Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

December 5, 1983

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

Subject: Byron Generating Station Units 1 and 2
Braidwood Generating Station Units 1 and 2
Masonry Walls
NRC Docket Nos. 50-454, 50-455, 50-456, and 50-457

Reference (a): November 30, 1981 letter from B. J. Youngblood to L. O. DelGeorge

Dear Mr. Denton:

This is to provide additional information regarding the design of Category I masonry walls at Byron and Braidwood stations. NRC review of this information should eliminate the need for License Condition 2 listed in the Byron SER.

Reference (a) provided NRC guidance for demonstrating the adequacy of Byron/Braidwood masonry walls. This matter was discussed in some detail during a conference call on July 1, 1983. It was agreed then that the following information would be provided:

1. Design details that account for the effects of out-of-plane load, in-plane interstory drift load and support column flexibility.

2. Design basis for reinforced masonry design.

3. Identification and a description of the effects of structural cracks in existing Byron Unit 1 walls.

4. Clarification of quality assurance requirements for safety related walls.

The enclosed report addresses all of these issues. Submittal of final information regarding the structural crack survey is scheduled for December 15, 1983. Please address further questions regarding this matter to this office.

One signed original and fifteen copies of this letter and the enclosure are provided for NRC review.

Very truly yours,

T. R. Tramm

T. R. Tramm
Nuclear Licensing Administrator

B001
1/1

bg/lm

7714N

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON MASONRY WALL DESIGN BASED ON TELEPHONE CONVERSATION OF JULY 1, 1983

1.0 Introduction

This report covers the following additional information which was requested by the NRC during the telephone conference call on July 1, 1983. The report:

A. Provides the calculation and basis of analysis for the masonry walls considering the following:

1) out-of-plane load
2) in-plane interstory drift load
3) the effects of masonry column flexibility.

B. Provides a description of the design basis for reinforced masonry wall design.

C. Identifies any structural cracks that exist in Byron Unit 1 walls with an explanation of their effect on the wall design.

D. Verifies that Byron/Braidwood Stations' safety related masonry walls were constructed in accordance with the criteria set forth in 10CFR50 Appendix B.

2.0 Design and Analysis Procedure for Unreinforced Concrete Masonry Walls

The following describes the design criteria used on the Byron/Braidwood project which is more stringent than the one earlier submitted to the NRC with a letter from D. L. Peoples of Commonwealth Edison to Darrell G. Eisenhut of NRC, dated July 1980. Commonwealth Edison Company has voluntarily used this criteria in reassessment of the nuclear safety related masonry walls.

2.1 Analysis Procedure

2.1.1 Determination of Dynamic Lateral Loads

Concrete masonry walls have been analyzed based on conventional elastic methods. Dynamic lateral loads have been determined by an equivalent static method using the expression:

$$W_D = g_W W_W + g_a W_a$$

where:

W_D = Dynamic lateral load

W_W = Weight of concrete masonry wall

W_a = Uniform or concentrated attachment load on the wall

g_W = Wall acceleration using appropriate damping values per Section 2.1.5

g_a = Peak acceleration for attachment loads using appropriate damping values per Section 2.1.5

2.1.2 Wall Frequency Calculations

The fundamental frequency calculations have been based on the plate theory for walls both with and without embedded steel columns. In developing the expression for frequency calculations for walls with embedded steel columns, the finite element technique has been used which takes into account the column flexibility, the wall edge conditions and the wall aspect ratios. Appendix A describes briefly the method used for development of the frequency equation and the wall edge conditions studied.

Frequency calculations have been based on moment of inertia of an uncracked section because the applied moments are always less than the moment capacities of uncracked section.

2.1.3 Material Property Variation Considerations

Variation in material properties which affects the stiffness of the concrete masonry wall is accounted for conservatively by assuming the following variation in the modulus of elasticity "E_m":

A. Hollow Units: $1000\ f'_m - 600\ f'_m$

B. Solid/Grouted Units: $1200\ f'_m - 800\ f'_m$

In design, the above variation in "E_m" is reflected by assuming a corresponding variation in frequency. The following frequency range has been used.

