TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

August 20, 1981

RECEIVED
1981
U.S. NUCLEAR REGULATORY COMMISSION

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Acting Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Ms. Adensam:

In the Matter of the Application of) Docket Nos. 50-390
Tennessee Valley Authority) 50-391

By letter dated February 12, 1981 from S. A. Varga, TVA was requested to provide information concerning the use of nonreinforced concrete masonry walls at Watts Bar Nuclear Plant. Information on this subject was provided by my letter to A. Schwencer dated April 20, 1981. The schedule provided in my April 20, 1981 letter was revised in my letter to you dated June 1, 1981.

The enclosed information is forwarded for your review. We expect to provide additional information concerning nonreinforced concrete masonry walls by January 15, 1982.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Regulation and Safety

Sworn to and subscribed before me
this 20th day of August 1981.

Paulette N. White
Notary Public

My Commission Expires 9-5-84

Enclosure

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Aperture Dist
SEND DRAWINGS to:
PDR

ENCLOSURE

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
RESPONSE TO INFORMATION REQUEST ON CATEGORY I MASONRY WALLS
EMPLOYED BY PLANTS UNDER CONSTRUCTION PERMIT (CP)
OR OPERATING LICENSE REVIEW

TVA's initial response to the subject information request concerned only reinforced masonry walls at Watts Bar Nuclear Plant (WBN). Since the initial response, TVA has expanded the investigation on the block walls twofold. First, the information request has been expanded to address all unreinforced masonry walls in category I structures. Secondly, the loading concerns expressed in NRC Bulletin 80-11 (impact loads, pressurization loads, etc.) are being assessed in the design of the unreinforced masonry block walls.

1. Are there any concrete masonry walls being used in any of the category I structures of your plant? If the answer is "no" to this question there is no need to answer the following questions.

   There are three types of unreinforced masonry walls being used in category I structures at WBN. They are mortared hollow core block, unmortared solid concrete block, and mortared solid concrete block. These walls are located as follows:

   Auxiliary Building: elev 676, 692, 713

   Condensate Demineralizer Waste Evaporator Building: elev 733.5

   Control Building: elev 755

   Reactor Building: elev 702.8, 716

2. Indicate the loads and load combinations to which the walls were designed to resist. If load factors other than 1 have been employed, please indicate their magnitudes.

   The unreinforced masonry walls were originally designed to function as either radiation shield walls, partition walls, or to provide access openings for enclosed equipment. These walls were not intended to serve any structural functions and thus were not designed to withstand any load or load combinations. An Evaluation Criteria, WBN DC-20-30, "Evaluation of Unreinforced Masonry Walls Constructed from Solid Concrete Blocks" (appendix A), was prepared for use in determining the structural capacity of the walls and their potential impact on nearby safety-related systems. The unreinforced solid block walls are being evaluated for the loads and load combinations as defined in section 3.0 of the above cited criteria. No factors other than 1 have been employed on the design loadings.

The mortared hollow core block walls have been reevaluated. They are located in areas where their failure would not damage safety-related equipment.

3. In addition to complying with the applicable requirements of the Standard Review Plan, sections 3.5, 3.7, and 3.8, is there any other code, such as the "Uniform Building Code" or the "Building Code Requirements for Concrete Masonry Structures" (proposed by the American Concrete Institute) which was or is being used to guide the design of these walls? Please identify and discuss any exceptions or deviations from the Standard Review Plan requirements or the aforementioned codes.

   The structural evaluation of the unreinforced walls is being completed in accordance with the previously referenced criteria which complies with the applicable requirements of sections 3.5, 3.7, and 3.8 of the Standard Review Plan. Where applicable in section 3.0 of appendix A, certain American Society for Testing Materials (ASTM) standards and American Concrete Institute (ACI) code 531-79, "Building Code Requirements for Concrete Masonry Structures," and standards were used in determining the allowable stresses.

4. Indicate the method that you used to calculate the dynamic forces in masonry walls due to earthquake, that is, whether it is a code's method such as Uniform Building Code or a dynamic analysis. Identify the code and its effective date if the code's method has been used. Indicate the input motion if a dynamic analysis has been performed.

   The dynamic forces acting on the unreinforced masonry walls were determined by one of two methods depending on whether the wall joints were mortared or unmortared (section 3.2.3 of appendix A). For walls having mortared joints, the dynamic forces were determined by classical dynamic analyses techniques as discussed in <u>Introduction to Structural Dynamics</u> by J. M. Biggs. Each building containing block walls had been seismically analyzed according to section 3.7 of the WBN Final Safety Analysis Report (FSAR), and a report containing acceleration response spectra for the various floor elevations was available for each building. TVA's method of analyzing unmortared block walls is presently being reevaluated. We will include this method of analysis for unmortared block walls in our final response to this information request.

5. How were the masonry walls and the piping/equipment supports attached to them designed? Provide enough numerical examples including details of reinforcement and attachments to illustrate the methods and procedures used to analyze and design the walls and the anchors needed for supporting piping/equipment (as applicable).

The unreinforced masonry walls are being analyzed for dead, live, seismic, tornado, pressure, jet impingement, pipe whip, missile, and flood loads in accordance with sections 3.2, 3.3, and 4.0 of appendix A. Restraints are being designed where necessary and will be installed after the walls have been constructed. Sample calculations of the structural capacity of the walls and design of the wall restraints completed to date are shown in appendix B.

No piping/equipment supports have been authorized for installation on the unreinforced block walls at WBN. Section 3.2.2 of appendix A states, "Attachments to the unreinforced masonry walls shall not be allowed."

6. Provide plan and elevation views of the plant structures showing the location of all masonry walls for your facility.

Locations (plan and elevation) of all unreinforced masonry walls in the category I structures at WBN are shown on the attached construction drawings as listed below:

41N366-1 R8	41N370-3 R3
41N366-2 R5	41N370-6 R1
41N368-1 R8	41W391-7 R3
41N368-2 R2	41W732-2 R1
41N368-3 R2	41W732-4 R1
41N368-4 R4	48N943 R4
41N368-5 R2	46W402 R24
41N370-1 R4	46W404 R7
41N370-2 R1	

021196.05

APPENDIX A

TENNESSEE VALLEY AUTHORITY

Division of Engineering Design

PLANT: WATTS BAR NUCLEAR PLANT

Design Criteria
For

EVALUATION OF UNREINFORCED MASONRY WALLS CONSTRUCTED FROM SOLID CONCRETE BLOCKS

Design Criteria No: WBN DC-20-30

Issue Date: ______

	Revision RO	R1	R2	R3	R4	R5
	Date MAY 21 1981					
Prepared	R.E. Field Jr. C.L. Buck					
Supervised	M.G. McDowell					
Reviewed	C. G. Hildwell					
Submitted	Robert O. Healy					
Approved	G.O. Barnett					
Reviewed NSSS Vendor						

TVA 10566 (DED-9-74)

TVA 10567 (EN DES-6-80)

Plant: Watts Bar Nuclear Plant

Design Criteria No: WBN-DC-V-1.1.1.1

Design Criteria For EVALUAT[illegible]N OF UNREINFORCED MASONRY WA[illegible] CONSTRUCTED FROM SOLID CONCRETE BLOCKS

Revision:

R – Denotes review.

