STRESS MAGNIFICATIONS IN WALLS WITH OPENINGS

Bisülay Utku[I]

This paper is a part of a larger effort (1) to establish the relationships between the parameters of a wall opening (such as aspect ratio, position, and area), and the rigidity and strength of one-storey walls with single openings under earthquake loads. The walls are analyzed as plane stress problems assuming linearly elastic isotropic material and small deformations. For the analysis ELAS75 (2) computer program is used. In this paper, walls having the aspect ratio of 1/2 with openings of aspect ratios 1/1 and 1/2 are studied with different sizes and positions, under uniformly distributed unit horizontal static loading. Stress magnification factors for 16 cases (out of 148 in the original work) are presented, and the effects of opening size increments on the maximum stress magnification factors are graphically shown.

In seismic regions, in addition to the gravity loads, buildings are subjected to earthquake accelerations causing large inertial forces, many times during their lifetime. The resultant of the gravity loads and the instantaneous seismic loads caused by the earthquake accelerations may be considered as an inclined gravitational force. The degree of its inclination from the vertical is a function of the horizontal component of the seismic acceleration. It is the horizontal component of the seismic accelerations which is of great concern in the design of load bearing walls. In this work only this horizontal component is considered.

The following assumptions are made:

1. The wall is a single storey load bearing outer wall which has a single opening.
2. The opening is rectangular in shape.
3. The cross walls are on the same side and at the ends only.
4. The wall is clamped at the bottom, and carries a reinforced concrete slab at the top.
5. The wall material is linearly elastic homogeneous and isotropic.
6. The wall is subjected to a uniformly distributed unit horizontal static load in its plane at its upper edge.

The wall is shown in Fig. 1. Along the top and vertical edges thicknesses are varied to represent the stiffness of the cross walls and the slab. The responses of the idealized walls under unit loads are obtained by plane stress analysis, using the ELAS75 program. The program computes the responses by the displacement method of analysis and the finite element method. The key sketch of the wall with the finite element mesh producing less than 2% discretization error in the stresses is shown in Fig. 2. The program computes the displacements and the stresses at the mesh points. The standard

[I] Assistant Professor, Department of Architecture, Maçka, İstanbul Technical University

program is modified for this work to produce not only stresses σ_{xx}, σ_{yy}, σ_{xy} but also the principal stresses σ_1, σ_2, and the angle that σ_2 (smaller principal stress) makes with the horizontal direction.

The values of the wall parameters for the 16 cases studied in this work are given in Table I. The computer printouts for the stress magnification factors of these cases are presented in Figs. 3-6. The stress magnification factor at a wall point is defined as the ratio of the maximum shear stress at that point of the wall with opening to that of the corresponding wall without opening. Considering the largest magnification factor in the wall as the maximum magnification factor, the variation of this factor with the opening percentage (i.e., the ratio of the opening area to the wall area) is shown in Figs. 7-10.

From the results of this work, the following may be concluded:

i . The maximum stress magnification factor increases with an increasing rate as the opening percentage increases.

ii . The maximum stress magnification factor increases as the opening moves upward.

iii. The maximum stress magnification factor increases as the aspect ratio of the opening changes from 1/1 to 2/1.

Acknowledgements

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References

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(2) Utku, S., Instructor's Manual for Part II of Elementary Structural Analysis, Norris, Wilbur, Utku, 3rd Ed., McGraw-Hill Book Company, New York, 1976.

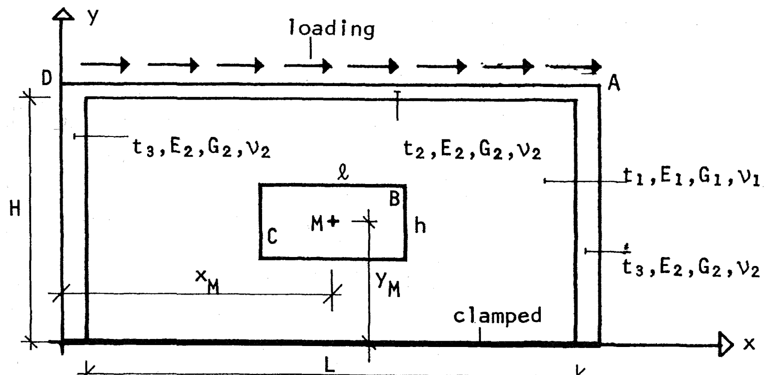

Figure 1. Idealized wall

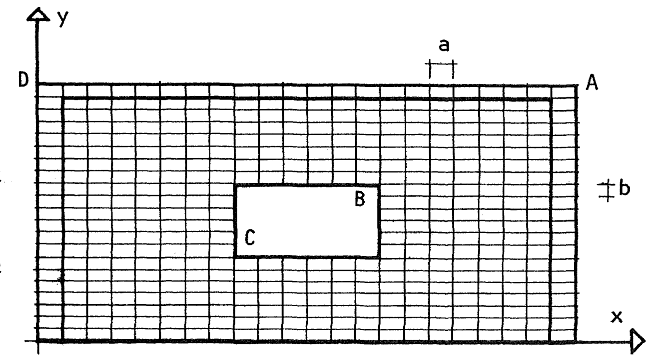

Figure 2. Key sketch

Table 1. VALUES OF WALL PARAMETERS

wall label	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
parameters	ranges of parameters															
opening(%)	4	9	16	36	2	8	18	32	2	8	18	32	2	8	18	32
ℓ/h	2				1											
x_M	11 a								15 a				11 a			
y_M	10 b												2b	4b	6b	8b
H	20 b															
L/H	2															
t_1	1															
t_2/t_1	5															
t_3/t_1	3															
E_2/E_1	1															
G_2/G_1	1															
$\nu_1=\nu_2$	1/4															

t_1 : wall thickness

t_2, t_3: thicknesses in the boundary zones

E_1, E_2: wall and boundary Young's Moduli

G_1, G_2: wall and boundary Shear Moduli

ν_1, ν_2: wall and boundary Poisson's ratios

a : horizontal meshsize (DDX in printouts)

b : vertical meshsize (DDY in printouts)