Solid/Grouted Units	0.9f - 1.1f
Hollow Units	0.8f - 1.0f

where:

f = frequency determined per requirements of Section 2.1.2 based on $E_m = 1000\ f'_m$

E_m = Modulus of elasticity for concrete masonry

f'_m = Masonry compressive strength equal to 1350 psi

2.1.4 Effect of Wall Opening on Frequency Calculations

Frequency values have been modified with the following adjustment factors to account for the openings in the wall.

Opening Area in Percent of Total Wall Surface Area	Adjustment Factor
0 - 10%	1.00
10 - 20%	0.95
20 - 35%	0.90
35 - 45%	0.85

The adjustment factors are based on the results of the finite element analysis of a wall panel in which various locations and sizes of the openings were studied. Also included in the study was the effect of different boundary conditions for the wall panel.

2.1.5 Determination of Wall Accelerations and Accelerations for Attachment Loads

A. Wall Accelerations

1. Damping values used:

   2% OBE
   4% SSE

2. The design "g" value has been determined by reading the largest value within the frequency range specified in Section 2.1.3 from the response spectra curves for each floor elevation at the top and bottom of the wall elevations and using the average of the two maximum values.

3. The design value of "g" determined above has been increased by a modal participation factor equal to 1.05 to account for participation of higher modes when wall frequency is less than 33 cps. The value of the modal participation factor has been determined by finite element modal analysis of typical wall panels.

B. Accelerations for Attachment Loads

1. Damping values of 2% for OBE and 4% for SSE load combinations have been used for attachment load.

2. The peak "g" value at each floor elevation corresponding to top and bottom of the wall elevations has been used to determine the design "g" value by taking the average of the two "g" values.

2.2 Design Procedure for Out-of-Plane Loads

2.2.1 Concrete masonry walls have been designed based on working stress principles. The design moments have been obtained considering a 12 inch wide beam strip. The walls have been assumed as simply supported or horizontally cantilevered, as applicable, with due consideration to the boundary conditions.

2.2.2 Structural steel columns have been used to provide lateral support for the masonry walls for out-of-plane loads, thereby creating horizontally spanning conditions. As such, the walls have been designed for horizontally spanning beam strip moments. A value of 36 psi has been permitted as the maximum value for the masonry stress parallel to the bed joint. A parametric study has been done to investigate the effect of column flexibility using different spacing and sizes of steel columns for various wall thicknesses. This study shows that a typical wall, which has a ratio of wall height to column spacing equal to 2.0, and which has been designed based on the above mentioned procedure, is subjected to secondary moments in the vertical direction smaller than the cracking moments.

The structural steel columns which have been provided to act as lateral support for the masonry wall are not subject to any axial load as the top connections of the columns have been provided with vertical slotted holes.

2.2.3 No overstress factor has been used in the design of masonry walls for load combinations containing OBE seismic loads which is in compliance with SEB Interim Criteria, Rev. 1, July 1981.

2.2.4 Horizontal joint reinforcement has not been considered for calculating the flexural strength of the wall.

2.2.5 The local pull-out effect due to an attachment load has been considered in the design.

2.2.6 Out-of-plane drift effects due to relative displacement of one floor with respect to the other are not imposed on the masonry walls at Byron/Braidwood Stations for the following reasons:

A. There is a 1" gap between the top of the walls and the underside of the floors above.

B. The top connections of the masonry lateral support steel columns are pinned connections.

2.3 Design Procedure for In-plane Loads

In-plane drift effects have been evaluated for the masonry walls with the following conditions:

A. As mentioned in our earlier responses, masonry walls are not part of the primary vertical or lateral load resisting system. They are non-load bearing, interior partition walls.

B. In-plane interstory drift is an imposed displacement on a masonry wall, and the resultant in-plane load is, therefore, a function of the in-plane shear stiffness of the masonry wall.

The in-plane stiffness is unpredictable, therefore a strain criteria, rather than stress criteria, is more reliable for evaluating drift effects. In-plane shear strain under SSE load condition is limited to 0.001 in. This allowable strain corresponds to initation of cracking in masonry, and not the failure of the wall. Therefore, the criteria is conservative.

