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INCLUDING THE INFLUENCE OF FINITE CAVITIES IN DOUBLE-LEAF STRUCTURES

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1. INTRODUCTION

It has long been known that if a double-leaf structure consists of a framework of beams, the beams will not only influence the vibration field directly, i.e. shortcutting the plates, but also affect the acoustic field in the cavity. The beams, or studs, can be seen as walls in the cavity, and are thus introducing finiteness. Consider a double-leaf structure excited by an incoming wave on the source side. The plate on the source side is excited and will radiate to the cavity and excite the framing beams. The plate on the receiver side is then excited by the acoustic field in the cavity and by the vibration of the beams, and will radiate to the surrounding acoustic fields. An expansion in a suitable orthogonal series of the field is made to take into account the finiteness of the cavities. This solution can be compared to the solution where the finiteness is ignored, i.e. the waves are let passing unaffected through the beams.

The classical work on double-leaf walls is made by London [1], and is not taking into account the studs or the finiteness of the cavity. Lin and Garrelick [2] investigated the transmission of a plane wave through two infinite parallel plates connected by periodical studs that behave as rigid bodies. A fluid coupling in the cavity between the plates is also present, which lets the waves passing unaffected through the beams. The two systems were solved simultaneously by means of Fourier transforms. Takahashi [3] considered noise control in buildings having double-plate walls. Each structure considered consists of two parallel plates of infinite extent connected by various connectors. The connectors are point connectors or rib-stiffeners. The structures were driven by point forces, and the resulting sound radiation was studied. The authors has studied impact sound transmissions in lightweight floors using transform technique [4].

The approach in the present paper is similar to the one introduced by Mace [5], but the treatment of the cavity is original for the present paper.

2. FORMULATION OF THE PROBLEM

Consider a double-leaf wall stiffened with studs, Figure 1. The studs are assumed to be infinitely stiff in bending round the z-axis and of zero thickness. However, they are allowed to bend round the x-axis. The structure is infinite in both the x- and y-direction.

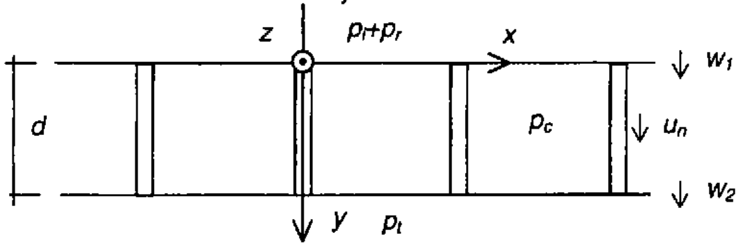

Figure 1 Double-leaf structure

where p_i is the pressure due to an exciting, or incoming, wave, p_r and p_t are reaction pressures due to reflected and transmitted waves. The exciting pressure is

$$p_i = \hat{p}_i \, e^{-i\left(k_x x + k_y y + k_z z - i\omega t\right)}$$

where a possible choice of the wave numbers are $k_x = k\cdot\sin\theta\cos\varphi$, $k_y = k\cdot\sin\theta\sin\varphi$, $k_z = k\cdot\cos\theta$, i.e. an incoming wave. The time dependence and the z-dependence $\exp(i\omega\, t - k_z\, z)$ will henceforth be suppressed throughout. Since the structure is periodic in x the response further satisfies the periodicity relation, se e.g. [5],

$$w_i(x + l) = w_i(x) e^{-ik_x l}. \qquad (1)$$

Let the plates be modelled according to thin plate theory. The equations that we have to solve can be written as

$$\begin{cases} D_1 \nabla^4 w_1 - m_1'' \omega^2 w_1 = p_i\big|_{y=0} - p_c\big|_{y=0} + p_r\big|_{y=0} - p_{f1} \\ D_2 \nabla^4 w_2 - m_2'' \omega^2 w_2 = p_c\big|_{y=d} - p_t\big|_{y=d} + p_{f2} \end{cases}$$
$$\nabla^4 = \frac{\partial^4}{\partial x^4} - 2k_z^2 \frac{\partial^2}{\partial x^2} + k_z^4 \qquad (2)$$

where D_i and m_i'' are the flexural rigidity and mass per unit area of plate number i, ω is the angular frequency and d the distance between the plates. It is convenient to decompose the reflected pressure into two components, $p_r = p_{r\infty} + p_s$, where $p_{r\infty}$ is the reflected pressure generated by a rigid reflector and p_s is the scattered part due to the elastic motion of the structure. The reaction pressures from the surrounding fluid can be assumed to be coupled to the displacements field by operators,

$$p_{r\infty}\big|_{y=0} = p_i\big|_{y=0}, \quad p_s\big|_{y=0} = \mathrm{R} w_1, \quad p_t\big|_{y=0} = \mathrm{T} w_2 \qquad (3)$$

where R and T are operators that will be determined in section 4. For the cavity reactions p_c and the frame p_f reactions the coupling to the displacement field is not so simple, and is therefor left to later discussion.

