OPTIMISATION OF THE SHOCK ATTENUATION PROPERTIES OF PLAYGROUND SURFACES.[*]

Martyn Shorten and Carr Creager
BioMechanica LLC, Portland, Oregon, USA.

INTRODUCTION

Playground accidents are the leading cause of injuries to children aged 5 – 14 in the US school environment. Falls to the surface are a primary causal factor and account for 31% of playground equipment-related deaths. While well-maintained loose-fill surfaces (e.g. wood chips, shredded rubber) provide cushioning which can reduce the risk of injury, accessibility requirements encourage the installation of unitary surfaces with less cushioning (e.g. rubber / urethane compounds). The purpose of this study was to survey the shock-attenuating characteristics of loose-fill and unitary playground surfaces with a view to determining optimal properties for unitary surface systems.

METHODS

The shock attenuation of 247 playground surface samples (217 unitary rubber/urethane, 30 loose-filled woodchips) , was tested *in situ* using a free-falling hemispherical headform with an internal triaxial accelerometer. Peak impact deceleration ($a_{\max}$) and Head Injury Criterion (HIC) [1,2] were recorded at drop heights from 0.9 m to 2.4 m.

RESULTS

Mean $a_{\max}$ scores for the two surfaces are shown in Figure 1. Consistent with previous reports [3], loose-filled, wood-chip products were found to have better impact attenuation than unitary rubber/urethane surfaces.

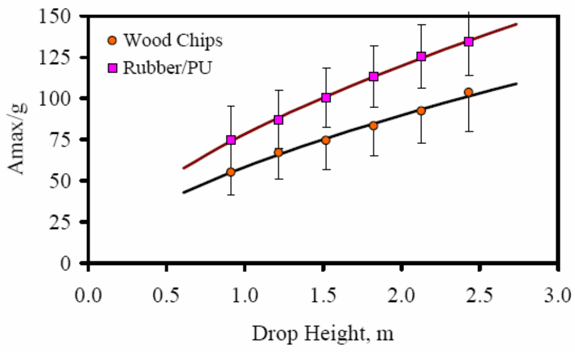

Figure 1:
Peak deceleration (mean ± sd) at different drop heights. Solid lines are best fit of Equation 1.

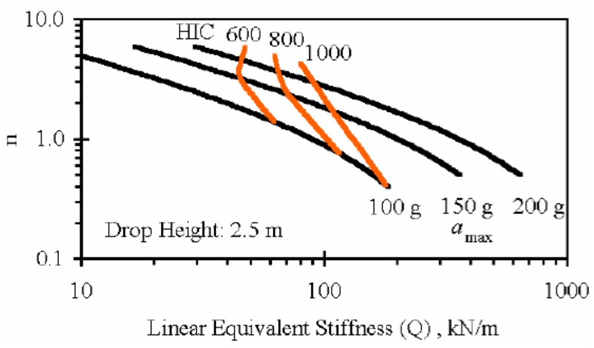

Figure 2:
Effect of surface stiffness (Q) and non-Linearity (n) on a_{max} and HIC scores.

MODEL

The peak deceleration of an impact ($a\ max$) between a headform of mass m falling from a drop height h onto a surface $S(k,n)$ with a compressive force-displacement relationship of the

---

[*] Source : Shorten, M.R. & Creager, C (1999) Optimisation of the shock attenuating properties of playground surfaces. p 541 in Proc XVII Congress ISB (Eds.W. Herzog, A. Jinha), University of Calgary.

form $F = kx^n$ is given by equation 1, where k is a stiffness constant and n is a non-linearity coefficient. The linear equivalent stiffness Q, is defined as the stiffness of a linear elastic surface with the same displacement and energy absorption as $S(k,n)$. The fit of the model to measured values of $a_{\max}$ is shown in Figure 1. Figure shows how n and Q influence shock attenuation performance. Lower *amax* scores are favored by low surface stiffness and low n. For a given *a max* target, however, lower HIC scores are favored by higher values of n.

$$a_{\max} = \sqrt[(n+1)]{(n+1)^n \frac{k}{mg} h^n}$$

Equation 1

DISCUSSION

Peak shock (a_{max}) scores are constrained by the strain energy that can be absorbed in the available thickness of surface cushioning material. High impact energies and/or low maximum displacements require surfaces to have low n , i.e. to be stiffer at low loads but to buckle at higher loads. However, this characteristic causes high decelerations to be maintained for longer periods of time and increases HIC scores. Within given thickness and energy input constraints, optimal cushioning performance is provided by a surface with maximal n.

REFERENCES

1. Versace, J. (1971) A review of the severity index. SAE Paper # 710881, Proc. 15th Stapp Car Crash Conference, Coronado, CA.
2. Lockett, F.J. (1985) Biomechanics justification of empirical head tolerance criteria. *J. Biomech* 18:217-224.
3. Lewis, L.M., Naunheim, R., Standeven, J. and Naunheim, K.S. (1993) Quantitation of impact attenuation of different playground surfaces under various environmental conditions. *J. Trauma* 35:932-935.