BRICK MASONRY EFFECT IN VIBRATIONS OF FRAMES

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Synopsis

This paper examines the effect of brick masonry walls on plane free vibrations of plane frames. Natural modes and periods are determined for frames taking into account the brick walls; results are compared with those obtained neglecting the wall effect.

Linear elastic behavior is assumed. The mass is lumped at several points and both horizontal and vertical translational inertia are taken into account.

Natural modes and periods are determined by the Stodola method; the reduced flexibility matrix is obtained using the finite element technique and the displacement method of analysis.

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The effect of brick masonry walls on the natural modes and periods of vibration of building structures has recently received attention because of its importance for an aseismic design of high-rise buildings. To this aim three cases on plane rigid frames are worked out here; natural modes and periods of vibration are determined in each case taking into account the walls, and they are compared with those obtained when the wall effect is neglected.

It is assumed linear elastic behavior and that the tie between frame and wall is not disturbed.

In order to discretize the problem, the mass is lumped at several points of the frame. In two cases, as it is usually done, only the horizontal translational inertia is taken into account and the vertical translational inertia is neglected. In the third case both horizontal and vertical inertia are accounted for and coupled modes of vibration are determined.

The natural modes and periods are determined by the Stodola iterative method; the dynamics equations are written in terms of the flexibility matrix so the iterative process converges to the lower modes. The effect of the brick walls on the flexibility matrix is accounted for by means of the finite element technique; the displacement method of analysis has been used.

The numerical results here presented were obtained by means of a computer program written in Fortran for the IBM 1130 system. This program has as input data the way the mass is lumped and the translational degrees of freedom that are taken into account.

The results of the examples below described are presented in the following units: kilogram, meter, second. For the reinforced concrete frames and the brick walls, it has been taken as elasticity moduli, 200 000 k/cm^2 and 20 000 k/cm^2, respectively; Poisson ratio is taken as 0.20. Horizontal displacements are considered positive when they occur to the right, and vertical displacements when they are upward.

Example A corresponds to a 10-story frame shown in Figure 1; there W stands for the weight of the particles. The mass has been lumped at the midpoints of each floor and the translational vertical inertia has been neglected, so it is ended up with a system of ten degrees of freedom. Table 1 shows the numerical results for the first five modes for both cases, with and without walls; T stands for the period. A total of 902 rectangular finite elements were taken when the wall effect is taken into account. Figure 2 shows the mode shapes for both cases.

Example B corresponds to a 3-story frame shown in Figure 3. The mass has been lumped again at the midpoints of each floor and the vertical inertia has been neglected, so it is a system with three degrees of freedom. The results are presented in Table 2 and Figure 4. A total of 368 finite elements were taken for the case without walls and 500 for the case with walls.

Example C corresponds to the same frame of Example B but with a different mass distribution, which is shown in Figure 5; the mass has been lumped at eleven points and both vertical and horizontal inertia are taken into account, so it is a system with twenty two degrees of freedom. Results for the coupled modes of vibration are presented in Table 3 and Figures 6 and 7. A total of 156 finite elements were taken for the case without walls and 288 for the case with walls.

The purpose of this paper has been to present a technique by means of which the effect of the walls could be accounted for in the vibration of frames. But from the few examples presented it can be seen that the wall effect has remarkable influence on the periods. In the Example C it can be seen that the first three coupled modes, when the wall effect is neglected, have predominantly horizontal displacements similar to those obtained in Example B, where only three degrees of freedom were considered; however when the wall effect is taken into account, the third coupled mode has predominantly vertical displacements. It can be seen in this same example that there exists a larger degree of coupling between horizontal and vertical vibrations when the wall effect is taken into account.