The Fourier transform of w with respect to the co-ordinate x and the corresponding inverse transform is defined as

$$\tilde{w}_i(\alpha) = \int_{-\infty}^{\infty} w_i(x) e^{i\alpha x} dx, \quad w_i(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \tilde{w}_i(\alpha) e^{-i\alpha x} d\alpha . \qquad (4)$$

Thus, the Fourier transform over x of the incoming wave yields a Dirac function. For the reaction pressure, the transform yields algebraic expression instead of operators. Thus, the transformed pressures are

$$\tilde{p}_i + \tilde{p}_{r\infty} = 2\hat{p}_i\, \delta\left(\alpha - k_x\right) e^{-ik_z y}, \quad \tilde{p}_s\big|_{y=0} = R\tilde{w}_1, \quad \tilde{p}_t\big|_{y=0} = T\tilde{w}_2 . \qquad (5)$$

Applying the Fourier transform with respect to x to equation (2), taking into account (5), gives

$$\begin{bmatrix} S_1 & 0 \\ 0 & S_2 \end{bmatrix}\begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \end{bmatrix} = 2\begin{bmatrix} \hat{p}_i \\ 0 \end{bmatrix}\delta(\alpha - k_x) - \begin{bmatrix} \tilde{p}_{f1} \\ \tilde{p}_{f2} \end{bmatrix} - \begin{bmatrix} \tilde{p}_c|_o \\ \tilde{p}_c|_d \end{bmatrix} \tag{6}$$

where

$$S_1(\alpha) = D_1\left(\alpha^2 + k_z^2\right)^2 - m_1''\omega^2 - R(\alpha), \quad S_2(\alpha) = D_2\left(\alpha^2 + k_z^2\right)^2 - m_2''\omega^2 + T(\alpha),$$

is spatial stiffnesses. Solve for the transformed displacement

$$\tilde{\mathbf{w}} = 2\mathbf{S}^{-1}\hat{\mathbf{p}}_i\delta(\alpha - k_x) - \mathbf{S}^{-1}\tilde{\mathbf{p}}_f - \mathbf{S}^{-1}\tilde{\mathbf{p}}_c \tag{7}$$

where the matrices $\mathbf{S}$ and $\tilde{\mathbf{w}}$ can be identified in (6). The displacements are found taking the inverse transform of (7). The inverse transform can formally be written

$$\mathbf{w} = 2\mathbf{S}^{-1}(k_x)\hat{\mathbf{p}}_i - F_x^{-1}\left(\mathbf{S}^{-1}\tilde{\mathbf{p}}_f\right) - F_x^{-1}\left(\mathbf{S}^{-1}\tilde{\mathbf{p}}_c\right). \tag{8}$$

3. THE CAVITY, FINITE CAVITY SOLUTION

3.1 FORMULATION

Consider Figure 1, where a fluid is occupying the space $0<y<d$, divided into subspaces $nl\leq x\leq(n+1)l$. An acoustic pressure $p_c(x,y,z)$ is present. The acoustic pressure satisfies the Helmholtz equation

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)p_c + \left(\frac{\omega^2}{c_c^{\,2}} - k_z^2\right)p_c = 0 \tag{9}$$

where c_c is the speed of sound in the cavity. The acoustic pressure also satisfies the boundary conditions

$$\left[\frac{\partial p_c}{\partial y}\right]_{y=0} = \omega^2\rho_c \cdot w_1, \quad \left[\frac{\partial p_c}{\partial y}\right]_{y=d} = \omega^2\rho_c \cdot w_2,$$
$$\left[\frac{\partial p_c}{\partial x}\right]_{x=nl} = 0, \; n = -\infty,\ldots,-1,0,1,\ldots,\infty \tag{10}$$

ensuring equality of the fluid displacement at the plate surface and the plate displacement, and absence of displacement at the rigid walls at $x=nl$. Divide the field into subfields corresponding the cavities

$$p_c(x,y) = \sum_{m=-\infty}^{\infty} p_c^{(m)}(x,y)\Theta(x,ml,ml+l),$$
$$\Theta(x,ml,ml+l) \equiv \theta(x-ml) - \theta(x-(m+1)l) \tag{11}$$

where $\theta(x)$ is Heaviside's step function and $\Theta(x,a,b)$ is the hat function that equals unity between a and b and are zero otherwise. Assume that the pressure field in the m'th cavity can be written as a orthogonal sum of cosinus functions in the x-direction.

