Proceedings of The Institute of Acoustics

THE PROGRESS OF THE "STRUCTURES" GROUP OF COMMISSION W.51 OF THE C.I.B. WITH PARTICULAR REFERENCE TO THE S.E.A. STUDIES CARRIED OUT ON A FULL SCALE BUILDING IN EDINBURGH.

R.J. CRAIK, R.K. MACKENZIE, & L.J. WONG
HERIOT-WATT UNIVERSITY, EDINBURGH .

1. Introduction

During 1974 a survey was carried out by the International Council of Building (C.I.B.) to establish the state of knowledge relating to noise and vibration within the Built Environment.

The results of the survey clearly demonstrated the need for a better understanding of the phenomena involved in the transmission of sound through connected structures and it was suggested the primary aims of any collaborative research should be (Ref. 1) :-

> "-The forecasting of the transmission of sound and vibration in a building, consisting of structural elements of a known or new design.
>
> -The invention of structures or of structural elements specially designed to guarantee a high level of acoustic performance."

It was further recommended that the solution of these problems would be best achieved by investigating :-

> "-The transmission factor of plane waves from one structural element to another.
>
> -The loss factors due to coupling between one structural element and another, in the presence of diffuse fields and of stationary vibrations, using S.E.A. methods."

2. Collaborative Research Programme

Following the initiative taken by Josse at the C.S.T.B. a meeting of representatives from 19 laboratories from throughout the world was held early in 1975 at Grenoble, France.

The outcome of this meeting was the establishment of a programme of collaborative study based on an agreed set of research priorities taking into account the capabilities and resources of each participating laboratory.

The exact form of the objectives of the cooperation were outlined as follows (Ref. 2) :-

> "-Understanding the mechanism of sound transfer at junctions, using a common method in order to analyse the parameters.
>
> -To predict the junction parameters from a knowledge of the physical properties of the walls.

-To agree of the most useful parameters to characterise junctions and to establish a catalogue of the junction characteristics.

-To evaluate the scatter of results found with similar junctions and to assess the effects of workmanship."

It was further agreed, that since the design of structural elements varied widely from country to country, that one common type of construction should form the basis of the initial studies. In this connection it was generally accepted that most countries had, in common, housing units, constructed in solid brick or dense concrete walls with in-situ concrete slab floors and that this type should be adopted for investigation in the first instance.

3. Types of Structural Junctions

In terms of complexity with regard to acoustic behaviour, the junctions were classified as follows:-

The straightforward symmetrical X and T junctions, with butt jointing at the intersection of homogeneous wall and floor elements.

The more complex joints involving non symmetrical junctions with and without ideal bonding at the joints, but still involving 'homogeneous' wall and floor elements.

Highly complex junctions formed from non homogeneous elements such as timber joisted floors and hollow block units.

4. Progress to date

In order to make the most effective use of the relatively limited resources available and to avoid unnecessary duplication, it was agreed that individual laboratories would tackle the same problem, but each by using a different analytical approach.

At one extreme, researchers in Poland are currently undertaking a 'macro-examination' of the situation by testing almost 50% of all new houses built in that country between 1975 and 1980 which will involve some 1.25 million tests. This has, of course, by the very nature of the scale involved, meant that a simplified test method has had to be used. This study will however provide invaluable information on the scatter of results.

On a smaller scale, single buildings have been examined by teams in England, France and Scotland. Various aspects have been examined, ranging from detailed measurements of coupling loss factors to studies of vertical transmission of vibration via columns in large buildings.

Full scale studies of junctions, in isolation, have been undertaken in Belgium, England, France, Holland and Germany.

SOUND TRANSMISSION THROUGH STRUCTURES

Model scale studies, normally using a 1:5 scaling factor, have been carried out extensively in England, France and Sweden.

With regard to theoretical work most of the experimental programmes described above have had associated theoretical studies carried out at the same time. However, indopendant theoretical studies are being carried out in Australia, Canada and the U.S.A.

Finally, computer simulation of junction behaviour is being developed in Germany.

The overall programme, therefore, is very comprehensive although for many laboratories it has taken several years to fully develop their own research programmes.

Working sessions, in order to study progress, are held every 18 months at different centres. These meetings are however only meant to consolidate the on-going collaboration through exchange of results and personnel

5. 'Riccarton' study

5.1 This study, in the context of the preceding categories, involves a full scale study of a whole building.

The actual building comprised of a three storey block of single study/bedrooms, constructed with brick and concrete block walls and concrete floors.

5.2 Aims of study

Apart from the general aims of the overall programme, the specific aims of this study can be summarised as follows.

a) To determine from measurements the coupling loss between such systems.

b) To compare these measured values with predicted values.

c) To calculate the 'hierarchy' of sound transmission loss paths.

d) To evaluate the effects of workmanship, cracks, settlement and other variables on the acoustic performance of otherwise identical joints.

e) To build a $1/5^{th}$ scale model and to develop simulation techniques.

5.3 Measurements

The measurements made in the building were taken in a form so that the investigation could be made using statistical energy analysis. For analysis of the measurements only bending wave energy was considered and this gave an energy model with 104 subsystems and 946 interconnections, and thus 946 coupling loss factors. This is a very large model but work has shown that analysis can be simplified by considering different parts in turn. By simplifying in this way, 172 coupling losses have been determined 61 reciprocity checks have been made and various comparisons of identical joints have allowed the effects of workmanship and cracks to be assessed.

5.4 Total Loss Factor

The total loss factor of all 104 subsystems was measured by exciting the subsystem with an impulse source and measuring the resultant decay curve. For the rooms the source was a pistol and for the walls and floors a rubber headed hammer was used. Of these measurements about 25 are concrete floors and 60 are block walls, the rest are rooms.

5.5 Energy

The most important measurement made was the distribution of sound energy through the buildings for a number of sources. Three different kinds of source were used including a loudspeaker for the room, a standard tapping machine for the floors and a shaker for the walls. Both the shaker and the loudspeaker were driven by broadband random noise. In all, 470 subsystem energy levels were measured, in most cases to a constant accuracy of ± 2 dB at 250 Hz.

5.6 Summary of Results

Whilst many of the results have agreed with theoretical S.E.A. prediction, variations due to workmanship and cracking have been found. Within the range of validity agreement with the existing theories has been good. A system of path hierarchy has been established and is being used to determine the acoustic path noise reduction between systems.

References

(1) R. JOSSE, Jan. 1975, C.S.T.B. Note/Ref. GA/75-44 KG/CB - "Structural Transmission of Sound".

(2) Commission W.51, Feb. 1975, C.S.T.B., Note/Ref. GA/75 - 104 KG/CB - "Proceedings of the Meeting on the Structural Transmission of Sound".