

Foam protection in sport

Three main types

- Static products where mass is unimportant (eg bouldering mats)
- Products worn on parts of the body, which change shape (eg back protectors)
- Products worn on the upper part of the head, which do not change shape (eg helmets)



Static products where mass is unimportant

- Foam must be protected against
 - Abrasive damage
 - Rain
 - UV radiation

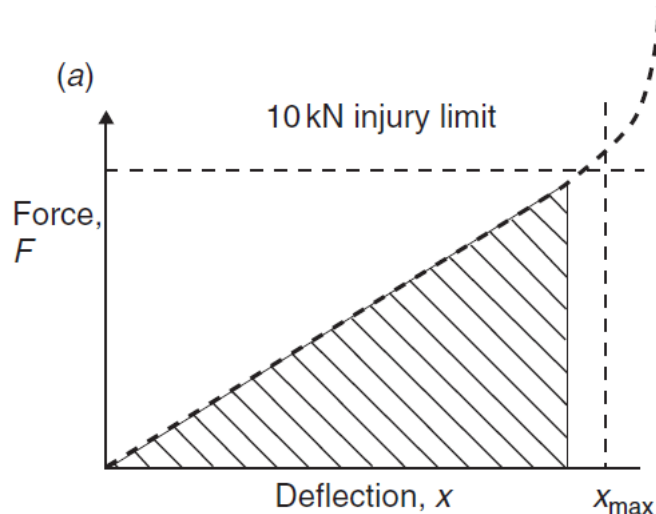


- Cloth coated with plasticised polyvinyl chloride (PVC) or polyurethane (PU)
 - Easy to bend (flexible)
 - Hard to stretch
 - Fire protection
 - Cover has fire retardant additives added
 - Slows ingress of air to the foam

- A thick mat reduces the fall distance
- Worst case: Head first
 - If body/arm hits the mat first the neck lessens the impact to the head
- Neck separates head mass (4-6kg) from body mass (50-100kg)
- Risk of concussion of minor head injury if $F > 10\text{kN}$

Static products where mass is unimportant

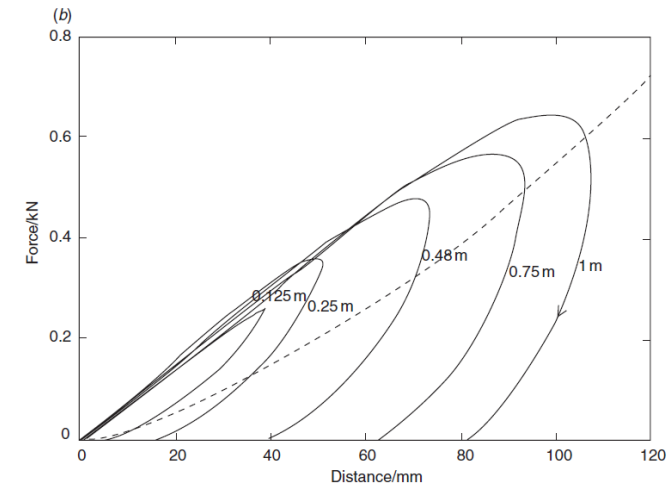
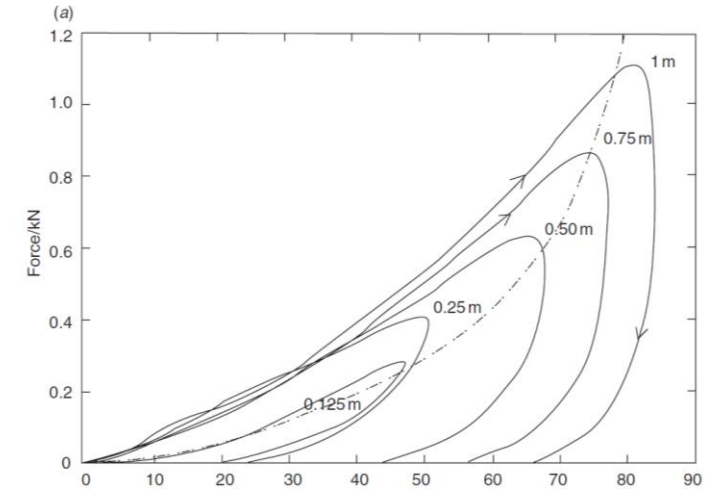
- Force is usually linear to deformation
 - If K.E increases, thickness must increase
- P.E (about to fall) > K.E. (at end of fall) > S.E. (during maximum compression) > K.E. (rebound velocity) > P.E. (rebound height)
- K is the stiffness of the material
- Closed cell mats have Young's Moduli $\geq 100\text{kPa}$
- Open cell mats have Young's Moduli $\leq 30\text{kPa}$



