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SOUND ABSORPTION TREATMENT FOR TRANSFORMER SUBSTATIONS

by

T.D. Northwood

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PREFACE

The Division of Building Research was requested by a large public utility to investigate ways in which sound absorbing materials and constructions might be used in the control of the noise produced by substation power transformers. The Building Physics Section has demonstrated that the Helmholtz Resonator Principle can be employed and has proposed several constructions which have now been evaluated in the laboratory. Data on a number of practical forms of materials have been obtained. The materials and constructions evaluated were selected in the first instance with the practical requirements of the specific problem in mind. The results obtained may be of interest in connection with similar problems elsewhere as well as in a number of other cases in which noises arising from sixty-cycle power are involved.

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Ottawa,
August 1955.

SOUND ABSORPTION TREATMENT FOR TRANSFORMER SUBSTATIONS

by T. D. Northwood

The noise produced by substation power transformers constitutes a special acoustical problem for two reasons:

a) the most important components in the noise are at 120 cycles per second and its lower harmonics, a region for which conventional acoustical materials are inefficient;

b) to facilitate cooling the transformers they are usually only partially enclosed, so that any acoustical treatment introduced should be weatherproof.

The object of this study was to develop sound absorbing systems to meet these special requirements.

DESIGN PROCEDURE

Absorption at low frequencies is most readily obtained with some type of resonant system tuned to the frequency range in which absorption is required. The system adopted in this project followed the principle of the Helmholtz Resonator, employing an air cavity coupled to the sound field by means of an orifice.

In principle one might take care of a few definite frequencies by using resonant elements sharply tuned to each of the frequencies. However, several factors make critical tuning an impractical procedure. The alternative is to introduce enough damping in the system to provide moderate absorption over the required frequency range. In the present work the range 120 to 360 cycles was considered important, with special attention to 120 cycles. Damping was achieved by using moderately porous materials for constructing the resonator.

Four structures were examined as possible absorbers:

Type A consisted of a series of cavities faced with a porous membrane, the porosity of the membrane being intended to act as an orifice and also as a damping element. It was proposed to use a thin layer of Limpet sprayed on expanded metal lath. However, it was found difficult to obtain the required properties with Limpet, and the system was abandoned;

Type B consisted of a cavity wall in which the inner leaf consisted of 4- by 8- by 16-inch building blocks. The ends of the blocks, i.e. the vertical joints, were left spaced slightly apart to provide orifices leading to the wall cavities.

Damping is provided by making the inner leaf of expanded slag or other porous blocks. For best performance in a random sound field the cavity should be partitioned into cells 4 feet square or smaller. During the development it was found that cavity bearing walls are not acceptable in some cities, including Toronto, and the development was, therefore, cut short. However, the system may be useful as a lining in existing stations where bearing wall requirements are already met. Reverberation tests (1), 2(b) and 2(c) (Table II) exemplify this type of structure;

Type C consisted of hollow building blocks with holes drilled into the individual cells. The procedure was tried successfully with several types of expanded slag and cinder blocks. Results are given in Tables II and III;

Type D was similar to Type C except that the particular block, a lightweight cinder block, was so porous that it was unnecessary to drill holes into the cells. Results are given in Table II, test No. 3. (Unfortunately the block was found to be not strong enough for bearing wall purposes).

Test Results

Impedance tube tests were made on nine samples of building blocks to provide design data and also to provide comparative information on available blocks. (For a description of the samples see Table I). Circular discs 2¼ inches in diameter were taken from each sample and fitted into a holder attached to the impedance tube. Absorption measurements were taken on the disc itself, on a pair of discs with a cavity between them, to simulate a hollow block, and on the same arrangement with a hole through the front disc. The impedance tube data are summarized in Table III.

Concurrently with the impedance tube tests a few large-scale tests were made in the reverberation chamber. These results are given in Table II.

There are several distinctions between the impedance tube measurements and reverberation chamber measurements. The former measures absorption for waves at normal incidence only, whereas the latter measures absorption for waves at all angles of incidence. Also, the simulated cells tested on the tube are only an approximation to the full-scale situation, since a block presents solid web sections to the sound field as well as the hollow sections. Finally there may be differences between the reverberation measurements and actual installations since the former were done without actually mortaring the blocks. For example there may be a significant reduction in cell volume due to mortar falling into the cavities.

However, it is considered that there are now sufficient data that structures similar to Type B, C or possibly D can be designed using any similar building block, on the basis of impedance tube measurements alone.

Recommendations

1) For new construction it is recommended that blocks similar to Samples No. 4 to 9 be incorporated in the inner face of bearing walls, and that each cell of each block be perforated with a ½ inch diameter hole. Impedance tube tests indicate that any of the blocks tested have satisfactory absorption properties. Samples No. 6 and No. 4 head the list; sample No. 9 appears slightly inferior.

This system should provide absorptions approximately as follows:

Frequency	120	240	360
Absorption coefficient	.50 to .70	.25 to .35	.15 to .20

2) As a rule, for similar acoustical materials, there is a correlation between high absorption and low density. However, the rule does not seem to apply here, and it is recommended that an impedance tube test be made before adopting a new block.

