INTRODUCTION

In the concrete prefab industry building elements are produced in steel moulds. When mould vibrators are used the vibration frequency is 50-150 Hz and the amplitude 0.1-0.8 mm. Vibration is used in order to give the product an acceptable quality with respect to homogeneity, appearance of the concrete surfaces and structural strength.

Sound levels at the moulds range from 95 to 110 dB(A). As vibration of the steel moulds is a part of the production process the noise problem can be very hard to solve.

Aiming at in the long range developing less noisy equipment for production of concrete elements theoretical models have been deduced of the

- Sound pressure level at the vibrator frequency for mould vibration
- Vibration propagation from mould vibrator to a point in the concrete.

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VIBRATION OF CONCRETE

In our literature study on vibration of concrete we found several models of the dynamic behaviour of concrete. From our point of view we found it natural to consider the concrete as a fluid with linear behaviour. This assumption ought to be valid at least after the first compaction stage which has been called the initial settlement.
Model tests have been performed on a vibration table (B&K 4802 + 4817). Plastic moulds (Ø 0.076 m, height 0.2 m) were filled with concrete. A raft with an accelerometer was placed on top of the concrete in order to measure the response. With constant mould bottom acceleration the sinusoidal vibration was swept from 25 Hz to approximately 300 Hz.

The response at the top of the concrete column was registered. The vibration increase was considerable, 8-18 dB, when the concrete thickness was about 1/4 of the wavelength. A similar response will occur in full scale moulds too.

From the tests the phase velocity could be calculated. The concrete can be considered as a fluid with air bubbles during vibration. The phase velocity has been calculated. The agreement between calculated and measured results are good, see figure 1.

![Figure 1](image)

**Figure 1**
Calculated phase velocity $c$ for fresh concrete versus air content. Measured value for 26 cm slump ($\cdot$), for 10 cm slump ($\circ$)

VIBRATION PROPAGATION FROM VIBRATOR TO CONCRETE

A theoretical model has been deduced of the vibration propagation in the concrete when mould vibration is used.

The vibrator creates flexural waves in the mould and compressional waves in the concrete, figure 2. The phase ve-
The flexural wave velocity for an empty mould is much higher for normal vibration frequencies, 50-100 Hz. When the mould is filled with concrete, however, the flexural wave velocity decreases to a little below coincidence. The vibration decrease from the vibrator to a point in the concrete has been calculated for loss factors $\eta = 0.2$ which is common and for $\eta = 0$, figure 3.

$$\frac{a_t}{a_0}$$

Figure 3
Reduction of the acceleration from mould vibrator, $a_0$, figure 2, to a point in the concrete. $\eta$ = loss factor for the mould (normally 0.2),
$\lambda$ = wave length for flexural waves $\approx$ wave length in the concrete

The mould acceleration at the vibrator position can be determined from

$$F = \frac{a_0}{\omega^2}$$

When the mould is filled with concrete the mobility decreases by approximately

$$\sqrt{\frac{\rho_o C_o}{\omega (m_m + m_c)}}$$

The mobility for a mould filled with concrete can be determined approximately from

$$Y = \frac{1}{8} \sqrt{\frac{\omega}{B \cdot \rho_o \cdot C_o}}$$

where $B$ = bending stiffness (Nm),
$Y$ = mould mobility at vibrator (m/Ns),
$C_o$ = phase velocity for concrete (m/s),
$m_c$ = 0.5 - concrete mass inside the mould (kg/m² mould surface),
$m_m$ = mould surface mass (kg/m²),
$\rho_o$ = density for concrete (kg/m³)
Thus for a certain acceleration demand in the concrete vibrator force and maximum distance between vibrators can be determined.

**NOISE EMISSION FROM THE MOULD**

A method for the calculation of the sound pressure level at the vibrator frequency has also been deduced for mould vibration.

The vibration velocity for the mould side can be determined from

\[ L_{uo} = 20 \log \frac{U_o}{U_{\text{ref}}} \]

where \( U_o = F \cdot Y_p \)

- \( F \) = vibrator force (N)
- \( Y_p \) = point mobility for the filled mould at vibrator

\( U_{\text{ref}} = 5 \times 10^{-8} \text{ m/s} \)

The mould mobility can be measured or determined by calculation.

The sound pressure level at the mould can be calculated according to the following formula:

\[ L_p = L_{uo} + D + E + G \]

\( D, E \) and \( G \) are corrections: \( D \) for resonances in the mould side, \( E \) a correction to get the mean vibration velocity and \( G \) the correction to get the radiated sound pressure at a certain distance from the mould side. Details about these corrections will be given in the speech.