MAG TABLE
JXA=23 IYA=22 JXB=14 IYB=13 JXC=10 IYC= 9 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	98	98	96	93	89	88	89	97	110	123	128	123	110	97	89	88	89	93	96	99	98
19	98	97	95	93	90	87	88	95	109	123	128	123	109	95	88	87	90	93	95	97	99
18	100	99	97	94	90	88	87	93	108	122	128	122	108	93	87	88	90	94	97	99	100
17	101	101	99	96	92	89	86	89	106	122	128	122	106	89	86	89	92	96	99	101	101
16	105	102	101	99	96	92	85	84	101	120	125	120	101	84	85	92	96	99	101	102	105
15	106	106	105	104	101	97	87	80	95	115	119	115	95	80	87	97	101	104	105	106	106
14	109	109	109	109	108	104	94	77	86	109	105	109	86	77	94	104	108	108	109	109	109
13	112	111	112	113	114	114	106	84	76	104	72	104	76	84	106	114	114	113	112	111	112
12	114	114	115	118	121	125	127	124	108	62	1	62	108	124	127	125	121	118	115	114	114
11	115	116	118	122	127	134	144	150	108				108	150	144	134	127	122	118	116	115
10	116	117	120	124	129	138	147	136	101				101	136	147	138	129	124	120	117	116
9	115	118	120	123	128	134	142	145	109				109	145	142	134	128	123	120	118	117
8	116	116	120	122	124	126	124	116	100	53	1	53	100	116	124	126	124	122	120	116	116
7	115	116	118	119	118	115	103	75	72	97	63	97	72	75	103	115	118	119	118	116	115
6	114	115	116	116	113	106	92	71	84	100	93	100	84	71	92	106	113	116	116	115	114
5	113	113	113	112	108	100	86	75	92	106	107	106	92	75	86	100	108	112	113	113	113
4	113	112	111	109	104	96	86	82	97	109	111	109	97	82	86	96	104	109	111	112	113
3	111	110	109	106	101	94	87	87	103	109	112	109	100	87	87	94	101	105	108	110	111
2	110	108	106	102	98	92	89	92	102	109	111	109	102	92	89	92	98	102	106	108	110
1	109	106	103	100	95	91	90	94	103	109	111	109	103	94	90	91	95	100	104	106	109
0	108	105	101	96	92	89	89	94	104	112	114	112	104	94	89	89	92	96	101	105	108

W1

MAG TABLE
JXA=23 IYA=22 JXB=15 IYB=14 JXC= 9 IYC= 8 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	93	93	88	81	74	73	83	104	127	143	149	143	127	104	83	73	74	81	88	93	93
19	93	91	87	81	75	72	81	103	126	141	147	141	126	103	81	72	75	81	87	91	94
18	97	95	91	85	78	74	77	100	125	137	141	137	125	100	77	74	78	85	90	95	97
17	101	101	97	92	85	78	75	96	122	131	132	131	122	96	75	78	85	92	97	101	101
16	110	107	105	102	96	86	73	91	118	120	116	120	118	91	73	86	96	102	105	106	110
15	117	116	115	114	110	100	79	86	118	101	91	101	118	86	79	100	110	114	115	116	116
14	124	124	126	127	127	120	97	85	132	74	52	74	132	85	97	120	127	127	126	124	124
13	132	131	135	140	144	149	149	133	111	48	6	48	111	133	149	149	144	140	135	131	132
12	138	138	143	150	159	168	173	118						118	173	168	159	150	143	138	138
11	140	143	149	158	167	170	141	99						99	141	170	167	158	149	143	140
10	142	145	152	161	167	169	131	96						96	131	169	167	161	152	145	142
9	141	146	151	158	164	164	135	112						112	135	164	164	158	151	146	143
8	141	143	150	153	155	156	155	140						140	155	156	156	153	150	143	141
7	138	140	144	144	141	133	122	116	73	26	7	26	73	116	122	133	141	144	144	140	138
6	135	137	138	135	126	107	75	84	112	47	27	47	112	84	75	107	126	135	138	137	135
5	132	132	131	126	113	93	71	94	102	71	57	71	102	94	71	93	113	126	131	132	132
4	130	128	125	117	104	86	78	101	103	86	77	86	103	101	78	86	104	117	125	128	130
3	127	123	118	110	98	85	85	105	106	95	90	95	106	105	85	85	98	109	118	123	127
2	125	119	112	103	93	85	91	107	108	102	99	102	108	107	91	85	93	103	112	119	125
1	121	115	107	97	88	86	94	107	109	106	105	106	109	107	94	86	88	97	107	115	121
0	119	111	100	90	82	82	92	107	112	113	113	113	112	107	92	82	82	90	100	111	119