A – Denotes approval

Thermal Power Engineering Branches						Thermal Power Design Project						Architectural, Hydro, & Special Projects Engineering & Design Branches							
MEB		EEB		CEB		Project Manager				R	A	AD		ME&D		CE&D		EE&D	
R	A	R	A	R	A						RWC	R	A	R	A	R	A	R	A
						MD		ED		CD									
						R	A	R	A	R	A								
				KM	KM					HDH	HDH								
				NHP	NHP					WDL	WDL								
				JAE	JAE					LHK	LHK								
				RDL	RDB					AJ	AJ								
				RJH	RJH														
				BBN	BBN														
				NES	NES														
					DRD														

NEB					
R	A	R	A	R	A
lrs	[illegible]				
CWP	CWP				
	lau				
	JAP/JRL				

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1.0 SCOPE

This evaluation criteria shall apply to the evaluation of unreinforced masonry walls constructed from solid concrete masonry units. The criteria addresses both mortared and unmortared joint conditions and gives specific details where differences occur.

2.0 PURPOSE

The purpose of this criteria is to establish a guide to gather and evaluate information in regard to the Nuclear Regulatory Commission's (NRC) "Information Request on Category I Masonry Walls" (NEB 800514 255) and NRC IE Bulletin 80-11. By using this criteria and the data gathered by a field survey, each unreinforced masonry wall shall be evaluated for its effect upon safety-related equipment should that wall fail. If the field survey indicated that a wall would not damage any safety-related equipment by its failure, no further action will be necessary for that wall. However, if the field survey indicated that a wall could damage safety-related equipment by its failure, the wall shall be evaluated for its structural ability to withstand combinations of the following: dead loads, impact or compartmental pressurization loads such as missile, pipe whip, pipe break, jet impingement, or tornado depressurization, flooding, and seismic loads described herein. However, for pipe break, unless the safety-related equipment is required following that specific break, no protection is necessary. If the evaluation determines that a wall can withstand the design loads, no further action will be required for that wall. However, if the evaluation indicates that a wall could not withstand any of the design loads, corrective action shall be taken to prevent damage to any safety-related equipment. This may be accomplished by designing and installing a restraint mechanism which will prevent the wall from failing or by designing and installing a barrier to protect the safety-related equipment from failure of the wall. If a restraint system is required, its design including anchorage shall conform to reference 5.5.

3.0 EVALUATION BASIS

3.1 Materials

3.1.1 Concrete Blocks

The solid concrete masonry units shall be conservatively assumed to conform to the requirements of American Society for Testing and Materials (ASTM) "Solid Load-Bearing Masonry Units," Designation C145-71, Grade S-II, unless records are available to substantiate that the masonry units conform to the requirements of the higher grades.

3.1.2 Mortar

The mortar shall be conservatively assumed to conform to the requirements of ASTM "Mortar for Unit Masonry," Designation

C270, type N, unless records are available to substantiate that the mortar used conformed to the requirements for types S or M.

3.2 Loads

3.2.1 Dead Loads (D)

D - Dead loads or their related internal moments and forces. The dead load shall be based on the density of the solid masonry units being 135 pounds per cubic foot (lb/ft^3).

3.2.2 Live Loads (L)

L - Attachments to the unreinforced masonry walls shall not be allowed. In the event that attachments are presently being utilized on the walls, corrective action must be taken to ensure their removal and relocation.

3.2.3 Seismic Load (E')

E' - Loads generated by the safe shutdown earthquake (SSE)

The seismic analysis will consider two types of block walls: unreinforced, mortared walls as discussed in section 3.2.3.1, and unreinforced, unmortared block walls as discussed in section 3.2.3.2.

3.2.3.1 Mortared Block Walls

Unreinforced, mortared block walls shall be dynamically analyzed on a case-by-case basis as necessary. Parametric studies or "worst case" walls may be utilized for analysis purposes as desired. Unless it can be verified that the top block is structurally restrained or adequately mortared, the wall shall be analyzed as a simple cantilever. Otherwise, the wall shall be analyzed as a propped cantilever.

3.2.3.1.1 Walls Analyzed As a Simple Cantilever

In a typical analysis, a unit width of wall shall be assumed to act as a cantilever. The following steps shall be followed to determine dynamic loads:

Step 1. The natural frequency of the wall shall be calculated as follows:

TVA 10535 (EN DES-7-77)

$$f_1 = \frac{(0.597)^2\pi}{2L^2}\sqrt{\frac{EI}{m}} \quad ,n=1$$

$$f_n = \frac{(n-\frac{1}{2})^2\pi}{2L^2}\sqrt{\frac{EI}{m}} \quad ,n>1$$

where,

n = Mode number
f = Frequency, Hertz (Hz)
m = Mass per unit length of wall for unit width (lb-sec^2/in^2)
E = 1,000,000 lb/in^2
I = Moment of inertia of unit width of wall (in^4)
L = Height of wall (in)

All frequencies ≤ 33 Hz shall be calculated and retained. In the vertical direction, the wall will exhibit rigid body behavior and a frequency ≥ 33 Hz is assumed.

Step 2. Each frequency calculated in Step 1 shall be broadened by ±10 percent. Using the 2 percent damping floor response spectrum curve from the appropriate published Civil Engineering Branch (CEB) Report, a horizontal acceleration value corresponding to 0.9 f_n, 1.0 f_n, and 1.1 f_n for each calculated mode (n = 1, 2, 3, ...) ≤ 33 Hz, shall be determined. The largest of the three accelerations determined for each mode shall be retained for use in Step 3. The vertical acceleration shall be determined from the structural response acceleration (ZPA) curve contained in the appropriate report.

Step 3. The retained horizontal acceleration for each mode from Step 2 shall be combined using the square-root-of-the-sum-of-the-squares-method (SRSS) as follows:

$$a_r = \sqrt{a_1^2 + a_2^2 + \ldots a_n^2}$$

where,

a_n = maximum modal horizontal acceleration for the n^{th} mode.

a_r = SRSS acceleration

TVA 10535 (EN DES-7-77)

Step 4. The calculated acceleration a_r, shall be multiplied by the deadweight of the wall and applied as a uniform static load in the direction normal to the wall. A vertical load shall be determined by multiplying the vertical acceleration determined in Step 2 by the weight of the unit width of the wall. The seismic stress (σ_E) in the wall is given by:

$$\sigma_E = \left(\frac{P}{A} \pm \frac{Mc}{I} \right)$$

where Mc/I is the bending stress due to the horizontal acceleration and P/A is the axial stress due to the vertical acceleration. Since the earthquake is cyclic in nature, the calculated forces are assumed to act in either direction. Section 3.4.7 of this criteria must be met in the combined stress state.

Step 5. If, from Step 4, it is determined that restraints are required to prevent failure of a wall, the wall restraints shall be designed for the loads produced by the accelerations calculated in Steps 2 and 3. First, select the structural shape and size restraint to be used and assume a 4-foot initial spacing. Then multiply the weight of the restraint plus the weight of the block wall (tributary width) by the acceleration given in Step 3 and apply these forces as a uniform load to the restraint. Designs that result in an unrealistically large restraint or closely spaced restraints may be coordinated with CEB personnel for further analysis on a case-by-case basis. Unless otherwise justified, restraints shall be placed on both sides of a wall.