The actual maximum shear strain in safety related masonry walls at Byron/Braidwood under SSE conditions is 0.0004"/" which corresponds to the maximum strain in the reinforced concrete shear walls. This strain is significantly less than 0.001".

2.4 Combined Effect of Out-of-Plane and In-plane Loads

The walls have been designed independently for in-plane and out-of-plane loads and no combined effect has been considered. However, the increase in stresses due to simultaneous application of loads due to two horizontal accelerations will be compensated because the actual stresses in each direction for the safety-related masonry walls at Byron/Braidwood Stations are low.

Table 1 indicates the maximum values of actual stresses as compared to the project allowable stresses and SEB allowable stresses. See discussion of allowable stresses in Section 2.6.

2.5 Loads and Load Combinations

The loads and load combinations used for the safety-related walls are in agreement with the loads and load combinations of SEB Interim Criteria, Rev. 1. As earlier mentioned in our responses, there are no safety-related concrete masonry walls at Byron/Braidwood Stations which are subject to accident pipe reaction (Y_r), jet impingement (Y_j) or missile impact (Y_m).

2.6 Allowable Stresses

A. The safety-related concrete masonry walls for Byron/Braidwood Stations have been designed using NCMA-1979 allowable stresses corresponding to the special inspection category. Commonwealth Edison Company's QA/QC procedures for the construction of safety related concrete masonry walls ensure compliance with the inspection requirements of the SEB Interim Criteria, Rev. 1, July 1981.

B. Table 1, attached, gives a comparison of the allowable stresses as used for the Byron/Braidwood Stations vs. SEB allowable stresses, both for OBE and SSE load combinations.

C. The allowable stresses used for the Byron/Braidwood Stations are in agreement with the Byron/Braidwood FSAR and SER.

D. SEB allowable stresses and project allowable stresses are compared as follows:

1. The project allowable tensile stress perpendicular to the bed joints due to out-of-plane loads is lower under OBE load combinations and exceeds SEB values by 19% to 25% under SSE load.

   The above increases in SEB allowable tensile stress perpendicular to the bed joints under SSE load combinations are not critical because all the safety related walls at Byron/Braidwood span horizontally.

2. The project allowable tensile stress parallel to the bed joints due to out-of-plane loads exceeds ACI 531-79 value by 4% under OBE load combinations and 3% to 16% under SSE load combinations.

   The above increases in SEB allowable tensile stress parallel to the bed joints are not a concern because the maximum actual stress under OBE or SSE load combinations is only 48% of SEB allowable value for hollow blockwalls and 32% for solid blockwalls. Moreover, horizontal joint reinforcement which has been ignored in the design does contribute towards the flexural strength of the wall. Also, the project allowable stress has an average factor of safety of 5.6 against failure loads under OBE load combinations and 3.35 (5.6/1.67) under the SSE load combinations. The failure loads are based on static monotonic tests performed in the past by various research organizations.

3. The project allowable shear stress is lower under OBE load combinations and exceeds SEB value by 10% under SSE load combinations. However, the maximum actual shear stress due to out-plane loads or in-plane inertia loads on any masonry wall at Byron/Braidwood is only 30% of SEB allowable value under OBE load combinations and 23% under SSE load combinations.

3.0 Design and Analysis Procedure for Reinforced Masonry Walls

3.1 Like unreinforced masonry walls at Byron/Braidwood Stations, safety-related reinforced masonry walls also have been used as non-load bearing, interior partition walls. These walls have been separated from the floor above by a gap to avoid any transfer of vertical loads on the walls. These walls have also not been considered as part of shear wall system for Category I structures. In addition, these walls have been separated from the building concrete or steel columns by a gap filled with compressible material running vertically the full height of the wall.

3.2 Reinforced masonry walls have been analyzed using the same procedure as described in Section 2.1 for unreinforced masonry walls. Like unreinforced masonry walls, the majority of these walls has also been designed spanning horizontally utilizing masonry support steel columns as lateral supports, whenever necessary. Based on the analysis the walls have been reinforced for the actual forces both vertically and horizontally. As a minimum, these walls have been provided with the minimum flexural reinforcement requirement of ACI 531-79.