W2

MAG TABLE
JXA=23 IYA=22 JXB=16 IYB=15 JXC= 8 IYC= 7 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	80	78	69	58	52	62	95	127	149	158	161	158	149	127	95	62	52	58	69	78	79
19	80	77	70	61	55	61	92	125	145	154	156	154	145	125	92	61	55	61	70	77	81
18	89	86	81	75	66	61	89	125	141	142	143	142	141	125	89	61	66	75	81	86	88
17	100	100	98	94	85	69	88	128	133	125	122	125	133	128	88	69	85	94	98	100	100
16	119	116	118	118	110	89	90	140	122	101	92	101	122	140	90	99	110	118	118	116	118
15	136	137	141	145	141	120	103	178	110	69	52	69	110	178	103	120	141	145	140	136	136
14	153	156	163	171	180	166	172	175	102	49	7	49	102	175	172	186	180	171	163	155	153
13	169	171	180	192	203	213	139								140	213	203	192	180	171	169
12	180	183	191	203	204	163	110								110	163	204	203	193	183	180
11	186	191	200	207	198	143	94								94	143	198	207	200	191	186
10	188	193	203	207	192	137	101								101	137	192	207	203	193	188
9	185	192	199	201	188	140	127								127	140	188	201	199	192	187
8	183	185	193	193	184	153	163								163	153	184	193	193	185	183
7	175	178	181	179	173	182	204								204	182	173	179	181	178	175
6	169	169	169	160	145	116	151	86	34	14	7	14	34	86	151	136	145	160	168	169	169
5	162	160	153	140	113	81	113	139	54	22	11	22	54	139	113	81	113	140	153	160	162
4	157	150	140	123	98	96	126	121	73	42	31	42	73	121	126	96	98	123	140	150	157
3	151	141	128	110	92	96	130	117	84	59	51	59	84	117	130	96	92	109	128	141	151
2	146	133	117	100	91	104	130	117	91	73	67	73	91	117	130	104	91	100	117	133	146
1	140	124	106	92	89	107	128	116	98	85	80	85	98	116	126	107	89	92	106	124	140
0	134	116	98	80	82	104	126	122	108	95	89	95	108	122	126	104	82	80	98	116	134

W3

MAG TABLE
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E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	30	28	43	24	68	135	172	179	176	174	174	174	176	179	172	135	68	25	41	28	31
19	21	53	77	59	58	148	176	173	165	160	159	160	165	173	176	148	58	60	77	53	22
18	50	102	138	127	94	213	206	175	150	132	127	132	150	175	206	213	94	128	138	102	50
17	119	165	206	204	172	339	253	189	138	97	79	97	138	189	253	339	172	204	206	165	119
16	201	234	286	325	321	406	294	214	140	70	4	70	140	214	294	406	321	325	286	234	201
15	272	299	340	379	233												233	378	340	299	272
14	324	339	346	275	182												182	275	346	339	324
13	358	357	334	230	142												142	230	334	357	358
12	371	363	322	209	136												136	209	322	363	371
11	369	361	311	204	157												157	204	312	361	369
10	362	350	303	209	192												192	209	303	350	362
9	347	335	294	220	237												237	220	294	335	351
8	334	315	288	237	288												288	237	288	315	334
7	312	296	278	257	347												347	257	278	296	312
6	293	273	266	279	417												417	279	266	273	293
5	271	244	239	310	486												486	310	239	244	271
4	253	211	185	215	318	115	41	24	14	7	2	7	14	24	41	115	318	215	185	211	253
3	234	179	135	156	256	224	67	31	17	9	7	9	17	31	67	224	256	155	135	179	234
2	220	154	118	182	272	198	93	46	26	17	14	17	26	46	93	198	272	182	118	154	220
1	205	129	108	194	265	177	108	62	36	24	21	24	36	62	108	177	265	194	108	129	205
0	187	97	80	183	262	196	130	77	44	29	25	29	44	77	130	196	262	183	80	97	187

W4

Figure 3. Computer printouts for walls W1,W2,W3,W4

MAG TABLE
JXA=23 IYA=22 JXB=13 IYB=13 JXC=11 IYC= 9 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	99	100	99	97	96	95	95	97	103	111	115	111	103	97	95	95	96	97	99	100	99
19	99	99	98	97	96	94	94	96	102	111	115	111	102	96	94	94	96	97	98	99	101
18	101	100	99	98	96	95	94	95	101	111	117	111	101	95	94	95	96	98	99	100	101
17	100	101	100	98	97	95	94	93	99	111	119	111	99	93	94	95	97	98	100	101	100
16	102	101	100	100	98	97	93	91	94	111	121	111	94	91	93	97	98	100	100	101	102
15	102	103	102	102	100	99	95	90	89	108	124	108	89	90	95	99	100	102	102	103	102
14	103	104	103	103	103	102	99	90	82	103	128	103	82	90	98	102	103	103	103	104	103
13	105	104	104	105	105	105	103	96	76	87	135	87	76	96	103	105	105	105	104	104	105
12	106	105	106	107	108	109	110	109	103	89	37	89	103	109	110	109	108	107	106	105	106
11	105	106	107	108	110	113	117	122	125	97		97	125	122	117	113	110	108	107	106	106
10	106	107	108	109	111	115	119	126	115	90		90	115	126	119	115	111	109	108	107	106
9	106	107	108	109	111	113	117	122	123	97		97	123	122	117	113	111	109	108	107	107
8	107	106	108	108	110	111	111	109	99	88	37	88	99	109	111	111	110	108	108	106	107
7	105	106	107	107	108	107	104	93	72	85	132	85	72	93	104	107	108	107	107	106	105
6	105	106	106	107	106	104	99	88	78	101	125	101	78	88	99	104	106	107	106	106	105
5	105	105	105	105	104	101	95	87	85	105	121	105	85	87	95	101	104	105	105	105	105
4	105	105	104	104	102	99	95	90	91	106	117	106	91	90	95	99	102	104	104	105	105
3	104	104	103	103	101	98	94	92	94	106	113	106	94	92	94	98	101	102	103	104	104
2	104	104	103	101	99	97	95	94	97	105	110	105	97	94	95	97	99	101	103	104	104
1	104	103	102	100	98	96	95	96	99	105	108	105	99	96	95	96	98	100	102	103	104
0	103	102	101	99	97	95	94	96	100	106	109	106	100	96	94	95	97	99	101	102	103