$$p_c^{(m)}(x,y)=\sum_{n=0}^{\infty}\varepsilon_n p_{c,n}^{(m)}(y)\cos(n\pi x/l),\quad \varepsilon_n\equiv\begin{cases}\frac{1}{2} & if\ n=0\\ 1 & if\ n\neq 0\end{cases} \tag{12}$$

It is easily shown that this assumption fulfils the boundary conditions, as well as the Helmholtz equation (9). The periodicity is taken into account by (1). This implies that the pressure acting on two neighbouring bays is related to each other trough a phase difference e^{-ikl}, and especially

$$p_c^{(m)}=p_c^{(0)}e^{-ik_x ml}$$

Hence, equation (11) reduces to

$$p_c(x,y)=p_c^{(0)}(x,y)\sum_{m=-\infty}^{\infty}\Theta(x,ml,ml+l)e^{-ik_x ml} \tag{13}$$

Thus, the total field in the cavity is determined by the field in the 0'th cavity. This field is expressed in terms of a cosinus series, equation (12). Hence, the two sums is separated.

3.2 THE FIELD IN THE 0'TH CAVITY

The cosinus expansion (12) is inserted into the Helmholtz equation (9). The so found expression reduces to a one-dimensional Helmholtz equation in the y-direction for each Fourier component. Define a wavenumber for the *n*'th component

$$k_{y,n}\equiv\sqrt{k_c^2-\left(\frac{n\pi}{l}\right)^2-k_z^2} \tag{14}$$

The solution can be written in a standing wave consisting of one wave in the positive *y*-direction and one in the negative *y*-direction,

$$p_{c,n}^{(0)}(y)=\hat{p}_{c,n+}\cdot e^{-ik_{y,n}y}+\hat{p}_{c,n-}\cdot e^{ik_{y,n}y}. \tag{15}$$

The remanding boundaries is now expanded into cosinus series

$$w_i(x)=\sum_{n=0}^{\infty}\varepsilon_n w_{i,n}\cos(n\pi x/l)\leftrightarrow w_{i,n}=\frac{2}{l}\int_0^l w_i(x)\cos(n\pi x/l)\,dx. \tag{16}$$

Thus, the boundary condition ensuring equal displacement in the cavity and the plate are expressed in terms of a cosinus-series. The boundary condition has then also to be fulfilled by every component

$$\left[\frac{\partial p_{c,n}^{(0)}}{\partial y}\right]_{y=0}=\omega^2\rho_c\cdot w_{1,n},\quad \left[\frac{\partial p_{c,n}^{(0)}}{\partial y}\right]_{y=d}=\omega^2\rho_c\cdot w_{2,n} \tag{17}$$

Taking into account the assumed standing wave in equation (15), and derivation and insertion in the boundary conditions (17) yields the amplitudes of the components in the standing wave. Insert this amplitudes in (15)

$$p_{c,n}^{(0)}(y) = -\frac{\omega^2 \rho_c \cdot \left(w_{2,n} \cdot \cos\left(k_{y,n} y\right) - w_{1,n} \cdot \cos\left(k_{y,n}(d-y)\right)\right)}{\sin\left(k_{y,n} d\right) \cdot k_{y,n}}. \tag{17}$$

Putting *y=0* and *y=d* respectively, and rewrite in a matrix form yields

$$\begin{bmatrix} p_{c,n}^{(0)}(0) \\ p_{c,n}^{(0)}(d) \end{bmatrix} = \underbrace{\frac{\omega^2 \rho_c}{k_{y,n}} \begin{bmatrix} \cot\left(k_{y,n} d\right) & \csc\left(k_{y,n} d\right) \\ \csc\left(k_{y,n} d\right) & \cot\left(k_{y,n} d\right) \end{bmatrix}}_{\mathbf{J}_n} \begin{bmatrix} w_{1,n} \\ -w_{2,n} \end{bmatrix}. \tag{18}$$