$$F = kx$$

$$S.E. = \frac{1}{2} kx^2$$

$$K.E. = \frac{1}{2} mv^2$$



2.5 Headform impact tests, onto remoulded PU foam mats of thickness (a) 0.1m, (b) 0.4m, for drop heights marked. — — — hyperelastic model predictions, 100mm radius headform (Lyn and Mills, 2001).

Products worn on parts of the body, which change shape

- Users may reject if they
 - Inhibit performance
 - Are bulky
 - Are uncomfortable
- Must not displace the injury (e.g. shin guard that damages the knee)
- Foam must be sufficiently flexible to prevent discomfort or rubbing
- Protector must not tear or perforate
- Shell must be sufficiently stiff to maintain its shape in order to ensure the majority of the foam is highly deformed
- Energy is absorbed by compression of the foam between the shell and the body
 - Increase in duration, decrease in acceleration, decrease in force.
- Material development is hindered by lack of knowledge of bruising criteria

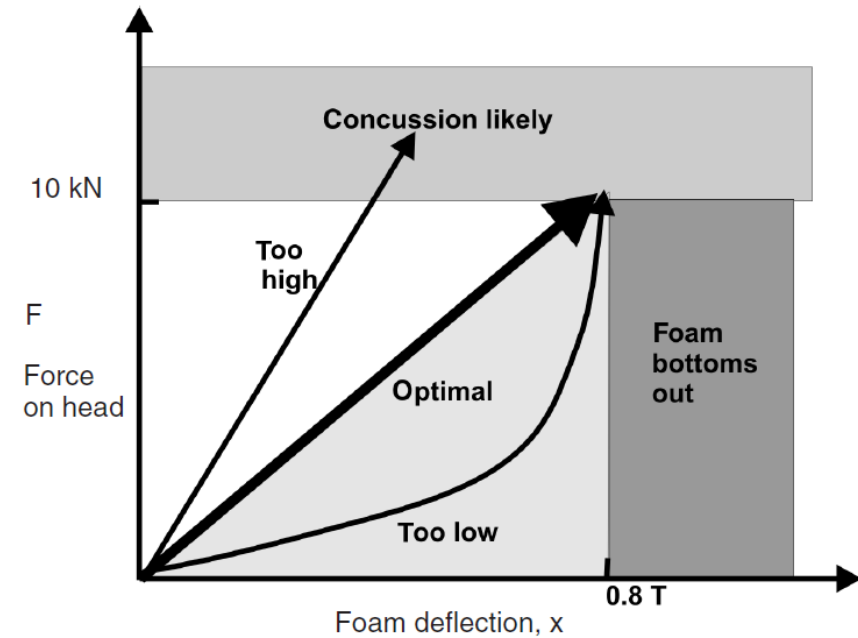
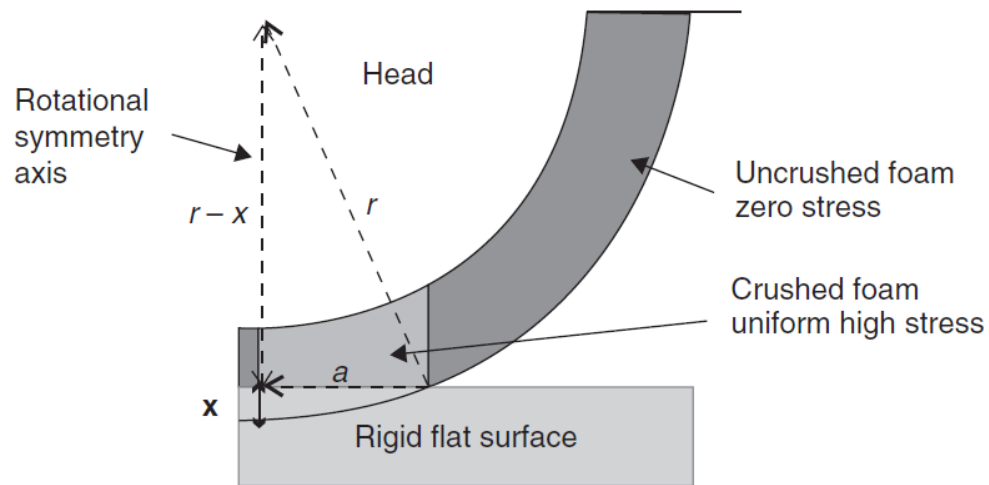
Products worn on the upper part of the head