W5

MAG TABLE
JXA=23 IYA=22 JXB=14 IYB=15 JXC=10 IYC= 7 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	100	99	95	88	81	75	75	89	119	145	156	145	119	89	75	75	81	88	95	99	100
19	99	98	94	88	82	75	75	87	117	144	154	144	117	87	75	75	82	88	94	98	101
18	103	101	97	92	85	79	75	82	114	141	150	141	114	82	75	79	85	92	97	101	103
17	105	105	101	97	92	86	78	75	107	137	143	137	107	75	78	86	92	97	101	105	105
16	111	108	106	104	101	96	85	71	97	129	125	129	97	71	85	96	101	104	106	108	111
15	115	114	113	113	112	109	99	77	82	123	84	123	82	77	99	109	112	113	113	114	115
14	119	119	120	121	123	124	123	120	111	71	0	71	111	120	123	124	123	121	120	119	119
13	124	123	125	128	131	136	140	145	115				115	145	140	136	131	128	125	123	124
12	129	127	130	134	139	143	142	115	89				89	115	142	143	139	134	130	127	128
11	129	131	134	138	143	146	140	102	70				70	102	140	146	143	138	134	131	129
10	130	132	136	141	144	147	137	98	68				68	98	137	147	144	141	136	132	130
9	130	132	136	139	143	144	135	99	82				82	99	135	144	143	139	136	132	131
8	131	131	135	137	139	139	132	108	107				107	108	132	139	139	137	135	131	130
7	128	130	132	133	133	131	126	127	135				135	127	126	131	133	134	132	130	129
6	127	128	129	129	126	119	108	97	104	47	3	47	104	97	108	119	126	129	129	128	127
5	125	125	125	121	118	107	87	63	85	100	56	100	85	63	87	107	118	123	125	125	125
4	124	122	121	119	111	98	81	71	99	103	99	103	99	71	81	98	111	118	121	122	124
3	122	120	117	112	104	93	81	82	107	109	104	109	107	82	81	93	104	111	117	120	122
2	120	117	113	105	98	89	83	91	110	112	110	112	110	91	83	89	99	106	112	117	120
1	114	113	113	101	91	86	86	96	111	113	113	113	111	96	86	86	91	101	108	111	112
0	116	111	101	96	91	82	83	95	112	119	121	119	112	95	91	82	88	96	103	111	116

W6

MAG TABLE
JXA=23 IYA=22 JXB=15 IYB=17 JXC= 9 IYC= 5 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	129	133	92	76	57	47	49	101	151	175	181	175	151	101	49	47	57	76	92	133	129
19	134	135	93	81	63	57	53	95	145	162	164	162	145	95	53	57	64	82	95	105	111
18	117	113	105	97	92	81	66	91	140	139	131	135	149	91	66	83	90	97	105	111	117
17	125	123	119	116	116	114	95	91	173	104	89	104	173	91	95	118	116	116	119	123	125
16	133	134	134	136	142	159	154	154	152	70	6	70	152	154	159	150	142	136	133	134	133
15	149	147	148	153	161	173	187	141						141	187	173	161	154	148	147	144
14	159	159	161	166	172	172	160	107						107	140	172	172	166	161	159	158
13	168	166	169	174	175	164	116	78						78	116	164	175	174	169	166	163
12	171	172	175	179	179	157	103	64						64	103	157	176	179	175	172	173
11	176	174	179	181	179	151	98	68						68	98	151	179	181	179	176	174
10	177	177	181	181	171	149	103	81						83	109	149	171	181	181	177	177
9	175	174	178	177	169	147	107	104						104	107	147	169	177	178	176	177
8	174	172	174	171	166	147	117	129						129	117	147	166	171	176	172	174
7	159	169	171	167	163	143	132	159						159	130	143	163	167	170	169	169
6	166	164	163	163	153	146	144	195						195	144	146	153	167	163	164	163
5	162	154	155	155	143	133	162	232						232	162	138	143	150	155	154	162
4	151	152	147	139	127	115	123	159	51	15	12	15	53	159	123	115	127	139	147	152	159
3	158	156	117	127	113	97	97	131	111	17	12	37	113	131	97	97	113	120	137	146	159
2	150	151	124	115	102	95	112	142	153	57	41	57	153	142	137	96	102	115	129	133	153
1	149	132	117	103	96	97	121	144	103	75	64	75	103	144	121	97	94	104	117	132	149
0	115	119	115	91	87	74	122	146	115	92	79	92	115	146	123	93	91	91	115	125	119

W7

MAG TABLE
JXA=23 IYA=22 JXB=16 IYB=19 JXC= 8 IYC= 3 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	152	134	113	86	68	56	55	161	158	145	141	145	158	161	55	56	68	86	113	134	152
19	155	145	129	116	110	112	82	206	147	110	96	110	147	206	82	112	116	116	129	145	157
18	172	163	155	158	175	202	197	245	158	78	5	78	158	245	197	202	176	158	155	163	172
17	189	184	182	190	211	241	169								169	241	211	190	182	184	188
16	210	201	202	209	213	177	128								128	177	213	209	202	201	210
15	223	219	217	219	205	146	95								95	146	205	219	217	219	223
14	235	231	227	220	196	131	84								84	131	196	220	227	231	235
13	245	236	231	219	187	125	91								91	125	187	219	231	236	245
12	249	239	232	217	183	126	108								108	126	183	217	232	239	249
11	248	240	231	214	181	133	130								130	133	181	214	231	240	248
10	247	237	228	211	179	145	154								154	145	179	211	228	237	247
9	242	232	222	206	181	158	180								180	158	181	206	222	232	244
8	239	224	218	203	184	174	207								207	174	184	203	218	224	239
7	231	218	209	198	187	191	238								238	191	187	198	209	218	231
6	226	211	201	194	191	208	273								273	208	191	194	201	211	226
5	219	202	191	187	193	226	310								310	226	193	187	191	202	219
4	214	193	180	177	191	242	359								359	242	191	177	180	193	214
3	206	183	167	162	180	254	408								409	254	180	161	167	183	206
2	200	172	150	142	157	210	271	41	15	6	1	6	15	41	271	210	157	142	150	172	200
1	190	159	130	121	145	194	222	109	26	9	6	9	26	109	222	199	145	123	131	158	190
0	179	141	105	101	136	202	240	125	50	18	11	18	50	125	240	202	136	100	135	141	179