Using (13) and (18), the reaction pressures can then the be expressed as

$$\begin{bmatrix} p_c(x,0) \\ p_c(x,d) \end{bmatrix} = \left(\sum_{n=0}^{\infty} \varepsilon_n \mathbf{J}_n \begin{bmatrix} w_{1,n} \\ -w_{2,n} \end{bmatrix} \cos(n\pi x/l) \right) \sum_{m=-\infty}^{\infty} \Theta\left(x, ml, ml+l\right) e^{-ik_x ml}. \tag{19}$$

The displacement field in the plates are yet unknown, and need to be solved for.

3.3 FOURIER TRANSFORM OF THE CAVITY PRESSURE

The spatial Fourier transform of the cavity reaction pressure is

$$\tilde{p}_c(\alpha, y) = \int_{-\infty}^{\infty} \sum_{n=0}^{\infty} \varepsilon_n p_{c,n}^{(0)} \cos(n\pi x/l) \cdot \sum_{m=-\infty}^{\infty} \Theta\left(x, ml, ml+l\right) e^{-ik_x ml} e^{i\alpha x} dx. \tag{20}$$

Define the abbreviation

$$\Phi \equiv F_x \left\{ \cos\left(\frac{n\pi x}{l}\right) \sum_{m=-\infty}^{\infty} \Theta\left(x, ml, ml+l\right) e^{-ik_x ml} \right\}.$$

It can be shown, using the Poisson formula and other manipulations, that

$$\Phi = \frac{2\pi}{l} \varsigma_n(\alpha) \sum_{m=-\infty}^{\infty} \delta\left(\alpha - k_x - 2m\pi/l\right), \quad \varsigma_n(\alpha) \equiv \frac{i\alpha - i\alpha e^{i\alpha l} \cos\left(n\pi\right) + \frac{n\pi}{l} e^{i\alpha l} \sin\left(n\pi\right)}{\alpha^2 - \left(n\pi/l\right)^2}. \tag{21}$$

Combining equation (19) with (21) yields the transformed cavity reaction pressures

$$\begin{cases} \tilde{p}_c(\alpha,0) = \dfrac{2\pi}{l} \left(\displaystyle\sum_{n=0}^{\infty} \left(J_{11,n} w_{1,n} - J_{12,n} w_{2,n}\right) \varepsilon_n \varsigma_n(\alpha) \right) \displaystyle\sum_{m=-\infty}^{\infty} \delta\left(\alpha - k_x - 2m\pi/l\right) \\ \tilde{p}_c(\alpha,d) = \dfrac{2\pi}{l} \left(\displaystyle\sum_{n=0}^{\infty} \left(J_{21,n} w_{1,n} - J_{22,n} w_{2,n}\right) \varepsilon_n \varsigma_n(\alpha) \right) \displaystyle\sum_{m=-\infty}^{\infty} \delta\left(\alpha - k_x - 2m\pi/l\right) \end{cases}. \tag{22}$$

4. THE REMAINING REACTION FORCES

The continuity equation at each plate-beam connection points are assumed to be spring like and takes the following form

$$\begin{aligned} & w_1(nl,0,z) = u_n(z) \quad n=-\infty,\ldots,\infty \\ & Q_{1,n}(z) - Q_{2,n}(z) = \mathrm{G}w_1(nl,0,z) \quad n=-\infty,\ldots,\infty \\ & Q_{2,n}(z) = K(w_1(nl,0,z) - w_2(nl,0,z)) \quad n=-\infty,\ldots,\infty \end{aligned} \tag{23}$$

where $\mathrm{G}(\cdot)$ is a linear operator. For the n'th frame, the equation of motion, modelled as a Euler beam and excited by a linear force $Q_n(z)$ along the line $x = nl$, is

$$E_f I_f \frac{d^4 u_n}{dz^4} - \rho_f A_f \omega^2 u_n = Q_{1,n} - Q_{2,n}, \tag{24}$$

where $E_f I_f$ is the bending rigidity and $\rho_f A_f$ is mass per unit length of the frame. From equation (24) the operator G in equation (23) can now be identified. The y-deviates will be replaced by k_y^4. The frame reaction pressure is

$$p_{f1} = \sum_{m=-\infty}^{\infty} Q_{1,n}\delta(x-ml), \quad p_{f2} = \sum_{m=-\infty}^{\infty} Q_{2,n}\delta(x-ml).$$

