)^2 + 2pn} - pn = 0.218$$

$$n = \frac{E_s}{E_m} = \frac{29 \times 10^6}{2 \times 10^6} = 14.5$$

$$p = \frac{A_s}{bd} = \frac{0.15}{(6)(12)} = 0.0021$$

Therefore

$$M_{xc} = (0.15)(40{,}000)\left[6 - \frac{0.218(6)}{3}\right]/12$$
$$= 2{,}782 \text{ ft-lb/ft}$$

F. Check Applied Moment Against Moment Capacity

M_{xe} = 2,460 in.ft
M_{xc} = 2,782 in.ft

$M_{xc} > M_{xe}$

Therefore

Wall okay

G. Calculate Actual Stresses in the Horizontal Reinforcement

$$f_s = \frac{F_s M_{xe}}{M_{xc}}$$

where

f_s = actual stress in the reinforcement
F_s = allowable stress in the reinforcement
M_{xe} = actual applied moment
M_{xc} = moment capacity

Therefore

$$f_s = \frac{(40 \text{ ksi})(2{,}460)}{2{,}782} = 35.4 \text{ ksi}$$

APPENDIX A

REFERENCES

A-1 Procedure to Analyze and Check Block Walls, Bechtel Civil Design Aid Number CA-2, Rev 0, July 1980

A-2 L.D. Root (Iowa Electric Light and Power Company) Letter with Enclosures to H.D. Denton (NRC), Subject: IE Bulletin 80-11, Masonry Wall Design October 6, 1982 (LDR-82-264)

A-3 DAEC Reactor Building Earthquake Analysis, JAB-DC-DAEC-2, November 1973

A-4 Building Code Requirements for Concrete Masonry Structures, ACI 531-79 and ACI 531-R-79, American Concrete Institute, 1979