W8

Figure 4. Computer printouts for walls W5,W6,W7,W8

MAG TABLE
JXA=23 IYA=22 JXB=17 IYB=13 JXC=15 IYC= 9 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	102	103	103	102	102	101	100	98	96	95	94	96	101	109	114	112	104	96	92	89	85
19	102	102	101	102	102	101	100	98	96	95	94	96	100	108	114	111	104	96	90	87	86
18	104	104	103	103	102	102	100	99	97	95	94	94	99	108	116	112	102	94	90	88	86
17	103	105	104	103	103	102	101	99	98	96	94	93	97	108	118	113	100	92	90	89	86
16	105	104	104	104	103	103	101	101	99	97	94	93	92	107	120	114	96	90	89	89	90
15	104	105	104	104	104	104	102	102	101	99	95	99	87	105	123	113	90	88	90	93	93
14	104	105	105	104	104	104	104	103	103	102	98	91	81	99	128	108	82	87	94	97	97
13	105	105	105	105	104	105	105	105	105	105	103	95	76	83	134	92	74	91	99	102	103
12	105	105	105	105	105	105	105	106	107	108	110	108	101	85	37	95	102	108	108	108	108
11	105	105	105	105	106	106	106	107	109	111	115	120	121	92		106	129	124	118	113	111
10	105	105	106	106	105	106	107	108	109	112	117	123	114	92		91	118	130	123	116	113
9	104	105	105	105	106	106	107	108	109	112	115	120	123	104		88	124	126	121	116	113
8	105	105	106	105	106	106	106	109	109	109	109	107	101	94	37	80	101	113	116	113	111
7	104	105	105	105	105	106	106	106	107	106	102	94	75	91	133	77	72	97	108	110	108
6	105	105	105	105	105	105	106	105	105	103	98	90	81	104	126	94	74	90	101	106	105
5	105	105	104	105	105	105	104	104	103	101	96	89	88	108	120	100	81	87	96	102	103
4	105	105	105	105	105	105	104	104	102	99	95	91	93	109	117	102	86	87	94	99	102
3	105	105	104	105	105	104	103	102	100	98	95	94	97	108	113	103	90	88	93	97	100
2	105	105	105	104	104	103	103	101	100	98	96	96	99	107	109	103	91	90	92	96	99
1	104	104	104	104	103	103	102	101	99	98	97	98	101	107	107	101	94	91	92	94	96
0	105	104	104	103	103	103	101	100	99	97	96	94	102	109	109	103	95	90	90	93	97

W9

MAG TABLE
JXA=23 IYA=22 JXB=18 IYB=15 JXC=14 IYC= 7 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 2 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	114	113	112	111	109	106	101	93	85	77	75	83	108	136	151	146	122	89	64	49	34
19	114	114	114	113	111	107	101	94	86	79	76	83	107	134	148	144	121	86	60	44	33
18	118	118	116	115	112	109	104	97	91	83	77	78	103	132	145	143	119	80	57	44	36
17	119	120	118	116	114	111	107	102	97	89	80	74	97	127	138	139	115	72	57	51	44
16	122	120	120	119	116	114	111	108	104	98	87	72	88	120	120	132	105	63	62	63	61
15	122	123	121	121	119	118	115	114	112	108	100	78	76	117	80	125	88	63	79	84	81
14	123	124	123	122	122	121	120	120	120	121	119	116	104	71	5	66	117	115	112	109	105
13	125	124	124	124	121	124	124	126	128	130	134	134	100				142	154	140	131	128
12	126	125	125	125	125	126	127	129	133	136	135	108	79				113	125	148	147	143
11	125	126	126	126	127	128	130	132	136	138	133	97	67				85	112	149	155	150
10	125	126	127	127	127	129	131	134	137	139	130	96	71				68	104	148	156	152
9	125	126	126	127	127	129	131	133	136	137	130	103	90				68	102	145	153	150
8	125	125	127	126	127	127	130	132	133	134	129	111	118				83	107	142	146	143
7	124	125	126	126	126	127	128	128	128	126	123	131	149				105	125	134	136	133
6	124	125	125	125	125	125	126	124	122	116	105	101	113	51	2	46	88	99	115	123	124
5	123	124	121	124	124	123	121	119	115	105	88	73	93	109	57	90	67	59	92	109	115
4	124	121	121	123	122	121	119	115	109	98	84	78	107	112	91	95	82	56	78	98	108
3	121	122	122	123	120	114	115	111	104	95	86	89	114	114	104	102	90	62	71	89	102
2	123	122	121	111	119	115	112	107	101	94	91	94	117	116	109	104	93	68	68	83	98
1	122	121	120	114	115	113	109	104	98	94	95	104	114	116	111	104	92	71	65	78	94
0	121	120	119	114	114	111	106	101	96	92	93	105	120	121	119	109	92	67	58	72	89