The displacement fields w_1 and w_2 satisfy the periodicity relation (1) since the structure and driving is periodic. Therefore

$$w_1(nl) = w_1(0)e^{-ink_xl}, \quad w_2(nl) = w_2(0)e^{-ink_xl}.$$

In terms of the displacement, the frame reaction pressure of the beams then is

$$\begin{bmatrix} p_{f1} \\ p_{f2} \end{bmatrix} = \begin{bmatrix} G+K & K \\ K & K \end{bmatrix} \begin{bmatrix} w_1(0,0,z) \\ -w_2(0,d,z) \end{bmatrix} \sum_{m=-\infty}^{\infty} e^{-imk_xl}\delta(x-ml) \tag{25}$$

where $G = E_f I_f k_z^4 - \rho_f A_f \omega^2$. The Poisson sum formula can be used to show that

$$\sum_{m=-\infty}^{\infty} e^{i(\alpha-k_x)ml} = \frac{2\pi}{l} \sum_{m=-\infty}^{\infty} \delta(\alpha - 2m\pi/l - k_x)$$

Applying the Fourier transform and the Poisson sum formula gives

$$\begin{bmatrix} \tilde{p}_{f1} \\ \tilde{p}_{f2} \end{bmatrix} = \frac{2\pi}{l} \begin{bmatrix} G+K & K \\ K & K \end{bmatrix} \begin{bmatrix} w_1(0,0,z) \\ -w_2(0,d,z) \end{bmatrix} \sum_{m=-\infty}^{\infty} \delta(\alpha - 2m\pi/l - k_x) \tag{26}$$

Consider now a fluid occupying the upper half space with an acoustic pressure $p_r(x,y,z)$, $z \le 0$, and the lower half space is occupied by a fluid with a acoustic pressure $p_t(x,y,z)$, $z \ge d$. It is assumed that the two fields have the same sound speed c_0 and density ρ_0. Two moving surfaces are occupying the x-y-plane in $z=0$ and $z=d$, vibrating with displacements $w_1(x,y)$ and $w_2(x,y)$. The acoustic pressure satisfies the Helmholtz equation, similar to (9) but with c_0 as the speed of sound, together with the boundary conditions

$$\left[\frac{\partial p_i}{\partial z}+\frac{\partial p_r}{\partial z}\right]_{z=0}=\omega^2\rho_0 w_1,\quad \left[\frac{\partial p_t}{\partial z}\right]_{z=d}=\omega^2\rho_0 w_2\,, \tag{27}$$

where ρ_0 is the density of the fluid. Decompose the reflected pressure into two components, $p_r=p_{r\infty}+p_s$, where $p_{r\infty}$ is the reflected pressure generated by a rigid reflector and p_s is the scattered part due to the elastic motion of the structure. The Helmholtz equation is now transformed, indicating a wave in the z-direction. Therefore, (27) and assuming only outgoing waves and using the definition of the rigid reflector, gives

$$\tilde{p}_s(\alpha,0)=\frac{\omega^2\rho\cdot\tilde{w}_1(\alpha)}{i\sqrt{k^2-\alpha^2-k_z^2}},\ \tilde{p}_{r\infty}(\alpha,0)=\tilde{p}_i(\alpha,0),\ \tilde{p}_t(\alpha,\beta,d)=-\frac{\omega^2\rho\cdot\tilde{w}_2(\alpha)}{i\sqrt{k^2-\alpha^2-k_z^2}} \tag{28}$$

where z=0 in the first to expressions and $z=d$ in the last expression. Hence, we can identify the coefficients in (5)

$$R=-T=\frac{\omega^2\rho}{i\sqrt{k^2-\alpha^2-k_z^2}}.$$

5. THE INVERSE TRANSFORM

In equation (8) was the inverse transform of the displacements formally given. The transformed pressures from the cavity (22) and frame reactions (26) is now inserted into (8). The Dirac functions ensure that the inverse transform can be taken and the displacement field can den determined. The displacements are

$$w_1(x)=\frac{\hat{p}_i e^{-ik_x x}}{\pi\cdot S_1(k_x)}-$$
$$-\frac{1}{l}\big((G+K)\cdot w_1(0)-K\cdot w_2(0)\big)\Sigma_1^{(f)}(x)-\frac{1}{l}\sum_{n=0}^{\infty}\big(J_{11,n}w_{1,n}-J_{12,n}w_{2,n}\big)\varepsilon_n\Sigma_{1,n}^{(c)}(x) \tag{29 a}$$