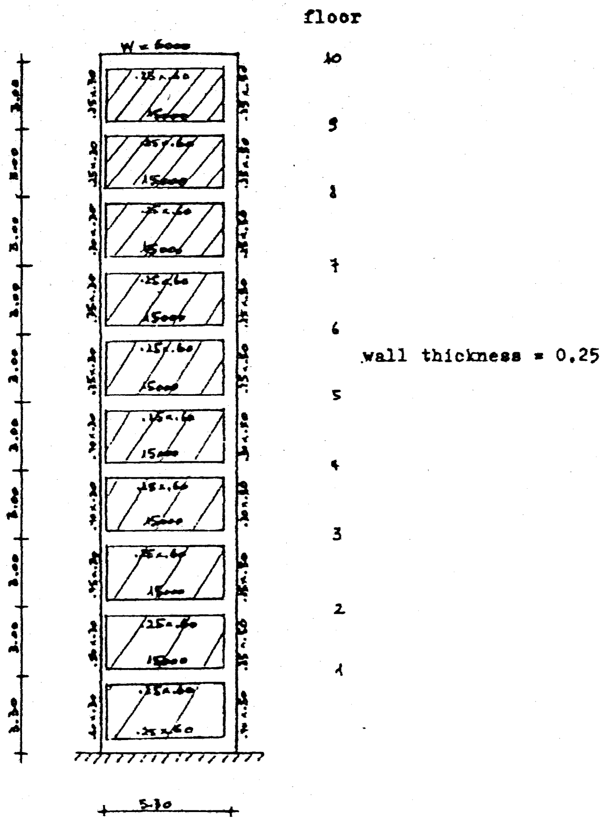

FIGURE 1. Frame of Example A

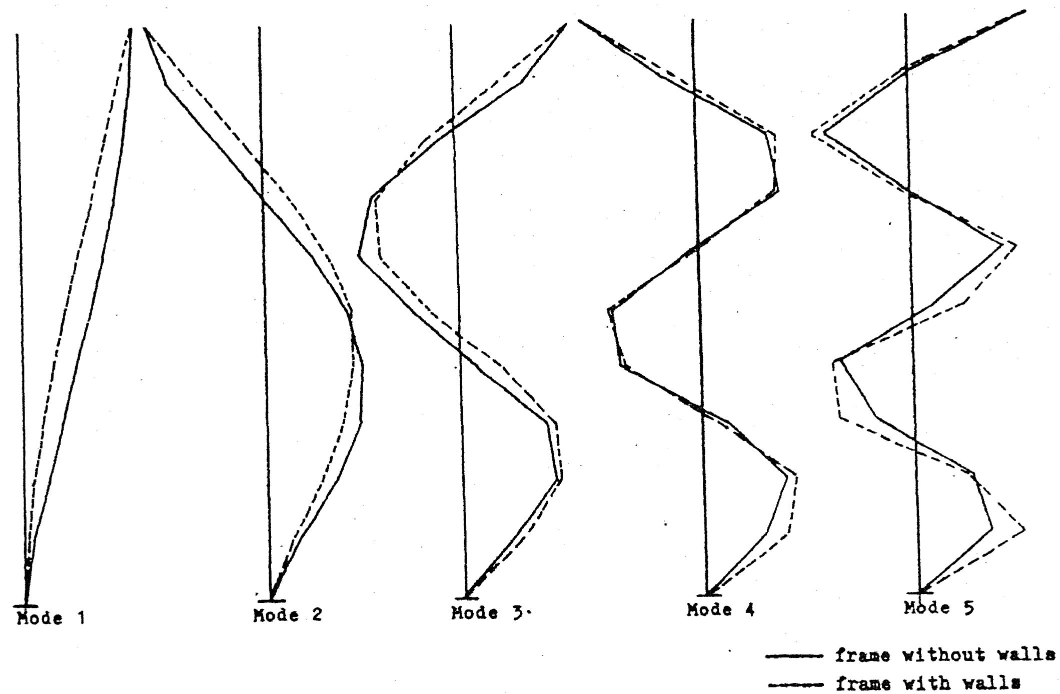

FIGURE 2. Mode shapes of Example A.

