Prediction of Noise Transmission through Commercial Profiled Metal Cladding Systems

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Abstract: A method for predicting the sound reduction index (SRI) of commercial cladding systems is presented. The method combines existing theory for orthotropic flat plates with finite element analysis to account for the pronounced "dips" in the SRI at mid frequencies which are caused by the resonances of the profile geometry. The method was further extended to cover commercial double-skin cladding constructions. Analytical equations were formulated to account for the orthotropic nature of the cladding sheets, the sound bridging through fixing supports, and the sound reduction through the infill insulation. Comparisons of predictions against laboratory and in situ sound reduction measurements were made on a range of commercial cladding products. Good agreements between predictions and measurements were found.

INTRODUCTION

The creation of a profile on an otherwise flat metal sheet substantially increases the mechanical bending stiffness of the sheet in one direction without incurring a significant increase in weight. This profiling however compromises the noise insulation performance of the sheet. Firstly the orthotropic mechanical property creates two coincidence frequencies, one of which appears at a rather low frequency (typically 200 - 300 Hz). Secondly the profile geometry creates localized vibrational resonances that cause a worsening of the SRI ("dips" in SRI around 1-2kHz). The frequency and the magnitude of these "dips" are both sensitive to small changes in the profile geometry [1].

NOISE REDUCTION PREDICTION

Earlier methods to predict the sound transmission through a single cladding sheet was largely based on the orthotropic flat plate theory [2] and there was no attempt to correlate the results with the SRI "dips". In the method presented here the sound transmission is separated into two paths - a global path that is determined by the global orthotropic property of the plate, and a SRI "dips" related path that is determined mainly by the local geometry of a single profile period. The "global" part of the transmission can be modelled by approximating the corrugated plate by an equivalent flat but orthotropic plate, and then calculated by Heckl's approximate formulae [2]. However comparison with 15 cladding sheets tested in this work showed that Heckl's formula needed to be modified to allow some low and mid-frequency discrepancies [3].

The "dips" in the SRI curve is caused by local mechanical resonances of the profile sections. The frequencies and the vibrational behaviours of these resonances can be predicted accurately by finite element analysis. Their influence on the noise transmission is then modelled by calculating their effective impedance to random plane wave incidence [3]. Further work has simplified the prediction of the SRI "dips" into a set of empirical formulae [4].

In a typical double sheet construction, the cladding is affixed by screws to the structural building frame or purlins. Z-spacer rails are fastened through the liner panel to the purlin and the external sheet is then affixed to the rail. The link between the liner and the external sheet can be considered as point-to-point. The sound bridging effect of these linkages in an orthotropic cladding system can be estimated from a consideration of sound radiation efficiency and mechanical impedance matching at each of the sound bridges, leading to the following noise reduction equation [5],

$$ R = R_{NB} - 10 \log_{10} \left( 1 + \frac{\sigma}{S_{g1}} \left| \frac{Z_{g1}}{Z_{g1} + Z_{g2}} \right|^2 \left[ 2(10^{10} - 1) \beta \right] \right) + TL_{ins} \quad (1) $$

where $R_{NB}$ is the noise reduction in the absence of sound bridges [6], $R_I$ is the noise reduction of the external sheet, $S_{g1}$ is the sheet area per sound bridge, $Z_{g1}$ and $Z_{g2}$ are the orthotropic point impedance [2] of the liner and external sheets, $TL_{ins}$ is the transmission loss through the insulation, $\sigma$ is the radiation efficiency of an orthotropic sheet with point excitation [2], and $\beta = \omega d / c$ or 1 for $f<f_L$ or $f>f_L$ where $f_L$ is the limiting frequency of the air gap with span $d$.

LABORATORY AND IN SITU PERFORMANCE

The single sheet prediction method works well on a large range of single-skin profiled metal cladding sheets with
varying profile geometries [3]. Figure 1 shows a comparison on a typical commercial single sheet cladding. The “Measured” data were laboratory SRI test result. Since the method of cladding construction inevitably varies between laboratory and on-site, it is important also to determine the noise performance of cladding systems in-situ. The “In Situ” data were measured by intensity method on a real workshop constructed using the same cladding as in the laboratory test. The sound field inside the workshop was generated by high power loudspeakers and the internal diffuse field sound intensity was calculated from sound pressure measured at 24 positions. The external intensity was measured by an intensity probe. The workshop is well away from any busy roads. The background noise level was generally low and the measurement was estimated to be valid up to about 3kHz, below which the low signal level, flanking transmission, and background noise adversely affected the reliability of the measurement. At frequencies below 160Hz the in situ data are significantly lower than the laboratory data. This is due to the stiffness effect of the smaller laboratory test sample and the finite room volumes of the transmission suite. The prediction, which is not affected by these effects, agrees better with the in situ result at low frequencies.

The double sheet prediction theory has been tested against and generally agreed well with laboratory measurements on 24 cladding systems [5]. Figure 2 shows a comparison on a commercial double sheet cladding system of standard construction. Also shown is the in situ data and a sketch of the corresponding on-site layout. The building measured is situated in an industrial estate with moderate background noise from adjacent work units. Furthermore, the external signal level was low at high frequencies due to the high SRI values of the double sheet cladding. The intensity measurement was affected at frequencies above 625Hz and became unusable at frequencies above 3150Hz. At frequencies below 160Hz the in situ values are again lower than those measured in laboratory as in Figure 1. In the intermediate frequency range the in situ and laboratory values agree very well and in particular the existence of a SRI “dip” around 2kHz is apparent in both cases.

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REFERENCES