Step 6. In lieu of performing a detailed dynamic evaluation, a factor of 1.5 times the peak horizontal acceleration value of the appropriate 2 percent damping floor response spectrum curve may be used for the horizontal accelerations of the wall. The vertical acceleration will be as defined in Step 2. Steps 4 and 5 shall then be performed to design the restraint. If Step 6 results in an unrealistically large restraint or closely spaced restraints the detailed dynamic evaluation shall be performed.

3.2.3.1.2 Walls Modeled As a Propped Cantilever Beam.

In a typical analysis, a unit width of the wall shall be assumed to act as a propped cantilever. The following steps shall be followed to determine dynamic loads.

Step 1. The frequency of the wall shall be calculated as follows:

$$f_n = \frac{(n + \frac{1}{4})^2 \pi}{2L^2} \sqrt{\frac{EI}{m}}$$

where the parameters are defined in Step 1 of section 3.2.3.1.1. All frequencies ≦ 33 Hertz (Hz) shall be calculated and retained. In the vertical direction, the wall will exhibit rigid body behavior and a frequency > 33 Hz is assumed.

Step 2 through Step 6 will be the same as those given in section 3.2.3.1.1.

3.2.3.2 Unmortared Block Walls

CURRENTLY
UNDER
RE EVALUATION

3.2.4 Pipe Break Loads (P_a, Y_j, Y_m)

P_a - Pressure equivalent static load within or across a compartment generated by the postulated break, and including an appropriate dynamic load factor to account for the dynamic nature of the load.

Y_j - Jet impingement equivalent static load on a structure generated by the postulated break, and including an appropriate dynamic load factor to account for the dynamic nature of the load.

Y_m - Missile impact load on a structure generated on or during the postulated break, as from pipe whipping and including an appropriate dynamic load factor to account for the dynamic nature of the load.

3.2.5 Tornado Loads (W_t)

W_t - Loads generated by the design tornado specified for the plant. Tornado loads on the masonry walls are due to tornado-created differential pressure.

3.2.6 Flood Loads (F)

F - Flooding equivalent static load on a structure generated by compartment flooding.

3.3 Load Combinations

Unreinforced concrete block walls shall be evaluated as defined in section 3.2. The horizontal and vertical loads used in the design of the wall shall be applied in combinations as prescribed in the following sections.

3.3.1 Service Loads

For loads encountered during normal plant startup, operation, and shutdown, the following load combination shall be considered:

(1) $S = D$

3.3.2 Extreme Environmental and Abnormal Loads

For extreme environmental and abnormal loads due to the safe shutdown earthquake, flood, tornado, or high energy pipe break accident, the following load combinations shall be considered:

(2) $S = D + E'$
(3) $S = D + P_a + Y_j + Y_m$
(4) $S = D + W_t$
(5) $S = D + F$

In load combination (3) the maximum values of P_a, Y_j, and Y_m should be used unless a time history analysis is performed to justify otherwise.

In the above load combinations, S is the required section strength based on the working stress design method and the allowable stresses defined in section 3.4.

3.4 Allowable Stresses

Allowable stresses shall be as given below for load combination (1) of section 3.3.1. These values may be increased 33 percent for load cases (2) through (5) provided the increased values do not exceed the stated maximums.

3.4.1 Compressive Strength

3.4.1.1 For walls with mortared joints, the compressive strength of the masonry wall, f_m', shall be taken as 700 pounds per square inch (lb/in^2) for an assumed compressive strength of the masonry units of 1000 lb/in^2 and Type N mortar. If records are available, as stated in section 3.1, a higher value of f_m' may be used as determined from table 4.3 of American Concrete Institute (ACI) "Building Code Requirements for Concrete Masonry Structures" ACI 531-79.

3.4.1.2 For walls with unmortared joints, the compressive flexural strength of the masonry wall, f_m', shall be taken as the compressive strength of the masonry units (3000 lb/in^2) unless records are available to substantiate a higher value. For unmortared block walls, f_m' shall be substituted for f_c' of the alternate design method.

3.4.2 Axial Stress

The allowable compressive stress due to axial loading on the wall shall not exceed

$$F_a = 0.225 f_m' \; [1 - (h/40t)^3] \text{ but } \leq 1000 \text{ lb/in}^2,$$

where h (effective height) and t (nominal thickness) are as defined in section 9.4.7 and 9.4.8 of ACI 531-79.

3.4.3 Flexure

The allowable flexural compressive stress shall be

3.4.3.1 $F_m = 0.33f_m'$ but $\leq$ 1200 lb/in^2 for mortared walls.

3.4.3.2 $F_m = 0.45f_m'$ but $\leq$ 1350 lb/in^2 for unmortared walls.

3.4.4 Shear

The allowable shear stress for solid concrete blocks with mortared joints shall be

$v_m = 1.1\sqrt{f_m'}$ but $\leq$ 50 lb/in^2.

The allowable shear stress for solid blocks with unmortared joints shall be

$v_m \leq f_s$

where f_s is the static friction. The coefficient of friction shall be taken as 0.7. f_s = 0.7 x normal force.

3.4.5 Tensile Stress

The allowable tensile stress in mortared joints due to bending shall be

$F_t = 1.0\sqrt{m_o}$ $\leq$ 40 lb/in^2 normal to the bed joints,

$F_t = 1.5\sqrt{m_o}$ $\leq$ 80 lb/in^2 parallel to the bed joints in running bond.

where m_o is the compressive strength of the mortar.

3.4.6 Limitations of Stresses

3.4.6.1 Neither the tensile strength nor the shear strength of the mortar shall be considered in the analysis of vertical continuous joints.

3.4.6.2 The tensile strength of the mortar shall not be considered in the analysis of the bed joint on the top of the masonry wall.

3.4.6.3 If construction inspection records conforming in general to the requirements outlined in section 4.5.2 of ACI 531-79 are not available, the allowable stresses in compression shall be reduced by one-third and the allowable stresses in tension and shear reduced by one-half.

3.4.7 Combined Stress

For combined stresses due to bending and axial loads, the following shall be met:

$$\frac{f_a}{F_a} + \frac{f_m}{F_m} \leq 1.0$$

where f_a is the calculated axial compressive stress in masonry and f_m is the calculated flexural compressive stress in masonry.

4.0 ANALYSIS

4.1 Mortared Block Walls

Masonry walls with mortared joints may be analyzed as a propped cantilever if adequate bond exists between the top block and the supporting structure, or if restraints are added at the top of the wall. Otherwise, the walls shall be analyzed as a cantilever beam. If the calculated stresses exceed the allowable stresses using the Working Stress Design Method of ACI 531-79, the walls shall be restrained. Restraints shall be analyzed as either a simple beam or a plate hinged on four sides if all four sides are restrained.