3) For non-bearing walls a block such as Sample No. 3 might be used without modification or Sample No. 2 might be used in a structure of Type B or Type C.

4) In all cases the walls should be constructed with a break in cell communication at intervals of 4 feet or less. This could simply be done in a Type C structure, by incorporating a strip of wire mesh in the occasional mortar joint, covering the whole surface with mortar.

TABLE I

DESCRIPTION OF SAMPLES

Sample 1	Perlite blocks 4" x 8" x 16"; 3 cells; weight per block 18.5 lb. Area correction applied to reverberation chamber data to make them comparable with standard sample area.
Sample 2	Cooper slag blocks 4" x 8" x 16"; 3 cells; weight per block 17.0 lb.
Sample 3	Cooper light-weight cinder block, 8" x 8" x 16"; 3 cells; weight per block 25.5 lb.
Sample 4	Cooper cinder block, 8" x 8" x 16"; 3 cells; weight per block 33.6 lb. One block tested.
Sample 5	Hayley cinder block, 8" x 8" x 16"; 3 cells; weight per block 33.5 lb.
Sample 6	Cooper slag block 8" x 8" x 16"; 3 cells, weight per block 37.2 lb. One block tested.
Sample 7	Maple cinder block, 8" x 8" x 16"; 3 cells; weight per block 37.2 lb.
Sample 8	Maple slag block, 8" x 8" x 16"; 3 cells; weight per block 38.5 lb.
Sample 9	Toronto Brick cinder block 8" x 8" x 16"; weight per block 35.7 lb.

Note: Samples 2 and 3 were reported by the interested agency to have failed to meet a compressive strength test. Samples 4, 6, 7, 8 and 9 passed the compressive strength test. Sample 5 has not been tested.

TABLE II

REVERBERATION CHAMBER DATA

Absorbing System	125	250	500	1000	2000	4000
	Frequency (c.p.s.)					
1. Perlite blocks; 4" x 8" x 16"; spaced 3-3/4" from wall; ends of blocks separated 3/4"; separators in back-space at 4' cc. (data corrected for effect of small sample area)	.65	.42	.27	.35	.28	.22
2. Cooper slag blocks 4" x 8" x 16";						
a) laid flat on floor	.14	.54	.31	.34	.44	.46
b) blocks spaced 3-3/4" from wall; ends of blocks spaced 3/4"; separators in back-space at 2' squares	.36	.51	.40	.33	-	-
c) as in (b) but blocks spaced 1/2" apart	.46	.55	.40	.33	-	-
d) blocks flat on floor; three 3/8" holes drilled in each block (one per cell); separators between courses	.40	.57	.37	.31	-	-
3. Cooper lightweight cinder blocks 8" x 8" x 16"; laid flat on floor	.43	.74	.34	.26	.71	.61

TABLE III

IMPEDANCE TUBE DATA

	Frequency (cycles per second) 125	150	175	200	225	250	275	300	500	1000
1. Perlite; 1" thick, no back-space						.11			.12	.13
2. Cooper 4" x 8" x 16" slag block; sample 1" thick										
a) No back-space						.06			.05	.06
b) Double sample, 2" inter-space	.04	.04	.045	.045	.05	.05	.05	.05		
c) Like (b) but with 3/8" hole	.065	.13	.26	.46	.79	.81	.57	.33	.09	.08
3. Cooper lightweight cinder block; 3/4" thick										
a) No back-space, nominally (readings indicate small space)	.025					.64			.08	.15
b) Double sample, 2" inter-space	.58	.78	.79	.62	.46	.36	.30	.25	.12	.10
c) Like (b) but with 3/8" hole	.12	.25	.46	.82	.95	.81	.58	.40	.12	.13
4. Cooper heavy cinder block, 1-3/4" thick										
a) No back-space	.01	.02	.025	.02	.02	.025			.025	.04
b) Double sample, 2" inter-space	.02	.03	.03	.04	.04	.04	.04	.04	.05	.06
c) Double sample, 3" inter-space 3/8" hole	.27	.60	.71	.34	.19	.13	.10	.08	.05	.05
d) Double sample, 5" inter-space 3/8" hole	.73	.44	.25	.15	.11	.08	.08	.06	.05	.06
e) Double sample, 5" inter-space 1/2" hole	.36	.59	.52	.32	.22	.15	.12	.10	.06	.07
5. Hayley Cinder Block, 1-3/4" thick										
a) No back-space	.02	.02			.025			.03	.03	.02
b) Double sample, 2" inter-space, 3/8" hole	.12	.32	.89	.67	.30	.16	.11	.08	.04	.02
6. Cooper 8" slag block; no back-space	.025	.025	.035	.035	.04	.04	.04	.045	.05	.06
7. Maple cinder block, no back-space	.015	.02	.025	.015	.012	.015			.01	.01
8. Maple slag block, no back-space			.01	.015	.02	.02	.025	.025	.025	.045
9. Toronto Brick cinder block, no back-space	.01	(- - - - - - - -very low- - - - - - -)								.015