Allowable stresses per ACI 531-79 have been used for design of reinforced masonry.

4.0 Miscellaneous Design Information

A. Vertical seismic acceleration is less than 1.0g for all of the safety related walls, thus causing no net tension on the walls.

B. The materials, testing, analysis, design, construction and inspection of safety related concrete masonry walls for Byron/Braidwood Stations are in general agreement with the Uniform Building Code-1979.

5.0 Effect of Cracks on Design of Concrete Masonry Walls

All safety-related masonry walls will be surveyed for the presence of structural cracks. At Byron Station

approximately 15% of the walls have been surveyed and no significant cracks have been found. It is anticipated that the entire survey will be complete by November 18, 1983.

6.0 Construction of Masonry Walls

All safety-related masonry walls at Byron/Braidwood Stations are identified as such on design drawings and have been constructed to the requirements of a safety-related specification. The resulting wall construction meets the criteria set forth in 10CFR50, Appendix B.

TABLE 1

Comparison of Actual Maximum Concrete Masonry Stresses

vs.

SEB and Byron/Braidwood Project Allowable Stresses

Hollow Block Construction

f'_m = 1,350 psi , M_o = 2,500 psi

Stress	Normal and OBE Load Combinations			SSE Load Combinations		
	Actual Maximum Stress (psi)	Byron/ Braidwood Project Allowable Stress (psi)	SEB Allowable Stress (psi)	Actual Maximum Stress (psi)	Byron/ Braidwood Project Allowable Stress (psi)	SEB Allowable Stress (psi)
Tension Parallel to Bed Joint f_t	24	46	50	36	77	75
Tension Perpendicular to Bed Joint f_t	12	23	25	12	38	32
Shear f_v	12	34	40	12	57	52

TABLE 2

Comparison of Actual Maximum Concrete Masonry Stresses

vs.

SEB and Byron/Braidwood Project Allowable Stresses

Solid Block Construction

f'_m = 1,350 psi , M_o = 2,500 psi

Stress	Normal and OBE Load Combinations			SSE Load Combinations		
	Actual Maximum Stress (psi)	Byron/ Braidwood Project Allowable Stress (psi)	SEB Allowable Stress (psi)	Actual Maximum Stress (psi)	Byron/ Braidwood Project Allowable Stress (psi)	SEB Allowable Stress (psi)
Tension Parallel to Bed Joint f_t	24	78	75	36	130	112
Tension Perpendicular to Bed Joint f_t	12	39	40	12	65	52
Shear f_v	12	34	40	12	57	52

APPENDIX A

PARAMETRIC STUDY TO DETERMINE WALL FREQUENCY

I. Fundamental wall frequency depends upon the following variables:

$$f, h, w, t, s, E_m, E_s, \rho_m, \rho_s, A_s, I_s$$

where:

f = fundamental frequency

h = height of wall

w = width of wall

t = thickness of wall

s = spacing of wall columns

E_m = masonry modulus of elasticity

E_s = steel modulus of elasticity

ρ_m = masonry mass density

ρ_s = steel mass density

A_s = total area of steel columns

I_s = total moment of inertia of steel columns

II. From Theory of Dimensional Analysis, the following functional relationship is derived:

$$\frac{f}{\sqrt{\frac{E_m}{\rho_m}\frac{t}{h^2}}} = f^* \left[\frac{E_m w t^3}{E_s I_s}, \frac{\rho_m w t}{\rho_s A_s}, \frac{h}{w}, \frac{h}{s}, \frac{h}{t}\right]$$

III. Normalized frequency may, therefore, be expressed as:

$$\frac{f}{\sqrt{\frac{E_m}{\rho_m}\frac{t}{h^2}}} = f^* \left[\frac{E_m w t^3}{E_s I_s}, \frac{\rho_m w t}{\rho_s A_s}, \frac{h}{w}\right]$$

IV. A family of curves may be generated for the frequency normalization factor (f^*) which is a function of:

$$A^* = \frac{\rho_m w t}{\rho_s A_s}, \quad I^* = \frac{E_m w t^3}{E_s I_s}, \frac{h}{w}$$