W10

MAG TABLE
JXA=23 IYA=22 JXB=19 IYB=17 JXC=13 IYC= 5 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	149	135	134	132	127	119	108	92	74	58	51	81	130	156	166	166	150	110	45	33	62
19	142	141	140	137	132	123	112	97	83	72	62	81	127	145	149	152	144	102	29	22	53
18	153	148	146	142	136	128	119	109	101	92	76	81	134	128	120	128	143	95	19	22	36
17	154	154	151	145	141	135	128	122	115	115	100	88	160	103	74	88	160	83	42	47	35
16	163	157	154	153	146	142	137	135	137	142	148	142	148	80	20	46	129	145	127	98	82
15	161	162	159	155	151	149	146	147	150	156	165	112						192	188	148	131
14	163	164	162	159	156	155	154	154	156	154	122	85						157	152	168	163
13	166	165	163	162	159	159	159	160	159	146	103	66						121	134	172	179
12	167	166	165	164	163	163	162	162	159	141	95	63						91	121	172	183
11	166	167	166	166	166	165	165	164	159	137	94	72						71	111	169	180
10	166	166	167	167	165	167	166	165	156	137	98	89						63	104	162	175
9	164	166	166	166	166	166	165	163	156	138	108	110						68	100	155	169
8	165	163	166	165	164	165	163	162	159	141	120	135						86	101	146	161
7	162	163	163	163	162	162	160	157	152	148	133	166						110	103	139	151
6	161	161	161	161	160	158	156	151	147	144	148	202						139	110	131	141
5	160	159	158	158	156	154	149	144	139	138	168	240						168	125	119	129
4	161	157	156	154	152	149	144	136	127	118	129	164	56	13	9	12	48	116	88	97	117
3	159	155	153	151	147	142	136	129	117	106	107	135	118	35	14	29	95	93	49	75	104
2	157	159	150	146	142	136	127	121	112	109	122	147	107	62	40	50	84	102	54	61	96
1	155	151	147	142	[illegible]	133	123	115	112	114	134	150	108	77	61	65	81	100	58	51	89
0	131	145	141	134	[illegible]	125	117	110	106	111	134	154	132	93	73	77	87	96	49	37	81

W11

MAG TABLE
JXA=23 IYA=22 JXB=20 IYB=19 JXC=12 IYC= 3 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	199	177	177	174	166	154	137	116	100	89	51	143	143	130	122	121	130	139	90	78	142
19	194	193	191	185	176	162	146	131	127	124	95	189	146	112	98	80	102	161	46	56	116
19	210	206	201	193	183	172	169	155	164	181	177	224	162	102	42	22	94	182	144	108	89
17	219	217	210	200	191	181	173	171	182	196	120								235	195	152
16	229	222	216	208	198	190	182	180	176	143	92								205	161	178
15	[illegible]	[illegible]	222	215	205	197	189	183	167	118	76								169	153	177
14	234	233	227	218	211	202	194	182	159	109	78								136	145	172
13	236	233	228	221	213	206	196	182	155	108	91								106	133	167
12	236	233	229	223	216	208	196	180	153	113	107								83	123	160
11	234	234	229	224	218	208	197	180	154	122	126								72	115	151
10	232	231	229	224	216	210	198	182	158	135	145								75	107	144
9	229	228	225	221	215	208	197	183	164	150	167								88	102	138
8	224	223	223	218	213	206	196	185	172	167	191								108	99	131
7	221	221	213	214	209	202	196	186	182	184	217								130	97	123
6	221	217	214	213	205	199	194	187	187	202	248								154	96	118
5	217	213	208	205	199	194	189	185	193	219	287								178	97	113
4	216	[illegible]	201	[illegible]	193	187	183	182	198	235	332								207	98	110
3	212	205	192	192	168	179	174	174	188	248	383								235	104	101
2	219	201	192	191	175	164	163	163	171	211	256	42	16	7	2	3	8	28	153	69	84
1	[illegible]	135	196	[illegible]	[illegible]	[illegible]	154	155	160	202	212	109	27	13	5	6	16	67	126	52	69
0	[illegible]	131	[illegible]	[illegible]	155	154	143	147	160	207	231	126	51	19	9	12	30	71	133	44	60

W12

Figure 5. Computer printouts for walls W9,W10,W11,W12

MAG TABLE
JXA=23 IYA=22 JXB=11 IYB= 5 JXC=11 IYC= 0 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	97	99	99	99	99	99	100	101	102	102	103	102	102	101	100	99	99	99	99	99	97
19	97	97	99	98	99	99	100	100	102	103	103	103	102	100	100	99	99	98	98	97	98
18	99	98	98	98	99	99	100	101	102	102	103	102	102	101	100	99	99	98	98	98	98
17	97	98	99	99	98	99	100	100	102	103	103	103	103	102	100	100	99	98	98	98	97
16	98	97	98	99	98	99	99	100	102	103	103	103	102	100	99	99	98	98	98	97	98
15	98	98	99	99	98	99	99	100	102	103	104	103	102	100	99	99	98	99	98	98	98
14	97	99	99	99	99	99	99	100	101	104	104	104	101	100	99	99	99	99	99	99	98
13	99	99	98	99	98	99	99	100	101	103	105	103	101	100	99	99	98	99	98	99	99
12	100	99	99	99	99	98	98	98	101	103	105	103	101	98	98	98	98	99	99	99	100
11	100	100	100	100	98	98	97	97	100	103	106	103	100	97	97	98	99	100	100	100	100
10	100	101	101	100	99	98	97	97	98	103	106	103	98	97	97	98	99	100	101	100	100
9	100	101	101	100	100	98	96	95	96	103	108	103	96	95	96	98	100	100	101	101	101
8	102	101	102	101	101	99	96	94	93	102	109	102	93	94	96	99	101	101	102	101	102
7	102	102	103	103	102	101	98	92	89	100	110	100	89	92	98	101	102	103	103	102	102
6	103	104	104	104	104	103	100	93	83	94	111	94	83	93	100	103	104	104	104	104	103
5	101	104	104	106	106	106	104	97	80	80	115	80	80	97	104	106	106	106	104	104	103
4	104	105	106	107	108	109	110	110	102	84	30	84	102	110	110	109	103	107	106	105	104
3	104	105	107	109	110	112	116	120	120	90		90	120	120	116	112	110	107	107	106	104
2	105	106	[illegible]	109	111	113	118	122	111	93		93	111	122	118	113	111	109	108	106	105
1	105	106	108	110	111	114	117	118	111	112		112	111	119	117	114	111	110	109	106	105
0	106	106	110	112	112	114	115	111	102	114		114	102	111	115	114	112	110	108	106	106