For multi-wythe walls which are subjected to seismic loads, the wythes shall be assumed to act independently of each other unless they are connected by ties or other mechanical means. Composite action of two or more wythes should not be assumed unless an analysis of the mechanical ties connecting the wythes is performed and the ties are deemed sufficient to assure the wythes act together. For pipe break, tornado, missile, or flood loads (loading in one direction), the loads shall be assumed to act on the external wythe and the load distributed through each successive wythe if there is no air space between the wythes. If an air space exists between the wythes, the external wythe shall be assumed to carry the total load.

4.2 Unmortared Walls

Masonry walls with unmortared joints shall be analyzed as a cantilever beam using stability analysis. Where restraints are required, the portion of the wall between the restraints shall be analyzed as a simple beam.

For multi-wythe walls subjected to seismic loads, the wythes shall be assumed to act independently. Externally applied loads in one direction such as pressure loads may be distributed equally to the wythes and each wythe analyzed individually for multi-wythe walls without an air space between the wythes.

The evaluation of unmortared walls shall be as follows:

<u>Seismic Evaluation</u> (Reversible Loading)

The walls shall be evaluated for all forces as shown in figure 4.0-1(b), where

- P = Axial force applied to top face of block (including vertical seismic effects)
- W = Weight of individual block (including vertical seismic effects)
- V_1 = Shear force on top face of block
- V_2 = Shear force on bottom face of block
- f_{s1} = Static frictional force at top face of block ($\mu = 0.7$)
- f_{s2} = Static frictional force at bottom face of block ($\mu = 0.7$)
- N = Normal vertical force at bottom face of block
- d = Distance of normal force (N) from front face of block
- M = Applied moment due to external loads
- L = Span between lateral supports

such that the moment formulated by the normal force N, and its moment arm d, will resist the moments which result from P, W, V_1, V_2, f_{s1}, f_{s2}, and M when moments are summed about point A (see figure 4.0-1(b)) while the normal force N, remains within the plane of the wythe (d < width of a single block).

The compressive stress on the bottom of the block caused by the normal force N, shall be evaluated as shown in figure 4.0-1(c) to ensure the stress involved does not exceed the allowable stress given in Section 3.4.3, that is

$$f_c < F_m$$

<u>Pipe Break, Missile, Tornado, and Flooding Evaluation</u> (Loading in One Direction)

The walls shall be evaluated for all forces as shown on figure 4.0-2(b) where

- P = Axial force applied to top face of block
- W = Weight of the individual block
- f_{s1} = Static frictional force at top face of block ($\mu = 0.7$)
- f_{s2} = Static frictional force at bottom face of ($\mu = 0.7$)
- N = Normal vertical force at bottom face of block
- L = Span between lateral supports
- w or Z = Equivalent uniform static load or concentrated load with an appropriate dynamic load factor
- Z = Equivalent point load

Pt = Equivalent axial load due to multi-wythe width
Wt = Equivalent weight of block within the span length due to multi-wythe width.

such that the static frictional forces (f_{s1} and f_{s2}) shall not be exceeded (see figure 4.0-2(b)) and the overturning moment does not exceed its internal resisting moment (see figure 4.0-2(c)).

5.0 REFERENCES

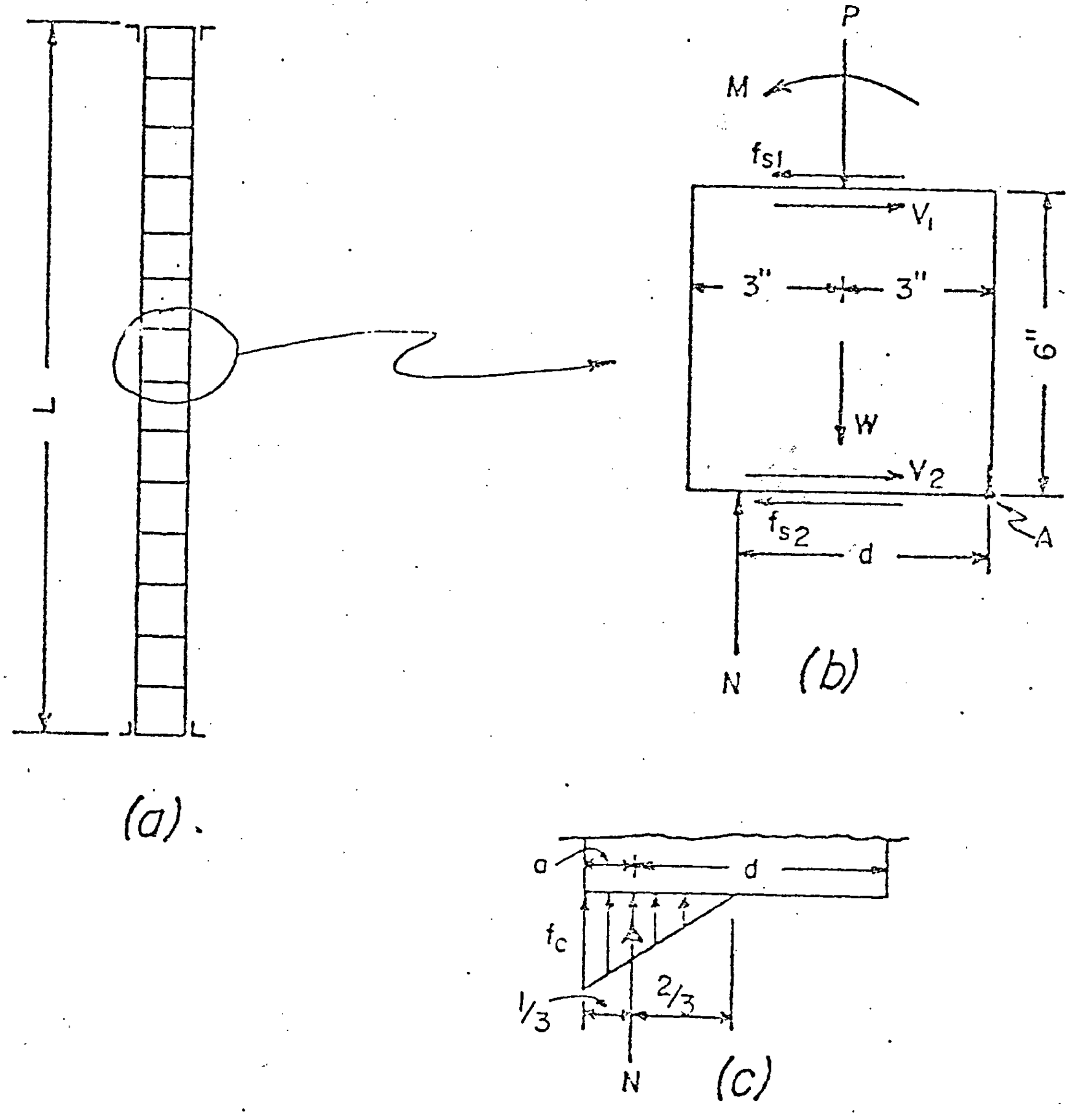
5.1 American Society for Testing and Materials (ASTM) "Solid Load-Bearing Concrete Masonry Units," Designation C145-71.

