OPTIMISING BALLET FLOOR DESIGN TO ASSIST IN INJURY PREVENTION

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INTRODUCTION

There are no published authoritative guidelines on acceptable values, or variability, for the performance of ballet floors. To overcome some of the limitations of variability in venue floors the Birmingham Royal Ballet (BRB) Company have utilized a portable floor system, comprising prefabricated panels, transported and assembled for each show. However, concerns were raised over the best design of the portable floor and this study aimed to evaluate and evolve a portable floor system to optimize performance and safety.

The Company's clinical director was looking to understand and control the floor system better as part of a long-term injury tracking project. It was clear that shock absorbency was a key parameter to provide comfort to the dancers, and to control the magnitude and uniformity. Dancer anecdotes had indicated the large range of surface 'hardness' they experienced around the country, borne out by a series of fieldwork measurements. Research has identified the shock absorbency of a sport surface can be linked to lower limb injuries, particularly from overuse [1]. For athletic performance, energy return [2] is also attributed to reduce fatigue and potentially susceptibility to injury. Ballet is an extreme example of prolonged athletic performance, especially in many maneuvers for control of the lower limbs during landing and take off.

There were no precedents found, however, in the literature for Ballet for typical loading, load duration or injury studies relating to surface behavior. The study thus required the selection of an appropriate test methodology and assessment criteria, against which to assess floor behavior and acceptable limits for impact protection.

EVALUATION METHODOLOGY

The standard method for measuring 'shock absorbency' of a sport surface is the 'Artificial Athlete' (AA) test, often known as the 'Berlin Athlete', and more recent version known as the Advanced AA or AAA. It is currently specified for soccer, rugby, hockey, tennis and sports hall floors. The AA measures the peak force, via accelerometer, of a controlled impact (fixed mass, drop height and spring damper). The peak force is expressed as 'Force Reduction', which is expressed as a % when compared to rigid concrete (standard = 6600N).

In the UK guidance for 'Floors for Indoor Sports' [3] suggests a suitable range for Force Reduction of 45 to 75% for 'combined elastic' floors (combined means floor bending and deformable support at the ground surface contact points). Based on the author's own research [4], a difference of 5% in FR is 'significant', and perceptible to users.

The study as a whole assessed the field venues. It also assessed a series of 'elastic' supports for a series of floor designs. The main focus was to design the portable floor system for the BRB.

Figure 1 shows the floor undercarriage system of the BRB original portable floor comprising rubber pads, in a pattern replicated for all boards, attached to the longitudinal wooden batons which in turn support the transverse batons to which the floor board is attached (size 2.5 by 1.2m).

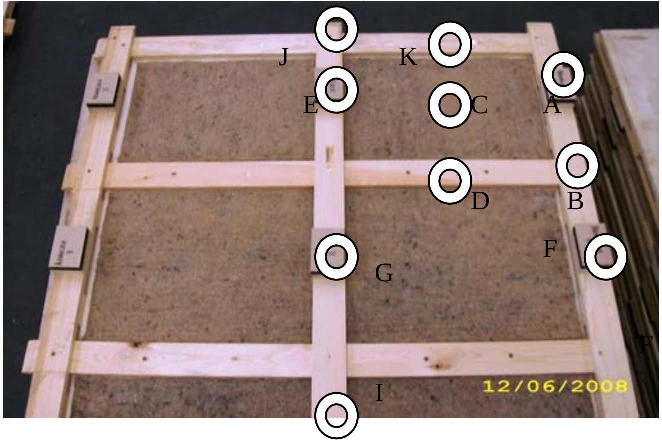

Figure 1: Original Floor System undercarriage(Test locations A, F, E and G are on pad positions, the space between batons create 'panels')

The locations of the AA tests was carefully chosen. To measure the variation in support across the floor system and the anticipated interaction of the components. In addition, all testing was undertaken with 6 panels fitted together to reduce boundary effects, with the middle panel assessed. Ten clear variations in support were identified (by observation), later modified to thirteen because of the varying load transfer across panels.