W13

MAG TABLE
JXA=23 IYA=22 JXB=14 IYB= 0 JXC=10 IYC= 0 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	88	91	91	91	92	94	99	104	111	116	119	116	111	104	99	94	92	91	91	91	88
19	88	89	90	93	92	94	99	104	111	117	120	117	111	104	98	94	92	90	89	89	89
18	89	89	90	90	91	93	97	103	112	118	120	118	112	103	97	93	91	90	90	89	88
17	88	90	92	92	91	92	96	102	111	118	122	118	111	102	96	92	91	90	90	90	88
16	91	90	91	91	91	92	94	101	110	119	122	119	110	101	94	92	91	91	91	90	91
15	92	93	92	92	91	91	92	98	109	119	123	119	109	98	92	91	91	92	92	93	92
14	94	95	95	94	92	90	90	94	107	120	123	120	107	94	90	93	92	94	95	95	94
13	98	98	98	97	94	90	87	90	105	118	123	118	105	90	87	90	94	97	98	98	98
12	102	101	101	100	97	92	85	84	100	116	121	116	100	84	85	92	97	100	101	101	102
11	104	106	106	105	102	95	86	78	94	112	115	112	94	78	86	95	102	105	106	105	104
10	108	109	111	110	107	102	90	74	85	106	100	106	85	74	90	102	107	110	111	109	108
9	110	113	115	115	115	111	101	78	74	101	67	101	74	78	101	111	115	115	115	113	112
8	114	116	120	121	123	123	113	114	99	59	1	59	99	114	119	123	123	121	120	116	114
7	116	119	123	126	129	133	135	133	97				97	133	135	133	129	126	123	119	116
6	118	122	127	131	135	138	137	109	78				78	109	137	138	135	131	127	122	118
5	120	124	129	134	138	141	133	98	69				69	98	133	141	138	134	129	124	120
4	122	126	131	135	139	140	132	96	77				77	96	132	140	139	135	131	126	122
3	122	127	131	134	138	138	129	98	96				96	98	129	138	138	134	131	127	122
2	123	127	131	134	135	133	125	104	123				123	104	125	133	135	134	131	127	123
1	124	126	131	132	131	127	119	115	155				155	115	119	127	131	132	130	126	124
0	124	125	129	[illegible]	[illegible]	122	110	105	153				153	105	110	122	128	130	129	125	124

W14

MAG TABLE
JXA=23 IYA=22 JXB=15 IYB=13 JXC= 9 IYC= 0 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	73	77	75	72	71	76	91	114	137	152	158	152	137	114	91	76	71	72	75	77	73
19	72	73	72	70	70	74	89	113	137	152	158	152	137	113	89	74	73	70	72	73	74
18	75	75	74	72	73	73	86	111	137	150	155	150	137	111	86	73	73	72	74	75	75
17	79	[illegible]	79	75	74	73	81	108	135	146	150	146	135	108	81	73	74	76	79	79	78
16	87	86	86	85	80	75	76	104	131	139	139	139	131	104	76	75	80	85	86	86	87
15	95	96	97	96	91	82	73	99	127	126	122	126	127	99	73	82	91	96	97	96	95
14	106	107	109	109	106	95	76	93	126	107	94	107	126	93	76	95	106	109	109	107	106
13	117	114	121	124	122	115	91	89	142	77	54	77	142	89	91	115	122	124	121	118	117
12	127	129	134	139	141	143	144	135	116	50	8	50	116	135	144	143	141	139	134	129	127
11	136	140	146	152	157	162	169	128						128	169	162	157	152	146	140	136
10	141	148	156	162	164	162	129	98						98	129	162	164	162	156	148	143
9	148	155	162	167	168	155	109	73						73	109	155	169	167	162	155	150
8	153	158	168	171	169	149	99	63						63	98	149	169	171	168	158	153
7	154	161	170	172	166	144	94	69						69	94	144	166	172	170	161	154
6	156	163	172	172	169	141	96	85						85	96	141	169	172	170	163	156
5	156	163	166	171	162	140	102	106						106	102	140	162	170	161	162	156
4	156	161	166	167	159	140	113	131						131	113	140	159	167	156	161	156
3	155	155	162	162	155	140	125	160						160	125	140	155	160	162	159	155
2	153	156	157	154	144	139	138	193						193	138	139	141	154	157	156	153
1	151	153	151	146	136	113	152	228						228	152	133	134	146	151	150	151
0	149	145	148	137	127	121	140	220						220	140	121	124	137	144	146	149

W15

MAG TABLE
JXA=23 IYA=22 JXB=16 IYB=17 JXC= 8 IYC= 0 DDX= 0.1000E 00 DDY= 0.5000E-01
E1= 0.1000E 01 E2/E1= 0.5000E 01
ACEL= 0.0 IP= 0 DH= 0.1000E 01 DV= 0.0 AH= 0.1000E 01 AV= 0.0
THICKNESSES: 1.00000 1.00000 0.60000 0.60000 1.00000
ALL ENTRIES ARE SCALED BY 10** 2