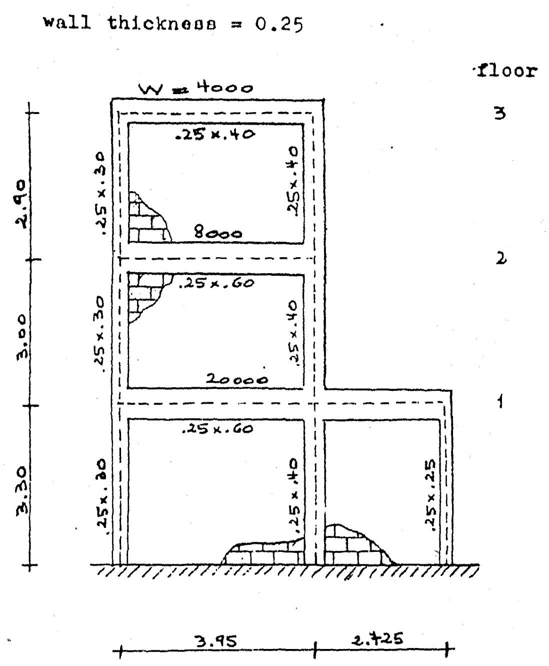

FIGURE 3. Frame of Example B.

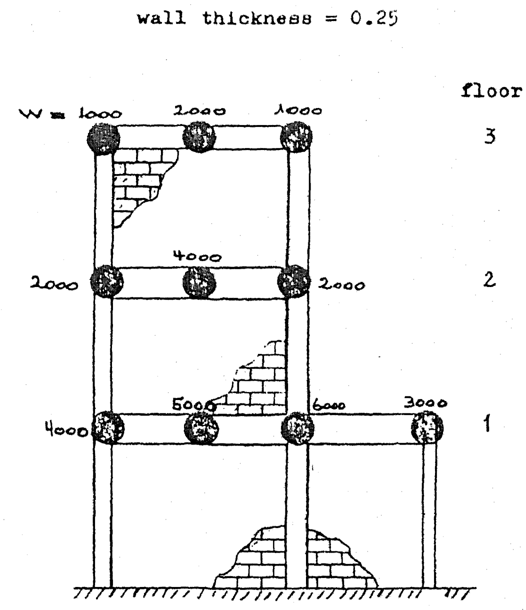

FIGURE 5. Frame of Example C.

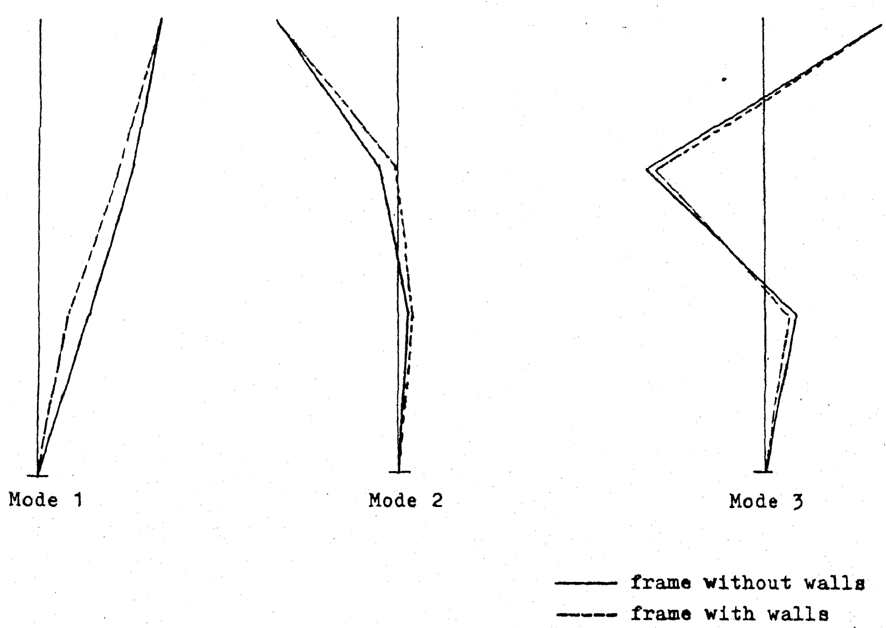

FIGURE 4. Mode shapes of Example B.