V. Fundamental wall frequency, therefore, reduces to:

$$f = \frac{1.64}{h^2} \left(\sqrt{\frac{E_m I_m}{W_w}} \right) f^*$$

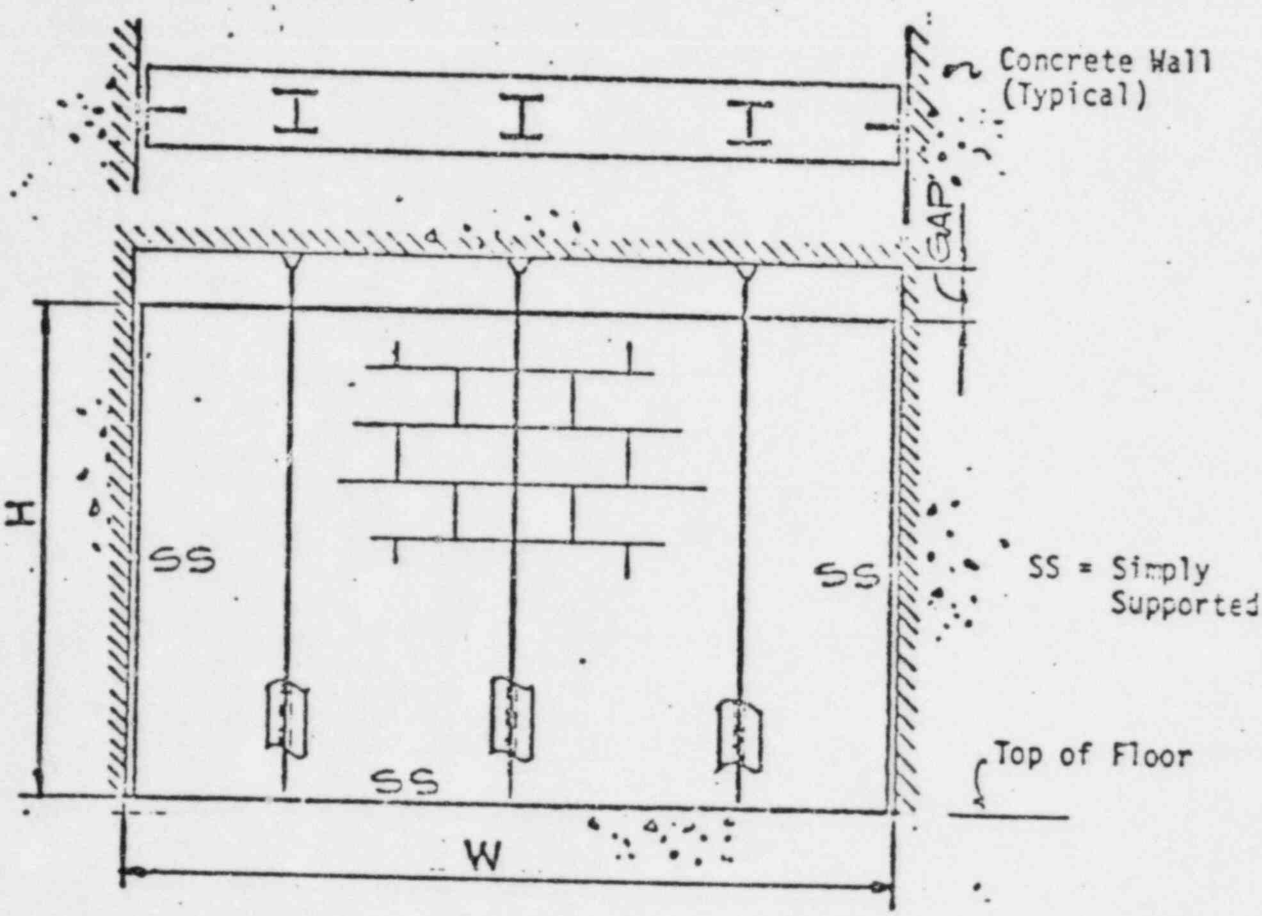
where:

I_m = masonry moment of inertia

W_w = weignt of wall per square foot of wall area

f^* = frequency normalization factor

Values of f* have been generated for Figures 1 through 3.