The development of the modified floor system focused on selection of the most appropriate rubber pad, and an iterative redesign of the baton sub-structure. Other modifications to the floor panel thickness (and hence stiffness) and to the baton thickness were discounted to reduce the number of variables and for cost reasons. A schematic of the final design is shown in Figure 2.

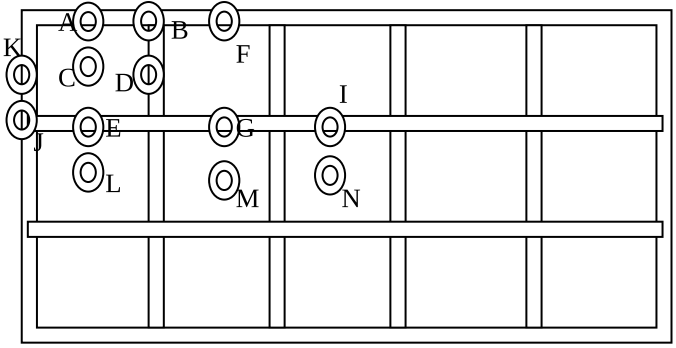

Figure 2. Modified Floor system, showing test positions similar to those in Figure 1.

RESULTS AND DISCUSSION

The force reduction behavior of the system is relatively complex. This is a combination of factors, including: the pad size, thickness, stiffness, and spacing; the board and baton size, weight and stiffness, area of unsupported 'panels' created by the baton spacing, the depth of baton creating space for the floor board to bend on its own, and the use of any stiffening supports to assist the interlocking of adjacent panels. In addition, clearly the rate and magnitude of (point) loading applied, though this is a constant for the AA test method. Modelling this behavior is complex, although it was demonstrated empirically – sufficiently to design the new system.

Figure 3 shows the modified floor system versus the original. Prior to modification the portable floor system generated a Force Reduction response in the range 38-65. The general effect of adding in the extra baton was to slightly stiffen the mid-panel response (see positions C and K). In addition, the mid-span supports to the batons were removed, lowering the stiffness of the pad support position and increasing FR (positions A, B, F and G). Positions A and F show an increased improvement in FR due to a 'half' pad being utilized overcoming the original design problem that adjacent panels had effectively 'double pads' where the edge located pads butted together. These modifications provided a much greater uniformity across the whole floor section. Further modifications to positions G and I to stiffen it back up appear warranted, however.

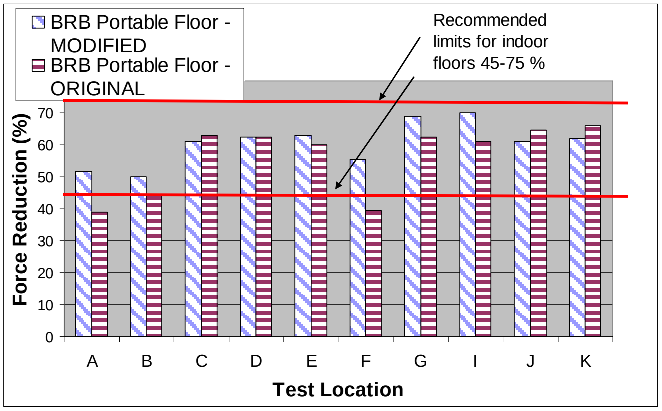

Figure 3. Comparison of FR between floor systems

Energy recovery was, in general, similar between the two systems, in the range 55-70%. Floor panel bending or pad resilient deformation generally gave the higher energy recovery response.

Feedback to date on the new system is positive from the ballet dancers. It is being trialed at venues and further fieldwork is planned.

CONCLUSIONS

The methodology, data and design modifications provide important benchmarking for ongoing studies into ballet dancer injuries. Few studies have previously identified the variation caused by the construction of the dance floor and shown the benefit of changes in design from mechanical testing.

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