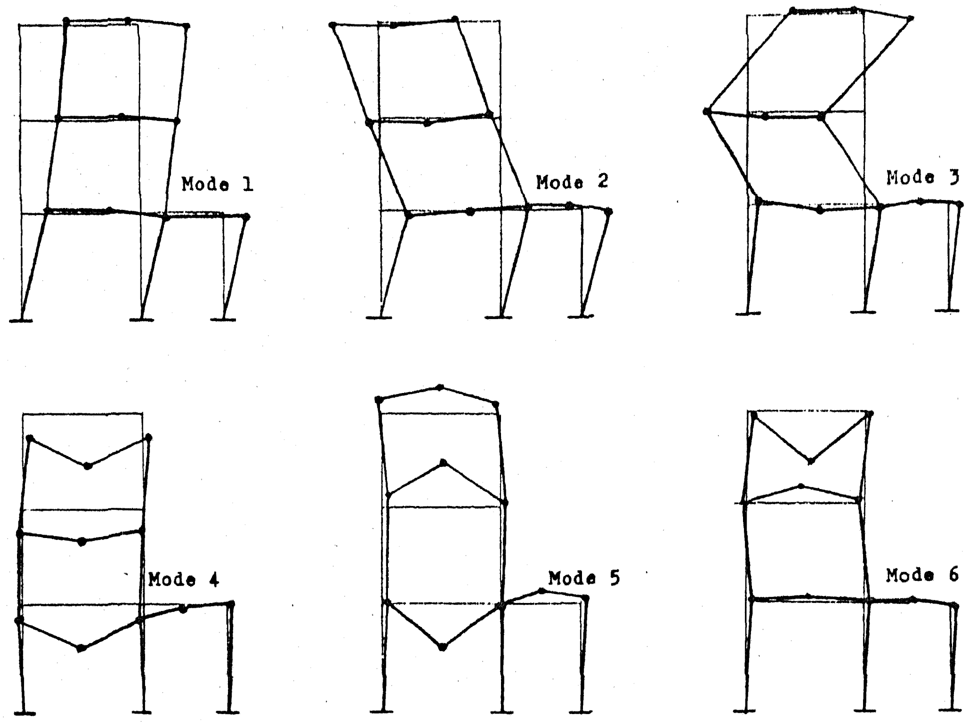

FIGURE 6. Mode shapes of Example C (without walls)

