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UPGRADING OF FLOORS IN REFURBISHMENT PROJECTS

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1. INTRODUCTION

Guidelines on remedial work in conversions are given in Approved Document E of the Building Regulations 1991 (1). The specifications which are given provide a set of solutions to the problem of poor sound reduction in existing timber floors. A number of constraints, however, exist in practice which render four of the five specifications unsuitable. These constraints involve restrictions on floor to ceiling height, the safety consideration of introducing a step into a flat and the need to retain ornate cornices. Consulting experience suggests that these constraints exist in the majority of conversions which raises the question of the need for additional specifications to address the problems encountered. In common with problems found in conversion work are constraints encountered in the upgrading of floors in refurbishment projects. For timber floors the problems are identical to those described above. In the case of concrete bases, the floor to ceiling height limitation is a very common restriction and the step detail is invariably questioned at building warrant stage. There is, therefore, a need to have additional or modified specifications within the Building Regulations to accommodate the demand for shallow profile treatments which do not raise the existing floor level by more than 15mm. These specifications cannot be met by traditional mineral fibre layers or strips in view of the thickness required from these materials. Research has been carried out to develop shallow profile resilient layers using alternative flexible cellular polymer based materials.

2. CELLULAR POLYMERS

Polymers can be organic or inorganic in structure with polyethylene and polyisoprene (natural rubber) being amongst the most common of the former type whilst ordinary window glass represents the most common form of the latter. Frequently polymers are produced as co-polymers containing a combination of two or more components. Cellular forms of many polymers have been developed, largely for their thermal and mechanical properties. The technology has been applied most extensively to polyurethane, polystyrene, polyvinyl-chloride, polyethylene, polypropylene, phenolics, natural rubber and synthetic rubber. Both rigid and flexible cellular materials are manufactured in open and closed cell form. Closed cell materials have much higher elastic moduli in compression than similar open cell foams as a result of the presence of trapped air.

Polymers have long been recognised for their damping properties and one of the most important factors for this application is the glass transition stage. From the initial glass state a polymer becomes rubbery as the temperature is raised. If the polymer is cross linked it will behave like a rubber band in this region. During the stage of glass transition (Figure 1) a polymer is at its most efficient in converting sound and vibrational energy into heat.

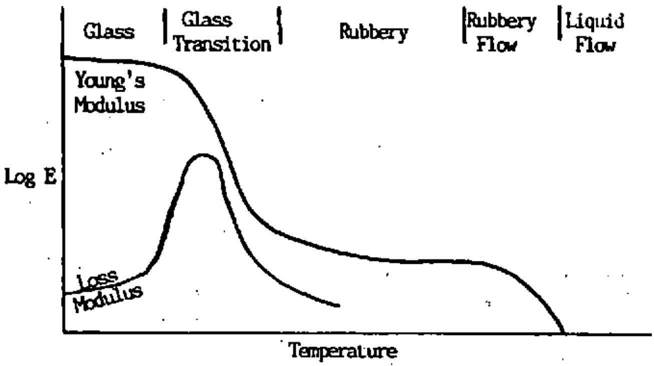

Figure 1 - The five regions of visco elastic behaviour in polymers

All polymers exhibit the five regions shown above but cross linking, crystallinity and molecular weight affects the shape of the curve. The loss modulus is at its maximum just after the Young's Modulus enters the glass transition stage.

The most suitable materials for open cell manufacture would appear to be co-polymers involving hard (i.e. glass state) polyurethane blocks linearly joined or cross linked to soft (i.e. rubber state) polyether or polyester blocks. More expensive versions include epichlorhydrin which is a polyether based co-polymer with excellent elastic properties. Natural or synthetic rubbers may also be foamed into open cell configuration with polymers such as neoprene or styrene-butudiene being the most appropriate.

3. DYNAMIC PROPERTIES OF CELLULAR POLYMERS

The advantages of open cell polymer foams for use as resilient layers has already been described in earlier publications (2 -6). The characteristic difference between closed cell and open cell foam under an applied load is found in their relative static deflections. A closed cell foam strip, 12mm thick, under normal domestic loading, is unlikely to deflect by more than 1mm compared to a figure of 6mm obtained with open cell foam of similar thickness.