- Head injuries are more likely to be life threatening than broken limbs
 - The medical profession can rarely reverse brain damage
- Serious injuries to the brain can be attributed to three causes
 - Skull fractures
 - Linear acceleration of the brain
 - Rotational acceleration of the brain
- Helmets should thus
 - Not allow penetration or allow a local pressure of $\sim 2.5\text{MPa}$
 - Not allow a normal force of 10kN ($\sim 200\text{g}$ for a 5kg headform)
 - Not allow a tangential force of 2kN
- Designs tend to be driven by limiting linear acceleration

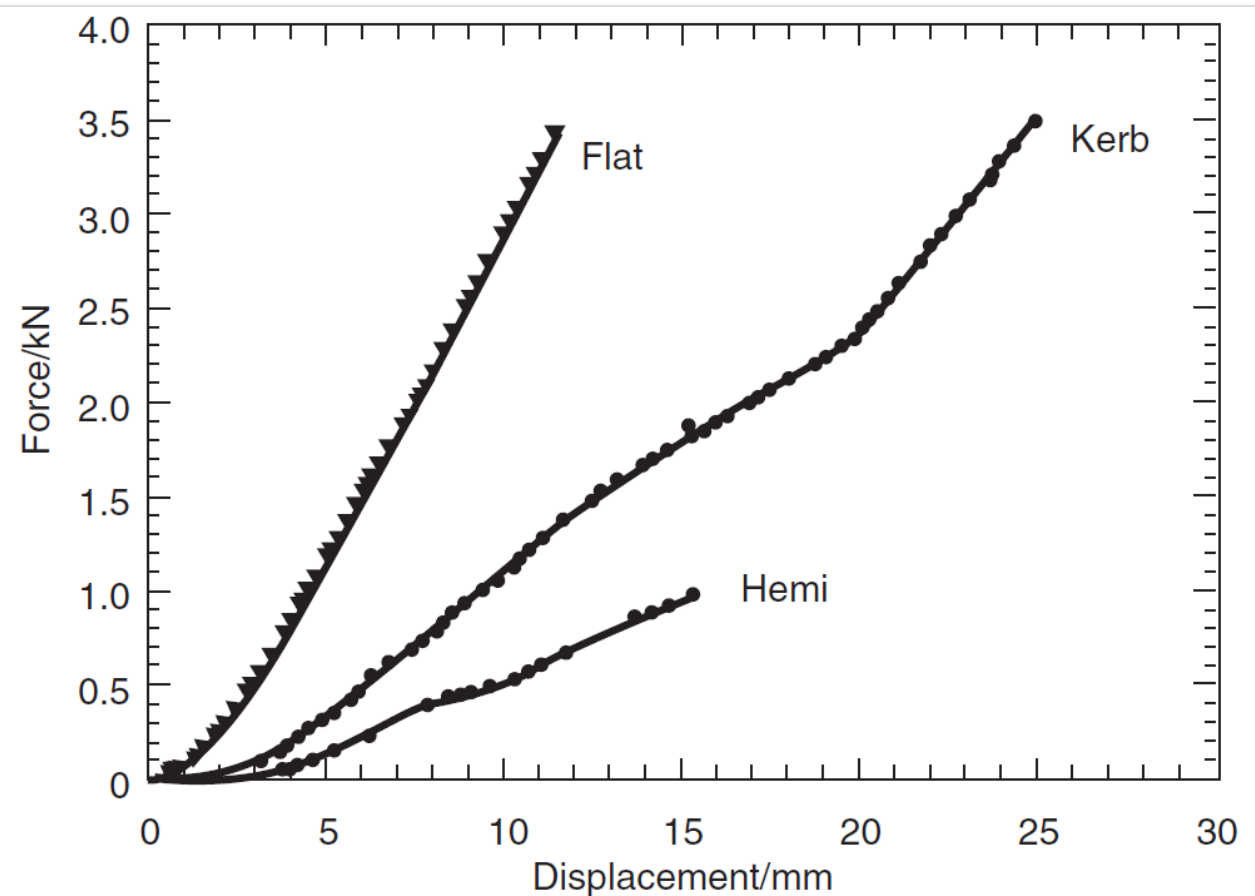
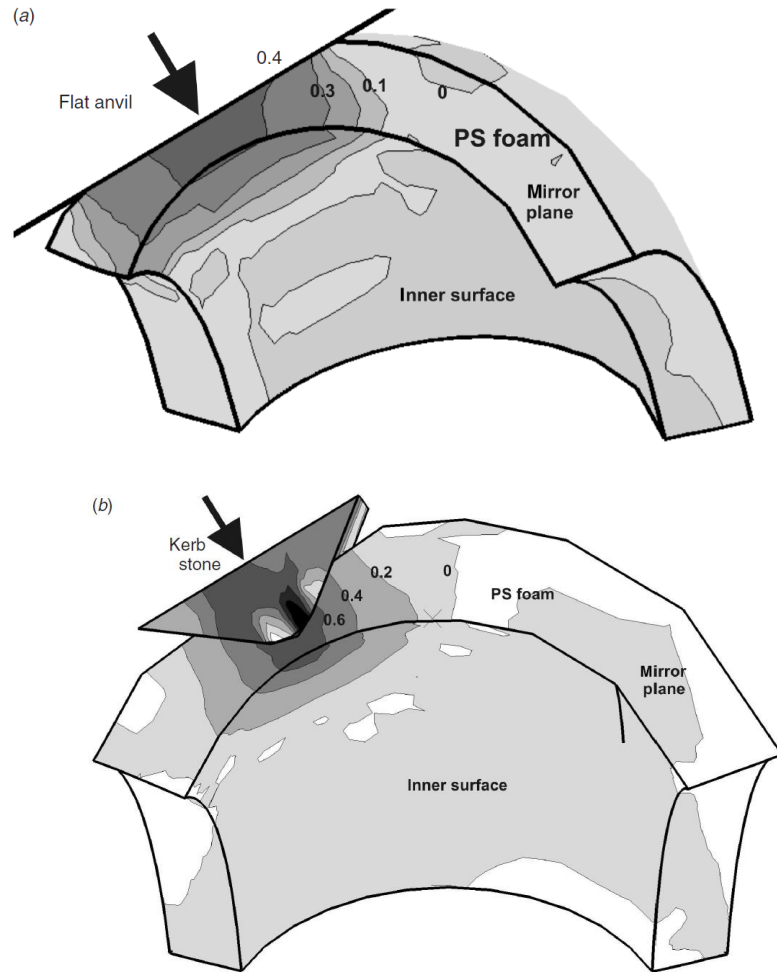
Products worn on the upper part of the head

- Cork – pre-1960
 - Limited sizes
 - Expensive
 - Dense
- Honeycomb Polymer, paper or aluminium foil
 - Optimal for energy absorption when loaded along cell axis
 - Cannot be shaped easily to fit inside the helmet
 - Cells split easily
- Polymer bead foams (e.g. EPS, EPP, PU)
 - Can be moulded into complex shapes
 - Cheap
 - Light
 - EPP is less brittle and recovers after impact – Skateboard helmets (lots of minor impacts)
 - EPS is brittle and does not recover and must be destroyed after impact – Cycling helmet

Products worn on the upper part of the head: simple hand calcs



Products worn on the upper part of the head: FEA models



Notes adapted from/further reading

- Materials in sports equipment, Mike Jenkins, 2003