5.2 ASTM "Mortar for Unit Masonry," Designation C270.

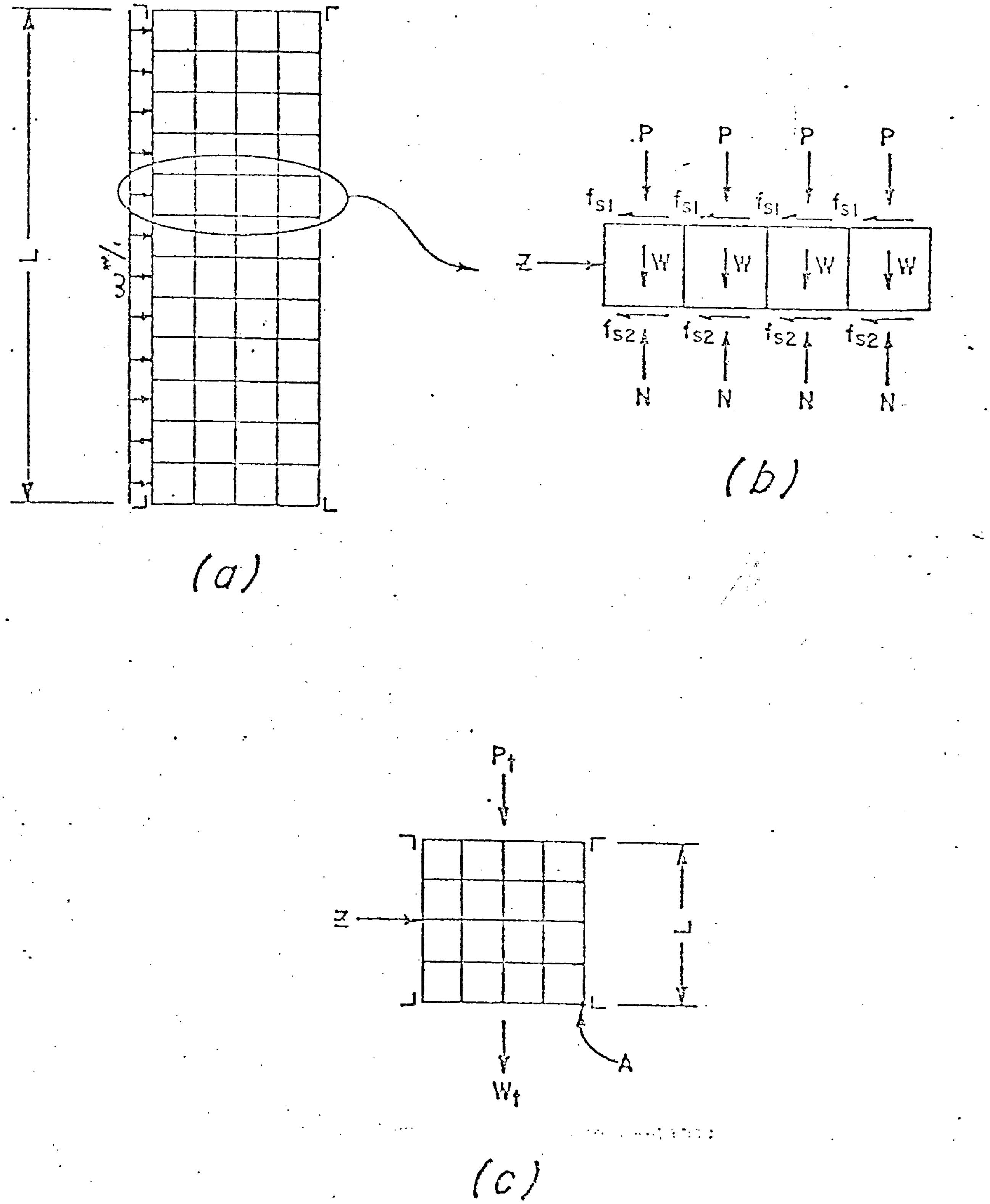
5.3 American Concrete Institute (ACI) "Building Code Requirements for Concrete Masonry Structures," ACI 531-79.

5.4 Introduction to Structural Dynamics, John M. Biggs, 1964, Chapter 4.

5.5 Design Criteria for Miscellaneous Steel Components for Seismic Class I Structures, WB-DC-20-21.



ANALYSIS OF SOLID SHIELD BLOCK WALLS
FIGURE 4.0-1



ANALYSIS OF SOLID SHIELD BLOCK WALLS

FIGURE 4.0-2

APPENDIX B

PURPOSE

CALCULATION FOR ONE (1) UNREINFORCED MASONRY WALL SUBJECTED TO LOADS & LOAD COMBINATIONS GIVEN BELOW.

REFERENCES

1. DELETED
2. MEMO FROM BARNETT TO CANTRELL, 4/16/81, CEB '81 0416 00[illegible]
3. SEISMIC ANALYSIS OF AUX-CONTROL BLDG, 6/19/74
4. MEMO FROM RAULSTON TO BARNETT, 3/30/81, NEB '810330 263
5. EN DES-NEB CALCULATIONS, TI-ECS-11
6. WBN-DC-V-1.1.1.1, 5/21/81, "EVALUATION OF UNREINFORCED MASONRY WALLS CONSTRUCTED FROM SOLID CONCRETE BLOCKS"
7. ASTM C270-73
8. TVA CIVIL DESIGN STANDARD DS-C6.1, "CONCRETE ANCHORAGES

LOADS & LOAD COMBINATIONS (FROM REF. 6, SECT. 3.3)

1. $S = D$
2. $S = D + E'$ (REF. 3)
3. $S = D + P_a$ (REF. 4) $+ Y_j$ (REF. 2) $\to 0$ $+ Y_m$ — NOT YET AVAILABLE, PROBABLY NO MISSLE LOADS
4. $S = D + W_t$ (REF. 5)
5. $S = D + F$ — NOT YET AVAILABLE