$$w_2(x)=\frac{1}{l}\big(K\cdot w_1(0)-K\cdot w_2(0)\big)\Sigma_2^{(f)}(x)+\frac{1}{l}\sum_{n=0}^{\infty}\big(J_{21,n}w_{1,n}-J_{22,n}w_{2,n}\big)\varepsilon_n\Sigma_{2,n}^{(c)}(x) \tag{29 b}$$

where the following abbreviations has been used

$$\Sigma_j^{(f)}(x)\equiv\sum_{m=-\infty}^{\infty}\frac{e^{-i(2m\pi/l+k_x)x}}{S_j(2m\pi/l+k_x)},\quad \Sigma_{j,n}^{(c)}(x)\equiv\sum_{m=-\infty}^{\infty}\frac{\varsigma_n(2m\pi/l+k_x)e^{-i(2m\pi/l+k_x)x}}{S_j(2m\pi/l+k_x)}$$

where j=1, 2. The $w_1(0)$, $w_2(0)$ and the Fourier components are still unknown. To determine them, let $x\to 0$ in (29),

$$w_1(0)=\frac{\hat{p}_i}{\pi\cdot S_1(k_x)}-$$
$$-\frac{(G+K)}{l}\Sigma_1^{(f)}(0)w_1(0)+\frac{K}{l}\Sigma_1^{(f)}(0)w_2(0)-\frac{1}{l}\sum_{n=0}^{\infty}J_{11,n}\varepsilon_n\Sigma_{1,n}^{(c)}(0)\,w_{1,n}+\frac{1}{l}\sum_{n=0}^{\infty}J_{12,n}\varepsilon_n\Sigma_{1,n}^{(c)}(0)\,w_{2,n}$$
$$w_2(0)=\frac{K\Sigma_2^{(f)}(0)}{l}w_1(0)-\frac{K\Sigma_2^{(f)}(0)}{l}w_2(0)+\frac{1}{l}\sum_{n=0}^{\infty}J_{21,n}\varepsilon_n\Sigma_{2,n}^{(c)}(0)\,w_{1,n}-\frac{1}{l}\sum_{n=0}^{\infty}J_{22,n}\varepsilon_n\Sigma_{2,n}^{(c)}(0)\,w_{2,n}$$

Multiply (29) by $\cos(s\pi x/l)$ and integrate from 0 to l, s being an integer, in order to identify the Fourier components,

$$w_{1,s}=\frac{2}{l}\int_0^l\frac{\hat{p}_i e^{-ik_x x}\cos(s\pi x/l)\,dx}{\pi\cdot S_1(k_x)}-$$
$$-\frac{2(G+K)}{l^2}I_{1,s}^{(f)}w_1(0)+\frac{2K}{l^2}I_{1,s}^{(f)}w_2(0)-\frac{2}{l^2}\sum_{n=0}^{\infty}J_{11,n}\varepsilon_n I_{1,s,n}^{(c)}w_{1,n}+\frac{2}{l^2}\sum_{n=0}^{\infty}J_{12,n}\varepsilon_n I_{1,s,n}^{(c)}w_{2,n}$$
$$w_{2,s}=\frac{2K}{l^2}I_{2,s}^{(f)}w_1(0)-\frac{2K}{l^2}I_{2,s}^{(f)}w_2(0)+\frac{2}{l^2}\sum_{n=0}^{\infty}J_{21,n}\varepsilon_n I_{2,s,n}^{(c)}w_{1,n}-\frac{2}{l^2}\sum_{n=0}^{\infty}J_{22,n}\varepsilon_n I_{2,s,n}^{(c)}w_{2,n}$$

where the following abbreviations has been used,

$$I_{j,s}^{(f)}\equiv\int_0^l\cos(s\pi x/l)\Sigma_j^{(f)}(x)\,dx\quad I_{j,s,n}^{(c)}\equiv\int_0^l\cos(s\pi x/l)\Sigma_{j,n}^{(c)}(x)\,dx\ .$$

where i=1, 2. A system of equations can now be set and solve for $w_1(0)$, $w_2(0)$ and the Fourier components. Hence, the problem is solved.

6. CONCLUDING REMARKS

The paper has shown that it is possible to use periodic assumption and transform technique to include the effects of the finiteness when treating a double-leaf wall with studs.

7. REFERENCES

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