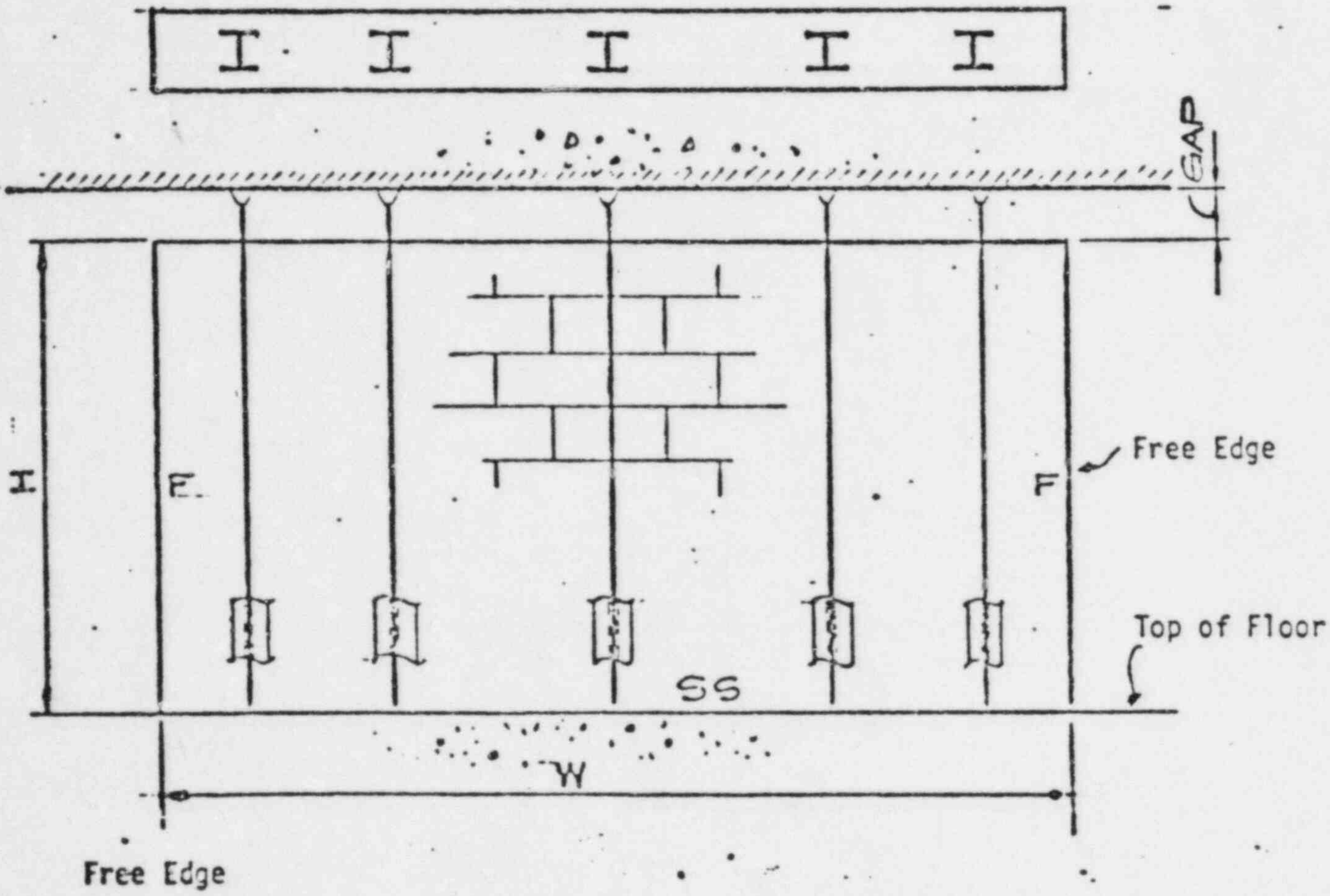


Boundary Condition SSS

I End supports non-yielding. Intermediate support flexible.