MATERIAL & PROPERTIES

CONCRETE BLOCK

6" × 8" × 12" SOLID CMU
$\gamma = 135$ pcf

MORTAR

TYPE N
$\gamma = 135$ pcf
m_o = 750 psi, FROM REF. 7

ANALYSIS / DESIGN PROCEDURE

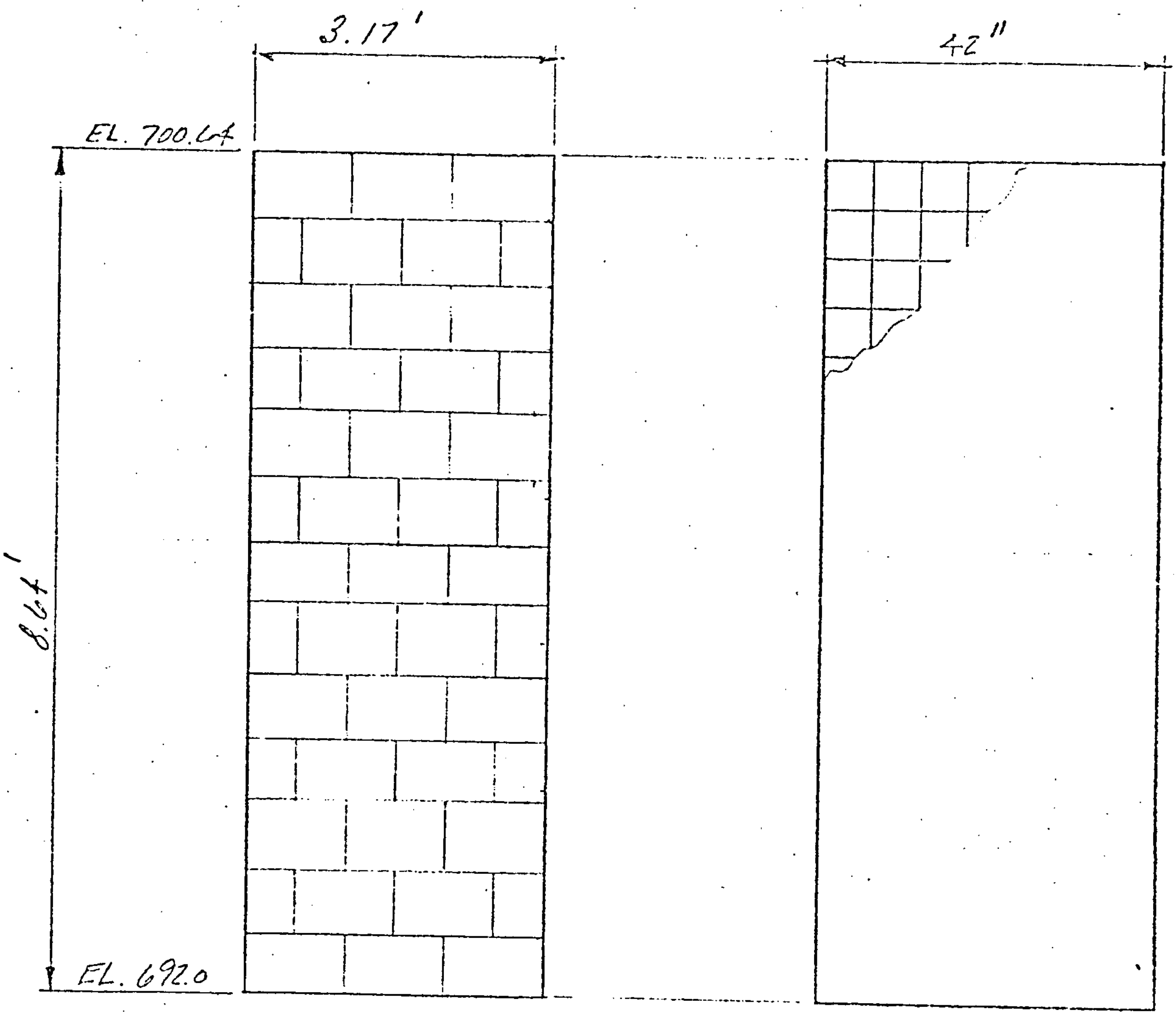
- WALL 8.64' HIGH × 3.17' WIDE × 42" THICK (7-6" WITHES) OF DWG. NOS 41N368-1 (PLAN) & 41N368-3 (ELEV., SECT B3-B3) SHALL BE USED FOR THE SAMPLE CALCULATIONS.

- ASSUMPTIONS SHALL BE GIVEN AS ANALYSIS PROCEEDS.

- BY INSPECTION LOAD CONDS. 2, 3, & 4 WILL CONTROL

- NO LOADS ARE EXERTED FROM ABOVE MASONRY WALLS BY REINF. CONC. STRUCTURE.

ANALYSIS OF LOADING CONDITIONS



ASSUMPTIONS

WALL ACTS AS A PROPPED CANTILEVER THAT IS FIXED AT THE BOTTOM AND PINNED AT THE TOP (REF 6, 3.4.6.2) EACH WITHE ACTS INDEPENDENTLY* & VERTICAL JOINTS TO EACH SIDE OF WALL ARE NEGLECTED (REF 6, 3.4.6.1)

* IN FLEXURE ONLY, LOADS DUE TO DIFFERENTIAL PRESSURES (i.e., W & P) TO BE PROPORTIONED TO EACH WITHE

LOAD COND. #3

$S = D + P_a$

FROM REF. 4 (WALL A4-5 OF TABLE 1)

PEAK DIFFERENTIAL PRESSURE = 0.27 psi

FOR 1 WITHE, $P_a = (0.27)(144 \frac{IN^2}{FT^2}) / 7_{WITHES}$ = 5.55 psf

FOR 1' STRIP OF WALL, UNIFORM LOAD, W_{P_a} = 5.55 plf ←

LOAD COND. #4

$S = D + W_t$

FROM REF. 5 (ACROSS NODE 114 ; 108)

MAXIMUM Δp = 0.342 psi

FOR 1 WITHE, $W_t = (0.342)(144 \frac{IN^2}{FT^2}) / 7_{WITHES}$ = 7.04 psf

FOR 1' STRIP OF WALL, UNIFORM LOAD, W_{W_t} = 7.04 psf ←

AUXILIARY BUIL[illegible]NG — WBNP

EVALUATION OF UNREINFORCED MASONRY WALLS

COMPUTED PKL DATE 7/22/8[illegible]
CHECKED F.B DATE 7/[illegible]

LOAD COND #2

$S = D + E'$

FROM REF. 6, 3.2.3.1.2

STEP 1. CALC NATURAL FREQUENCY OF WALL (USE 1' STRIP)

$$f_n = \frac{(n + 1/4)^2 \pi}{2L^2} \sqrt{\frac{EI}{m}}$$ w/ VARIABLES DEFINED IN REF.

$$f_1 = \frac{(1 + 1/4)^2 \pi}{(2)(8.64' \times 12''/')^2} \sqrt{\frac{(1{,}000{,}000 \frac{LB}{IN^2})(12)(6)^3/12}{(135\,pcf)(.5')(1')/(32.2\frac{ft}{sec^2})(12''/')(12''/')}}$$

$= 17.8\,(1.25)^2 = 27.8$ Hz

$f_2 = 17.8\,(2 + 1/4)^2 = 90.1$ Hz > 33 Hz ∴ DON'T USE

$\Rightarrow f = f_1 = \underline{27.8 \text{ Hz}}$ ←

STEP 2. BROADEN FREQUENCIES ±10% ; DETERMINE MAX ACCELERATIONS [illegible]

$0.9 f_1 = 0.9\,(27.8) = 25.02$ Hz PERIOD, $T_1 = \frac{1}{0.9 f_1} = 0.040$ SEC.

$1.1 f_1 = 1.1\,(27.8) = 30.58$ Hz PERIOD, $T_1 = \frac{1}{1.1 f_1} = 0.033$ SEC.