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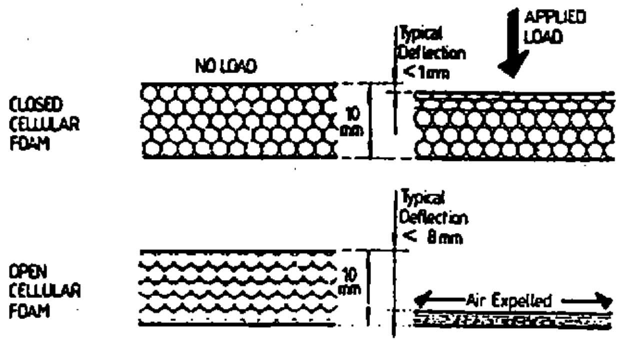


Fig. 2 - Diagram showing the relative effects of open and closed cell foams under load. (Ref. 3).

Closer examination of the movement of open cell flexible foams under dynamic loading has indicated that it is the cellular structure which dictates the rate of deflection whereas it is the polymer material itself which determines its resilience or ability to return to its original state.

The main problem with rock (i.e. mineral wool) or glass fibre quilts is that they comprise of strands of brittle material (i.e. glass state) which achieves resilience by means of interweaving in free form or by resin bonding. Over a period of time these fibres break and in low density form are frequently ground to dust.

Open cell polymer flexible foams do not exhibit such brittle fracture because of the elastic behaviour of the soft co-polymer. The only problem which can arise, therefore, is due to a breakdown in the chemical bond or a change of chemical state. Under normal domestic loading, bond breakdown is extremely unlikely and virtually impossible where cross-linking has been carried out. A change of state is, however, a possibility with some materials more susceptible than others. Natural rubber will oxidise and after a period of time lose its resilience. This, however, is a slow process in an underfloor location where catalysts such as UV light are absent. The polyester-urethane co-polymer is essentially unstable and through being hydrolytic will, in a damp or humid environment, gradually lose its compressive strength giving rise to creep.

In terms of dynamic behaviour, chemical stability and cost, polyether based polyurethane open cell foam is the most suitable material. For heavy duty work such as gymnasium floors, polyether based epichlorhydrins may have a special role, but are very expensive. Recent developments in Germany (7) have produced a range of heavy duty open cell polyether-urethanes suitable as anti-vibration layers under buildings, railway tracks etc. The polyether-polyurethane co-polymer would seem to be, for all building vibration isolation applications, the most promising currently available.

4. LAMINATED CELLULAR FOAM STRIP

Floor treatment 3 as specified in the Approved Document E (1) is the only detail amongst the five treatments given which can address the problems of critical floor level. Given the recommended density of the mineral fibre strip (80 - 140 kg/m^3), this will still cause floor levels to be raised by over 20mm which is unacceptable to many architects and building control authorities. Research has been carried out in order to provide a shallower strip using polymeric materials with similar isolation properties to the mineral fibre strip described above. This has been achieved using a lamination of closed and open cell polyurethane foam as shown in Figure 3 below.