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	84	79	63	42	25	26	90	148	177	183	184	183	177	148	90	26	25	42	63	79	84
19	96	81	72	62	55	44	84	146	167	168	167	168	167	146	84	44	55	62	71	81	97
18	99	97	96	97	96	78	87	167	159	139	132	139	159	167	87	78	96	97	96	97	99
17	117	119	125	133	139	125	111	224	149	100	80	100	149	224	111	126	139	133	125	119	117
16	142	142	154	169	187	207	204	236	145	72	6	72	145	236	204	207	187	169	154	142	142
15	164	168	179	197	216	242	168								168	242	216	197	179	164	164
14	185	189	209	211	214	174	128								129	174	214	211	200	199	195
13	203	204	212	216	201	142	93								93	142	201	216	212	204	203
12	215	215	220	216	191	124	77								77	124	191	216	229	215	215
11	221	223	224	215	182	116	81								81	115	183	215	224	223	221
10	224	225	226	212	175	115	97								97	115	175	212	226	225	224
9	224	225	223	206	172	121	118								119	121	172	207	223	225	[illegible]
8	224	221	221	203	171	132	141								141	132	171	203	221	221	[illegible]
7	220	218	215	199	172	146	167								167	146	[illegible]	199	215	[illegible]	[illegible]
6	216	210	210	197	175	161	195								195	161	175	197	[illegible]	214	[illegible]
5	212	207	[illegible]	191	179	179	221								222	171	179	[illegible]	[illegible]	[illegible]	[illegible]
4	259	[illegible]	[illegible]	[illegible]	185	[illegible]	257								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	216	[illegible]								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	199	[illegible]	177	[illegible]	[illegible]	211	[illegible]								[illegible]	211	[illegible]	[illegible]	177	[illegible]	[illegible]
1	191	[illegible]	[illegible]	[illegible]	177	[illegible]	[illegible]								[illegible]	[illegible]	[illegible]	[illegible]	161	[illegible]	191
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

W16

Figure 6. Computer printouts for walls W13,W14,W15,W16

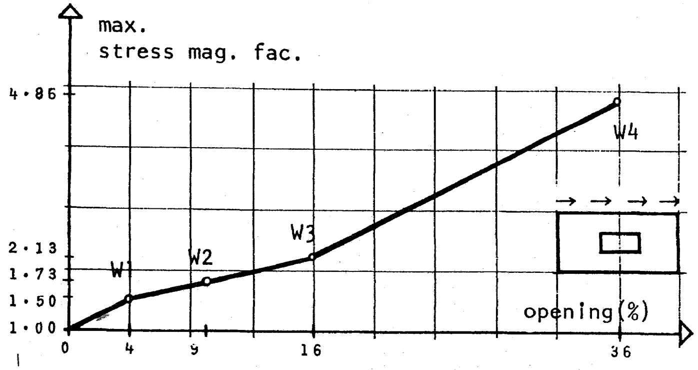

Figure 7. Opening percentage versus max.smf for walls W1,W2,W3,W4

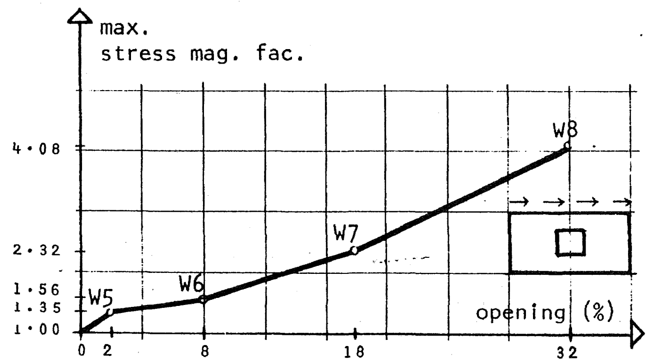

Figure 8. Opening percentage versus max.smf for walls W5,W6,W7,W8

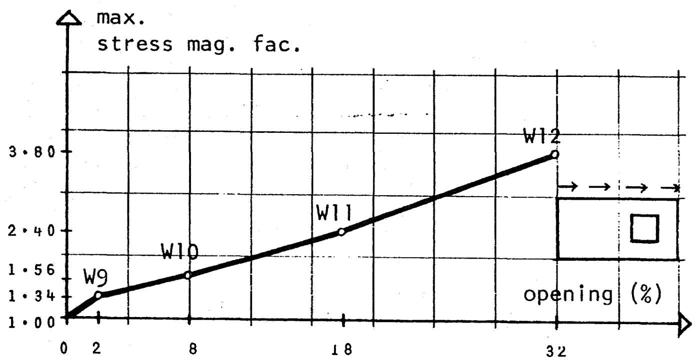

Figure 9. Opening percentage versus max.smf for walls W9,W10,W11,W12

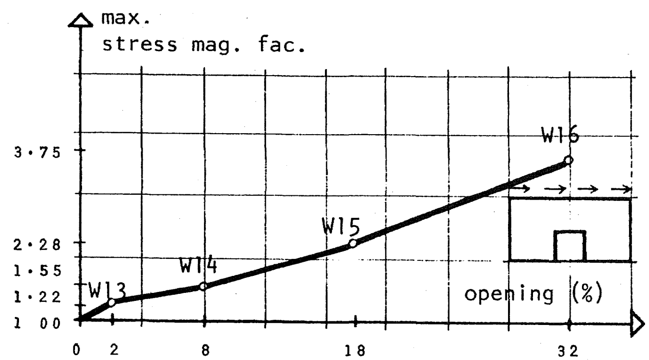

Figure 10. Opening percentage versus max.smf for walls W13,W14,W15,W16