FROM REF. 3, FIG. 30 (2% DAMPING)

$a_1 = a_{max}$ (FOR $0.033 \leq T \leq 0.040$) $= .135g \times 2$ (FOR SSE) $= \underline{0.27g}$ ←

FROM REF. 3, FIG 64 (2% DAMPING)

VERTICAL ACCEL., $a_v = 2 \times 0.09g = \underline{0.18g}$ ←

STEP 3. USE a's FOR EACH MODE FROM STEP 2 & COMBINE USING SQUARE-ROOT-OF-THE-SUM-OF-THE-SQUARES-METHOD (SRSS)

a_r = SRSS ACCELERATION = $\sqrt{a_1^2 + a_2^2 + \ldots a_n^2}$

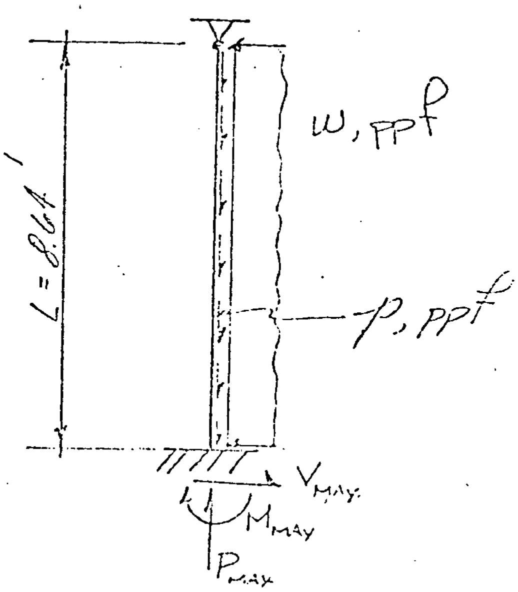
SINCE ONLY MODE 1 APPLIES

$a_r = a_1 = 0.27g$

FOR 1' STRIP OF WALL, UNIFORM LOAD, $w_{E'} = (0.27)(135)(.5) = \underline{18.23\ ppf}$ ←

STEP 4. CALC. MAX STRESSES & COMPARE TO ALLOWABLE STRESSES.

SINCE $w_{E'} > w_{wt} > w_{Pa}$, LOAD COND. #2 CONTROLS ←



$w = 18.23\ ppf$

$P = (135\ pcf)(.5')(1')(1 \pm a_v)$

$= 67.5\,(1 \pm 0.18)$

$= 55.35\ ppf \Rightarrow 79.65\ ppf$

$V_{MAX} = \dfrac{5wL}{8}$

$M_{MAX} = \dfrac{wL^2}{8}$

MAXIMUM STRESSES WILL OCCUR AT BOTTOM END OF WALL.

NOTE. FOLLOWING CALCS BASED ON 1' STRIP OF WALL

MAX AXIAL STRESS, f_a

$f_a = P_{max} L / A = (79.65)(8.64) / (6")(12") = 9.56$ psi

ALLOWABLE AXIAL STRESS, F_a — REF 6, 3.4.2

$F_a = 0.225 f'_m [1 - (h/40t)^3] \le 1000$ psi (ASSUME K = 1.0)

$f'_m = 700$ psi — REF. 6, 3.4.1.1

$\therefore F_a = 0.225(700)[1 - (8.64'/(40)(.5'))^3] \times 2/3 \times 4/3$ (2/3 ← REF 6, 3.4.6.3; 4/3 ← REF. 6, 3.4)

$= 128.7$ psi > 9.56 psi OK ←

MAX FLEXURAL COMPRESSIVE STRESS, f_m

$f_m = \frac{M_{max}}{S}$ $\quad S = \frac{I}{c} = \frac{bh^2}{6} = \frac{(12")(6")^2}{6} = 72\ IN^3$

$= \frac{(18.23)(8.64)^2(12)/8}{72}$

$= 28.35$

TVA 11030 (WM-7-75)

ALLOWABLE FLEXURAL COMPRESSION STRESS, F_m REF , 3.4.3

$$F_m = 0.33 f'_m \leq 1200 \text{ psi}$$

$$= 0.33(700) \times 4/3 \times 2/3 \quad \leftarrow \text{REF 6, 3.4 (4/3)}; \text{ REF 6, 3.4.6.3 (2/3)}$$

$$= \underline{205.3 \text{ psi} > 28.35 \text{ psi OK}}$$

REF. 6, 3.4.7

CHECK COMB. FLEX + AXIAL COMP $\Rightarrow \frac{f_a}{F_a} + \frac{f_m}{F_m} = \frac{9.56}{128.7} + \frac{28.35}{205.3} = 0.21 <$

MAX SHEAR STRESS, v_m

$$v_m = \frac{5wL}{8A} = \frac{(5)(18.23)(8.64)}{(8)(6)(12)} = 1.37 \text{ psi}$$

ALLOWABLE SHEAR STRESS, V_m REF 6, 3.4.4

$$V_m = 1.1\sqrt{f'_m} \leq 50 \text{ psi}$$

$$= 1.1\sqrt{700 \times 4/3 \times 1/2} \quad \leftarrow \text{REF 6, 3.4 (4/3)}; \text{ REF. 6, 3.4.6.3 (1/2)}$$

$$= \underline{19.40 \text{ psi} > 1.37 \text{ psi OK}}$$

MAX FLEXURAL TENSION STRESS, f_t

$$f_t = \frac{M_{max}}{S} - \frac{P_{MIN}}{A}$$

$$= \frac{(18.23)(8.64)^2(12)/8}{72} - \frac{(55.35)(8.64)}{(6)(12)}$$

$$= 28.35 - 6.64 = 21.71 \text{ psi}$$

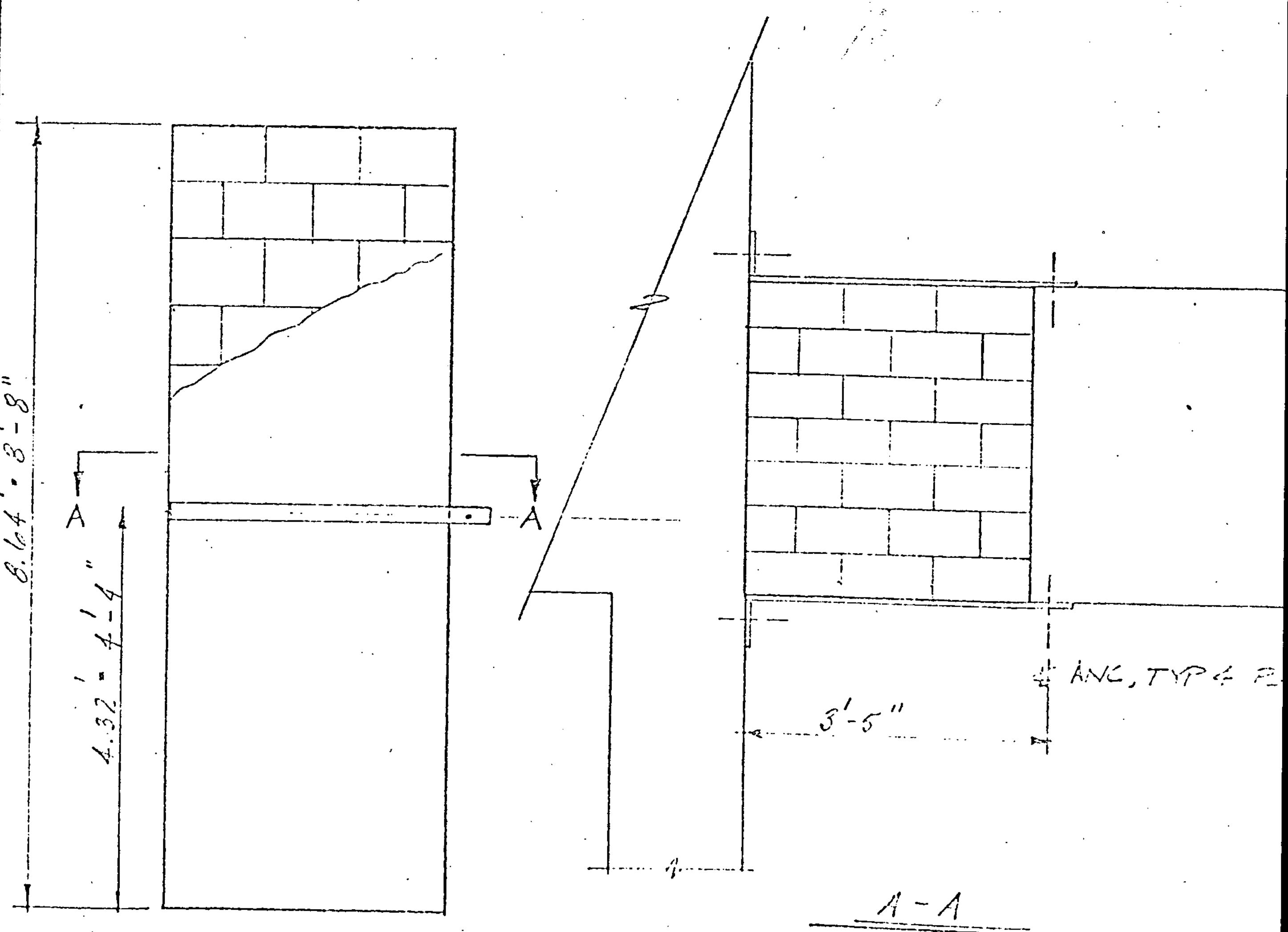
ALLOWABLE FLEXURAL TENSILE STRESS, F_T REF 6, 3.4.5