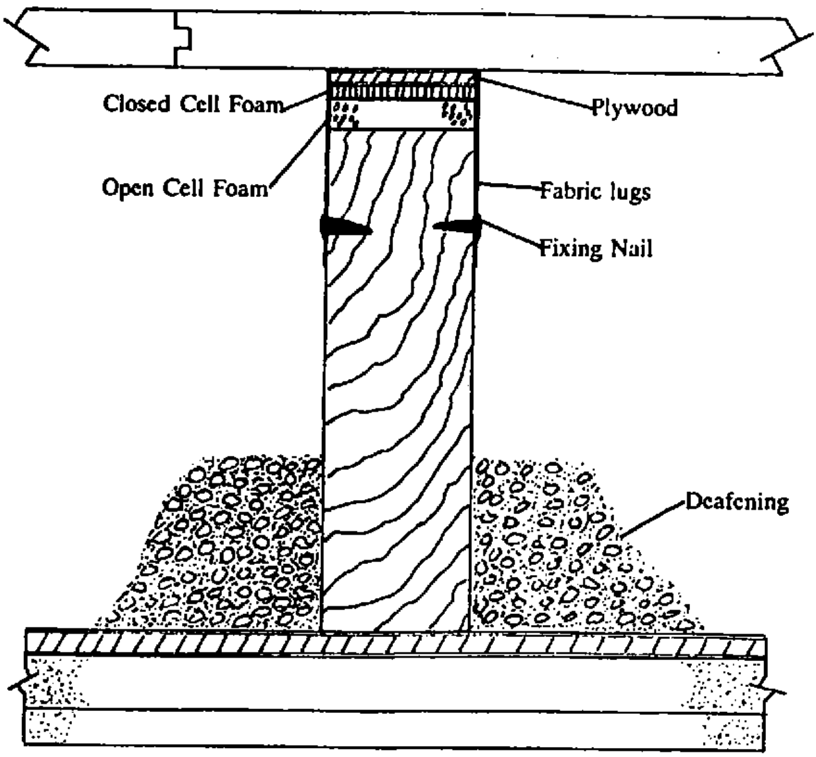
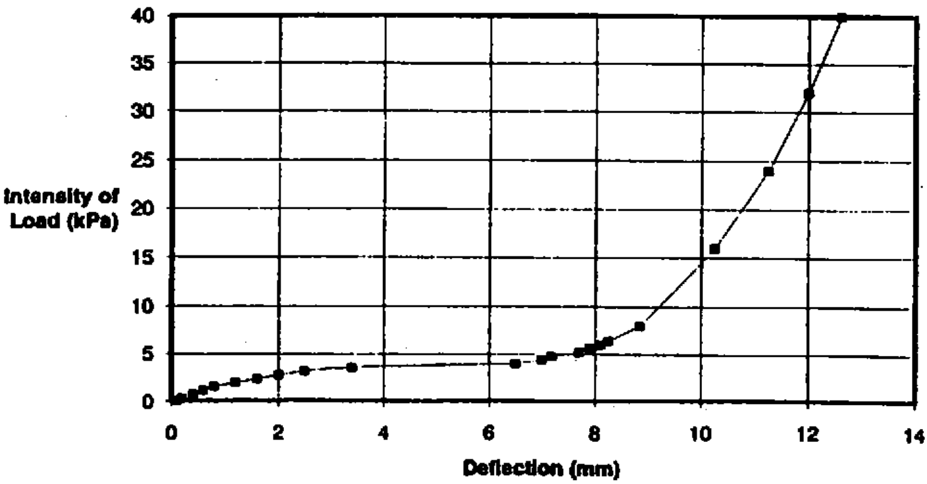


Figure 3 - Laminated Cellular Foam Strip

The 12mm thick open cell foam deflects by up to 6mm under normal domestic loading to provide a suitable isolation efficiency against impact sound. Further deflection is resisted by a combination of the compressed elastomer in the open cell foam together with the pneumatic resistance provided by the entrapped air within the closed cell strip. The elastic behaviour under normal domestic loading, < 4kPa, is clearly shown in the plateau in Figure 4 below, between 2mm and 6mm deflection.

Figure 4 – Deflection of Laminated Cellular Foam Strip



5. INTEGRAL FLOOR WITH LAMINATED CELLULAR FOAM STRIP

A natural extension of the technology involved in the laminated foam strip was to produce a flooring system for use in the upgrading of concrete floors. There is, however, a parallel need for such a deck system in the upgrading of timber floors where there is either sufficient deafening to provide satisfactory initial airborne sound reduction or simply where the client does not wish to incur the expense of lifting the existing floorboards. The attenuation provided by such a system is shown below in Figures 5(a) and 5(b).

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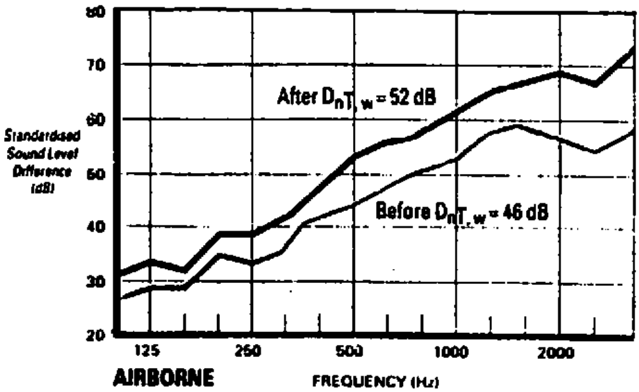

Figure 5(a) – Improvement in Airborne Sound Insulation Measured after Laying Integral Floor with Laminated Cellular Foam Strip upon a Timber Joist Floor

(Source: Heriot-Watt University)