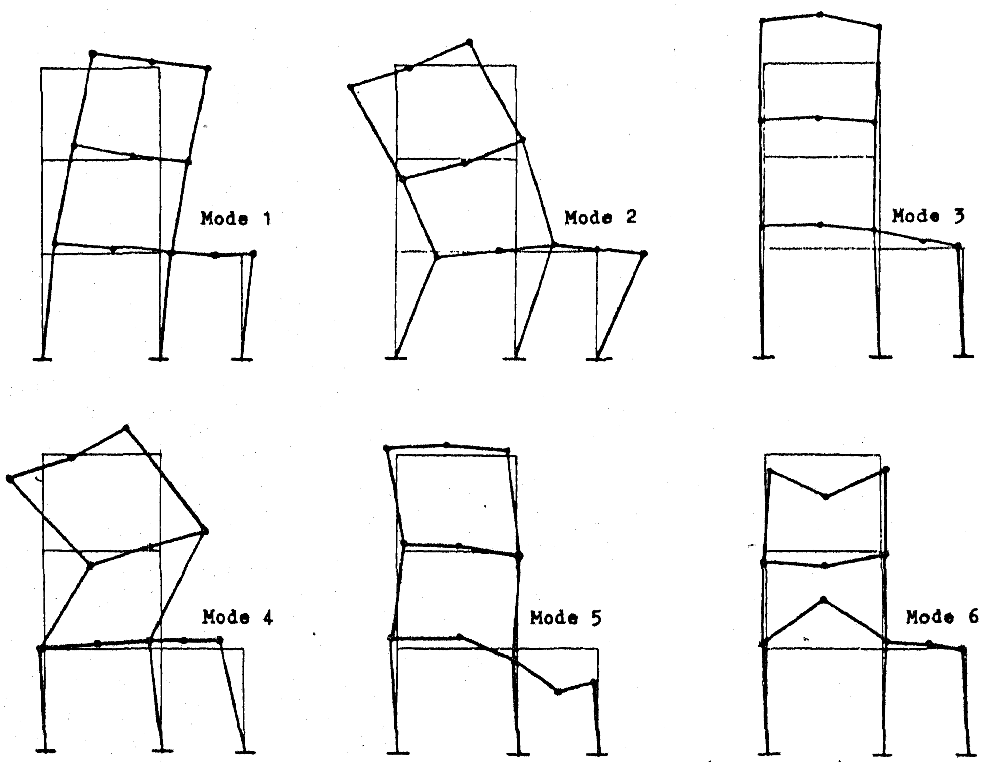

FIGURE 7. Mode shapes of Example C (with walls)

FRAME WITHOUT WALLS	Mode 1 T=1.4572	Mode 2 T=0.4848	Mode 3 T=0.2746	Mode 4 T=0.1899	Mode 5 T=0.1422
Floor	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.
1	0.0875	0.2749	0.4427	0.5687	0.6117
2	0.2095	0.5952	0.8070	0.7657	0.4946
3	0.3378	0.8132	0.7532	0.2012	-0.3824
4	0.4690	0.8693	0.2601	-0.6137	-0.6701
5	0.5927	0.7353	-0.3881	-0.7734	0.1689
6	0.7105	0.4209	-0.8304	-0.0436	0.7687
7	0.8124	0.0002	-0.7358	0.7375	-0.0175
8	0.8968	-0.4423	-0.1421	0.6366	-0.7810
9	0.9599	-0.8016	0.5844	-0.2823	-0.0473
10	1.0000	-1.0000	1.0000	-1.0000	1.0000

FRAME WITH WALLS	Mode 1 T=0.6266	Mode 2 T=0.1267	Mode 3 T=0.0596	Mode 4 T=0.0397	Mode 5 T=0.0307
Floor	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.
1	0.0308	0.2273	0.5159	0.7503	0.9124
2	0.0843	0.4747	0.8496	0.8285	0.4581
3	0.1598	0.6783	0.7966	0.1078	-0.7000
4	0.2544	0.7807	0.3577	-0.7130	-0.7130
5	0.3639	0.7460	-0.2452	-0.8067	0.4498
6	0.4844	0.5609	-0.6873	-0.0731	0.9057
7	0.6120	0.2421	-0.7100	0.7136	-0.0995
8	0.7424	-0.1644	-0.2775	0.6931	-0.8790
9	0.8725	-0.5997	0.4093	-0.1730	-0.0711
10	1.0000	-1.0000	1.0000	-1.0000	1.0000

TABLE 1. Shapes and periods of first five modes of Example A.

FRAME WITHOUT WALLS	Mode 1 T=0.2946	Mode 2 T=0.1156	Mode 3 T=0.0628
Floor	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.
1	0.4249	0.6007	0.2214
2	0.7789	-0.1774	-0.9440
3	1.0000	-1.0000	1.0000

FRAME WITH WALLS	Mode 1 T=0.0777	Mode 2 T=0.0359	Mode 3 T=0.0201
Floor	Horiz. Displac.	Horiz. Displac.	Horiz. Displac.
1	0.2573	0.8529	0.2033
2	0.6794	-0.0717	-0.9285
3	1.0000	-1.0000	1.0000

TABLE 2. Shapes and periods of modes of Example B.