TYPICAL BOUNDARY AND SUPPORT STIFFNESS CONDITIONS

FIGURE 1

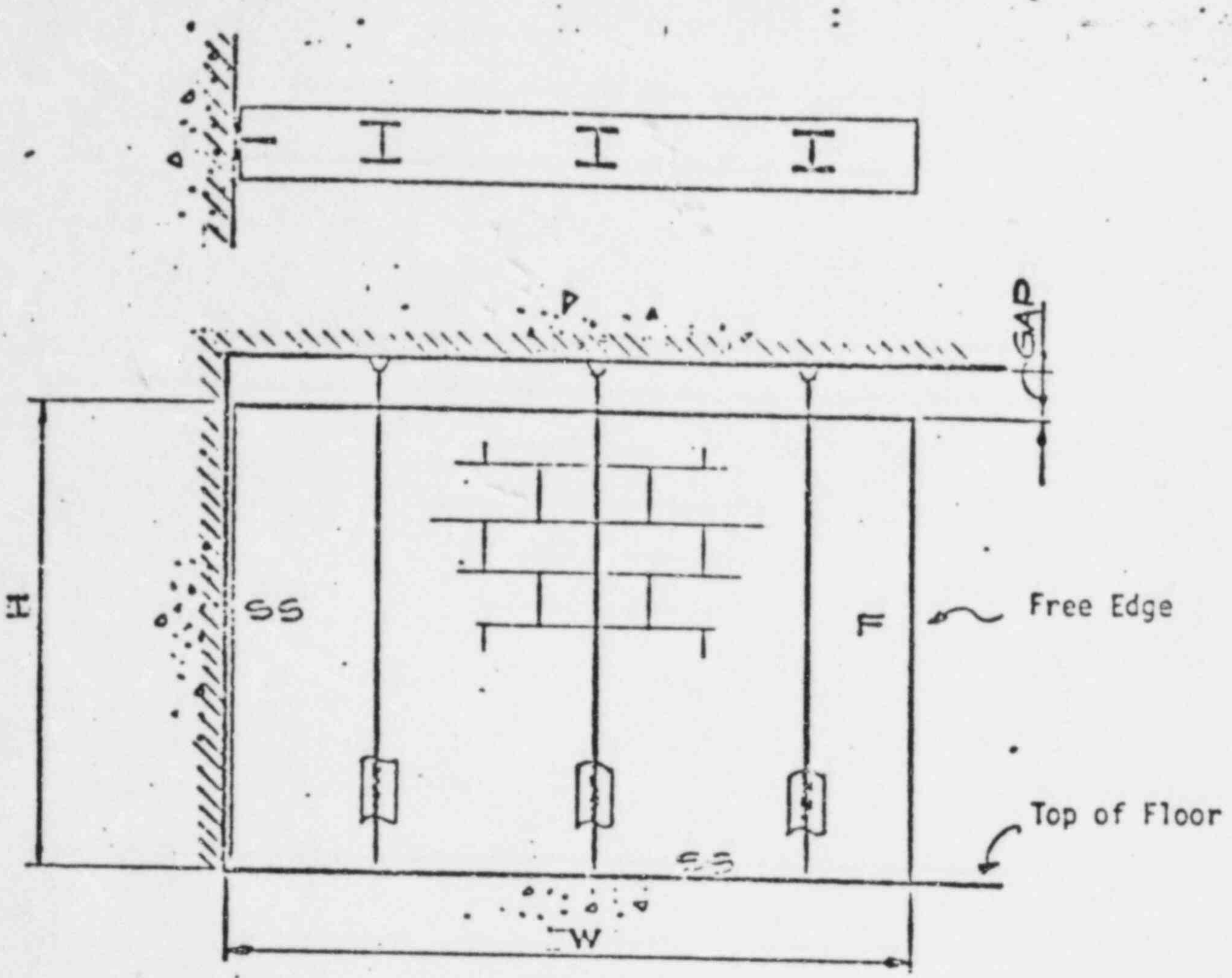


Boundary Condition FSF

II End supports flexible. Intermediate supports flexible.

TYPICAL BOUNDARY AND SUPPORT STIFFNESS CONDITIONS

FIGURE 2



Boundary Condition SSF

III One end support non-yielding. All other supports flexible.

TYPICAL BOUNDARY AND SUPPORT STIFFNESS CONDITIONS

FIGURE 3