$F_T = 1.0\sqrt{m_o} \le 40\,psi \qquad m_o = 750\,psi$, FROM REF. 7

$= 1.0\sqrt{750} \times 4/3 \times 1/2$ ← REF. 6, 3.4.6.3 (4/3: REF. 6, 3.4)

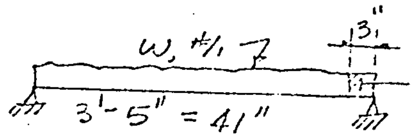
$= 18.26\,psi < 21.71\,psi$ NO GOOD - RESTRAINT REQ'D ←

STEP 6. DESIGN OF RESTRAINT



TRY RESTRAINT AT MID-HEIGHT OF WALL

ASSUMPTION: MID-HALF OF WALL ACTS ON RESTRAINT W/ ACCELERATION OF 0.27g. ∴ TRIBUTARY AREA IS 4.32' HIGH BY *3.42' WIDE.



*ASSUME w ACTS HERE FOR SIMPLICITY.

(THICKNESS OF WALL)

$w = (0.27g)(135\,pcf)(3.5')(1') = 127.6\ plf$

$M = w\ell^2/8 = (127.6)(41)^2/(12)(8) = 2234.3\ ''\# \doteq 2.23\ ''k$

$Ft_{ALLOW} = 0.9\,F_y = 0.9(36) = 32.4\ KSI$

$S_{REQ'D} = M/Ft_{ALLOW} = 2.23/32.4 = 0.07\ IN^3$

TRY PL 3/4" THICK x 3" WIDE

$S = (3)(3/4)^2/6 = 0.28$ OK $\quad I = Sc = (.28)(3/8) = 0.105$

CHECK DEFLECTION, Δ

$\Delta = \frac{5w\ell^4}{384EI} = \frac{(5)(.1276)(41)^4}{384(29\,000)(.105)(12)} = 0.13'' = L/315$ OK

USE PL 3/4" x 3" x 3'-8" 2 REQ'D
& PL 3/4" x 3" x 0'-6" 2 REQ'D

AUXILIARY BUILDING
EVALUATION OF UNREINFORCED
MASONRY WALLS

SHEET 11 OF

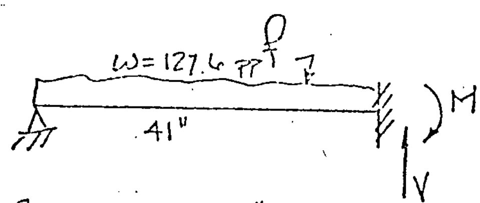
COMPUTED PKL DATE 7/22/81
CHECKED BHS DATE 7/22/81

CHECK ANCHOR REQ'D

MAX SHEAR = 127.6 ppf × 3.42' × ½ = 218.2# ←
(AT END WHERE CONC. WALL IS PERPENDICULAR TO MAS. WALL)

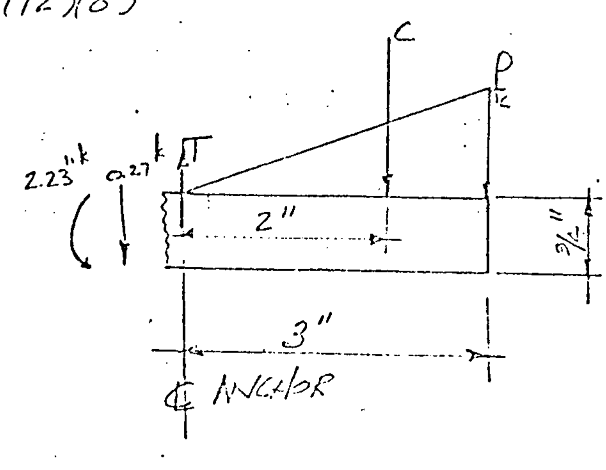
MAX TENSION

TO DETERMINE MAX TENSION SOME PRYING ACTION MUST BE CONSIDERED. IT WILL BE CONSERVATIVELY ASSUMED THAT FOR DETERMINING THIS TENSION THE RESTRAINT WILL BE FIXED AT THE END IN QUESTION (END WHERE CONC. WALL IS FLUSH w/ MASONRY WALL) AND PINNED AT THE OTHER END.



$$M = \frac{wl^2}{8} = \frac{(127.6)(41)^2}{(12)(8)} = 2234.3\ ''\# = 2.23\ ''k$$

$$V = \frac{5wl}{8} = \frac{(5)(127.6)(41)}{(12)(8)} = 272.5\ \# = 0.27\ k$$



$\circlearrowleft + \Sigma M_{℄ ANC.} = 0;$ $2C - 2.23 = 0$

$C = 1.115^{k} \Rightarrow f_c = \frac{(2)(1.115)}{(3)(3)} = 0.24\ ^{KSI}$ OK

$\Sigma F_y = 0;$ $T - C - .27 = 0$

$T = 1.115 + .27$

$= 1.385\ K$

TRY ½ϕ WEDGE BOLT

FROM REF. 8, TABLE III

$T_o = 3.35^{k} > 1.385^{k}$ OK
$V_o = 3.20^{k} > 0.22^{k}$ OK
} FACTORED LOADS

USE ½" ϕ WEDGE BOLTS ←