		Mode 1 T=0.2474		Mode 2 T=0.1111		Mode 3 T=0.0610		Mode 4 T=0.0435	
	Joint	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.
FRAME WITHOUT WALLS	1	0.4718	0.0185	0.5624	-0.0434	0.2261	0.0254	-0.0095	-0.2975
	2	0.4713	0.0016	0.5605	-0.0008	0.2246	-0.0149	-0.0091	-0.8361
	3	0.4706	-0.0064	0.5613	0.0291	0.2269	-0.0192	-0.0038	-0.2768
	4	0.4698	-0.0243	0.5605	0.0390	0.2282	0.0420	-0.0004	-0.0860
	5	0.4705	-0.0110	0.5623	-0.0005	0.2302	0.0102	0.0002	0.0084
	6	0.8063	0.0271	-0.1966	-0.0782	-0.9585	0.0686	-0.0150	-0.4387
	7	0.8058	0.0230	-0.1961	-0.0635	-0.9506	-0.0067	-0.0153	-0.6342
	8	0.8055	-0.0114	-0.1949	0.0483	-0.9487	-0.0524	-0.0153	-0.3888
	9	0.9999	0.0289	-0.9997	-0.0875	1.0000	0.1041	0.0703	-0.4927
	10	1.0000	0.0129	-1.0000	-0.0477	0.9997	0.1987	0.0659	-1.0000
	11	0.9999	-0.0125	-0.9989	0.0543	0.9930	-0.0741	0.0602	-0.4328

		Mode 1 T=0.0760		Mode 2 T=0.0356		Mode 3 T=0.0279		Mode 4 T=0.0189	
	Joint	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.
FRAME WITH WALLS	1	0.2594	0.1607	0.8381	-0.1829	-0.0031	0.5008	-0.1595	-0.0469
	2	0.2543	0.0375	0.8450	0.0266	-0.0118	0.6269	-0.2012	0.0269
	3	0.2422	-0.0666	0.8681	0.2148	-0.0211	0.4591	-0.3320	0.0907
	4	0.2327	-0.0710	0.8898	0.0534	-0.0187	0.2784	-0.4220	0.1422
	5	0.2301	-0.0633	0.9033	-0.1806	-0.0171	0.0784	-0.4593	0.2154
	6	0.6460	0.2347	0.0855	-0.4640	-0.0759	0.7755	1.0000	-0.3724
	7	0.6449	0.0585	0.0877	-0.0217	-0.0812	0.8844	0.9937	0.0223
	8	0.6439	-0.1260	0.0882	0.4386	-0.0875	0.7164	0.9770	0.3768
	9	1.0000	0.2529	-1.0000	-0.5622	-0.0788	0.8704	-0.7676	-0.6908
	10	0.9995	0.0605	-0.9970	-0.0301	-0.0674	1.0000	-0.7552	-0.0208
	11	0.9997	-0.1394	-0.9973	0.5172	-0.0559	0.7975	-0.7529	0.6444

TABLE 3. Shapes and periods of first six modes of Example C.

		Mode 5 T=0.0361		Mode 6 T=0.0350	
	Joint	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.
FRAME WITHOUT WALLS	1	0.0118	0.0726	0.0126	0.0320
	2	0.0097	-0.8817	0.0102	0.1524
	3	0.0035	0.0454	0.0063	0.0309
	4	0.0018	0.3261	0.0053	0.0117
	5	0.0012	0.1046	0.0054	-0.0004
	6	0.0216	0.2472	-0.0397	0.0274
	7	0.0173	1.0000	-0.0345	0.4541
	8	0.0110	0.1762	-0.0275	0.0228
	9	-0.0702	0.2940	0.0333	-0.0261
	10	-0.0620	0.5187	0.0315	-1.0000
	11	-0.0515	0.2139	0.0292	-0.0213

		Mode 5 T=0.0163		Mode 6 T=0.0147	
	Joint	Horiz. Displac.	Vert. Displac.	Horiz. Displac.	Vert. Displac.
FRAME WITH WALLS	1	-0.0443	0.1572	-0.0386	0.0482
	2	-0.0362	0.1670	-0.0210	1.0000
	3	-0.0096	-0.2828	0.0028	0.1443
	4	-0.0052	-1.0000	0.0002	0.0465
	5	-0.0156	-0.7514	-0.0013	0.0069
	6	0.0520	0.1500	-0.0786	-0.2010
	7	0.0551	0.1120	-0.0240	-0.3612
	8	0.0568	-0.0568	0.0363	-0.1299
	9	-0.2369	0.1158	0.1180	-0.3607
	10	-0.2272	0.1573	0.0751	-0.9457
	11	-0.2197	0.0286	0.0327	-0.2903

TABLE 3. (continuation)