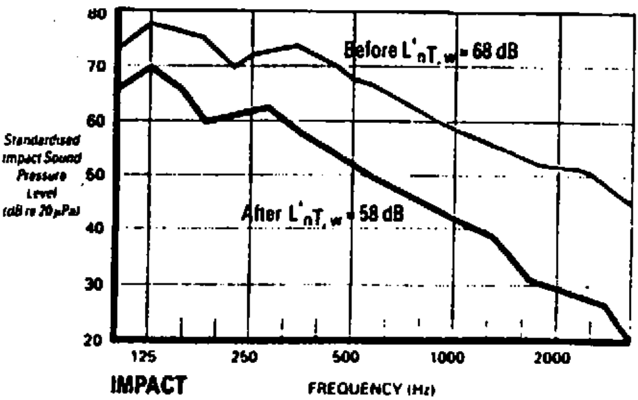

Figure 5(b) – Improvement in Impact Sound Insulation Measured after Laying Integral Floor with Laminated Cellular Foam Strip upon a Timber Joist Floor

(Source: Heriot-Watt University)

6. SHALLOW PROFILE PLATFORM FLOOR

The floor described above, although shallower than Floor Treatment 2 of Approved Document E (1), is still unsuitable for many refurbishment projects because of the step detail. There is, therefore, a need for very thin decks and although a few already exist, they are either very poor in terms of impact sound attenuation or very expensive by virtue of the sophisticated visco elastic design principles used.

The use of open cell polyurethane foam as the resilient layer was relatively quickly established as the most appropriate type of polymer. Various densities and thicknesses were investigated resulting in an 8mm thick layer of 33 kg/m^3 density being used. Several board finishes were examined including plywood, hardboard and medium density fibreboard (MDF). The latter board was chosen partly due to its superior finish but also due to its excellent machining properties which in the case of hardboard and plywood are relatively poor. A proper tongued and grooved joint was considered essential for stability of the floor surface. With regard to acoustical properties MDF has a higher internal loss factor than plywood, but lower than hardboard. Such decks have limited airborne attenuation properties and additional treatment (11) is essential in order to provide a balanced upgrade in terms of both airborne and impact sound reduction.

The question of stability of very thin boards is a major problem especially with high compliance resilient layers. This has been overcome in the design by incorporating a closed cell peripheral foam, 50mm wide, around two adjacent sides of each board so that each joint is supported by a low deflection strip as shown below in Figure 6.

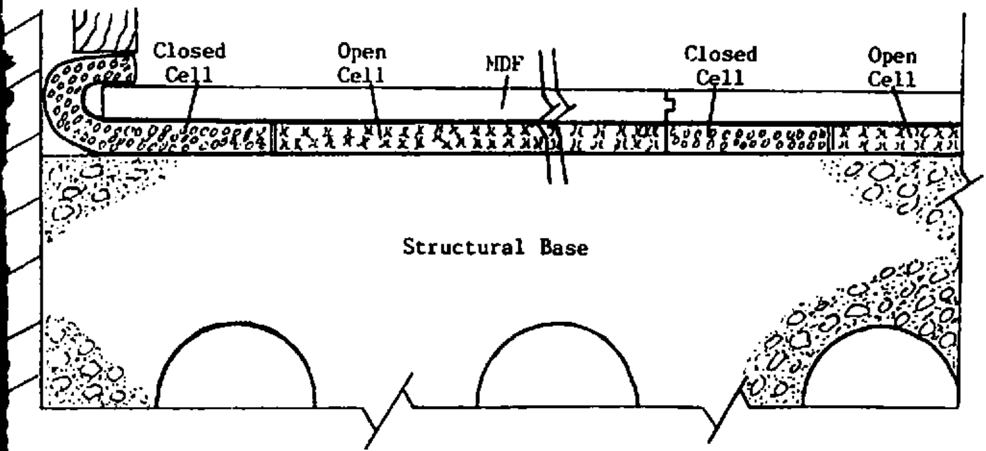

Figure 6 – Section through Shallow Profile Platform Floor
showing edge and board joint details

A shallow profile floor has been designed with both excellent walking stability and acoustic performance, giving an 18 dB weighted impact sound improvement as calculated in accordance with Annexe A of B.S. 5821:1984 (12).

7. ACKNOWLEDGEMENTS

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