KRANIUMDESIGN

RESEARCH AND METHODOLOGY

KRANIUM

Developed at Royal College of Art

Postgraduate Art and Design

DESIGNED BY

Contents

Introduction

(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

Introduction

Cycling has become one of the most effective methods of transport in many urban cities. With growing traffic and population, cycling proves to be a quick, easy and healthy way to get around a busy city. However Cycling through a busy city subjects to other difficulties such as road accidents, etc. A large percentage of these accidents are head related injuries.

Expanded polystyrene (EPS) has been used in creating bike helmets for the past few decades and no one has ever questioned their integrity. “16% of deaths could have been prevented if the cyclist had head protection”[ii]. This is a very small percentage and a huge gamble with regards to safety.

Helmets have been giving us the false implication of safety since the past 2 decades. Emphasis this day is given to styling and aerodynamics. However, while cycling at an average speed of 12mph through a busy street in London, one needs to be safer than more aerodynamic.

“Cycle helmets are the most fragile type of safety helmet”[iii]. In fact when purchasing the helmet, one is always advised to buy a new helmet when the helmet is involved in a minor crash or even a drop to the floor. Stickers with fine print are placed in your helmet, which says that if your helmet receives an impact it should be replaced. This is because it develops small fractures in the polystyrene core.

Why is this unsustainable, non-recyclable material, largely focused on aesthetics being pushed into our lives to promote safety?

Thus the following process has been undertaken to re look at the cycling helmet keeping the core value as the main goal for the project, namely safety.

Product / Market Analysis

This section deals with the research done into the following fields:

Existing products
Problems with existing Products
Market Analysis
User Analysis
Trend Analysis

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Product / Market Analysis:

Increase of cycling:

London is seeing a change in the way its population is travelling. “In London, trips by bike have increased by 50 per cent in five years to 450,000 per day”[iv]. This figure is said to double in the next few years with the ongoing cycle schemes and programs. By creating cycle lanes, Cycle hire Schemes the mayor of London is hoping to increase the number of cyclists on the road. “The Department for Transport (the Department) has several initiatives to reduce congestion, improve local environments, and encourage healthier and safer lifestyles, which entail, among other things, encouraging more people to walk and cycle”[v]

Problems with Existing Helmets

Cycling gives the user freedom to manoeuvre around the city. However in terms of personal Safety, an EPS Cycling helmet is the only safety device to protect your head during a crash. Ranging from 14.99£ to 136.99£ (from Halfords), cycling helmets are all made of the same composition. “Cheap helmets can be as good as expensive helmets”[vi]
These helmets are all largely made of the following 4 parts.

- o Expanded Polystyrene Core
- o Thin Polypropylene outer Shell
- o Nylon Straps
- o Clips/ buckles etc.

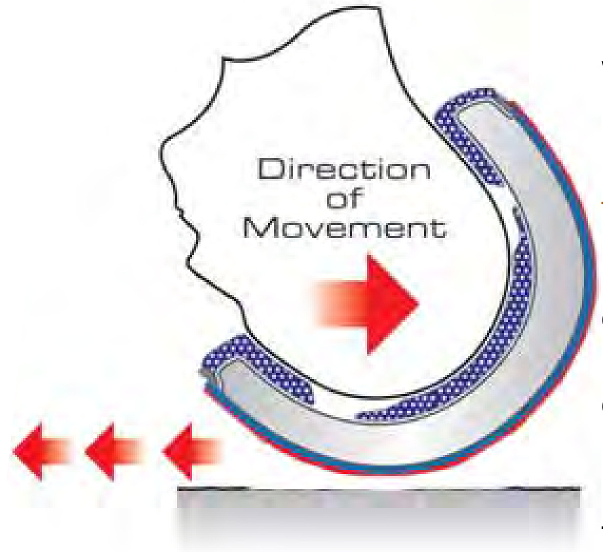
Since the past few decades this has been the general composition of the helmet. Advancements are made in styling and making it lighter but safety is taken for granted. "Cycle helmets sold in the UK today generally offer a lower level of protection than those sold in the early 1990s"[vii]

During a crash, helmets have a small crumple zone after which the force of impact is transferred into the head, consequently dispersing it over a wider area.
But on a large impact all that force causes rotational injuries to the brain, which rotates with respect to the skull due to inertia.

People assume that if their helmet cracks during impact, it has saved their life. This however is not true according to the Bicycle helmet research foundation.

"A helmet is a fragile piece of equipment. On seeing a damaged one, it is easy to assume that a serious injury has been prevented. Cycle helmets split very readily, and often at forces much lower than those that would lead to serious head injury. In high impact crashes, such as most that involve motor vehicles or fixed vertical objects like concrete barriers and lamp posts, the forces are so great that a helmet will compress and break in around 1/1000th of a second. The absorption of the initial forces during this very short period of time is unlikely to make a significant difference to the likelihood of serious injury or death."[viii]

Apart from this, a cycling helmet today is designed for single use. "It is not designed for multiple hits"[ix]. Upon



(Fig 0) Rotational Injuries

impact, may it be large or small; polystyrene develops fractures due to its porous nature. These fractures reduce the compression properties of polystyrene rendering helmets less effective during a crash.

The standards for testing have also changed severely during the past few years. For example, "Cycle helmets are designed for falls without any other vehicle involved"[x]. This does not include head on collisions and high impact collision, which usually occur during a crash.

Summary of Problems

o Helmets do little to protect against rotational injuries (Fig 0)
o When asked to design a helmet, emphasis is given to the shape, aerodynamics and the styling of the helmet rather than the main function of the helmet, namely safety.
o Polystyrene largely disperses the force onto a wider surface area.
o Polystyrene develops fractures on impact, which is covered up a thin polypropylene sheet. This leads people to believe that everything is fine with their helmets.
o Helmets do not provide a proper fit. They are either too big or too small, thus on impact they move and don't give enough protection.
o Recycling is non-existent to say the least.

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Trends and User Analysis

This section contains the summary of the research conducted on users and current cycling trends. This was done by spending four days in various cycling stores in London, observing customers purchase helmets.

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User and Trends

- Trends:

o The current trend in terms of design is largely towards a subtle styling of the helmets. Helmets by Bern and POC are now emerging as the design direction.
o Simple colours including an introduction of matt black is seen.
o Helmets are evolving to fashion accessories with players such as Yakkay, who are developing helmets for the urban cyclist


- User Analysis:

Cyclist can be largely classified into the following categories:

o Regular urban cyclists (Helmet wearing)
These are the everyday cyclists who cycle from work, school etc everyday. Cycling is their main mode of transport and they believe cycling to be an exercise method as well as a means to get from A to B in the shortest time. Safety plays a major role in their lives since an average of 1 hour is spent on the road through busy traffic. They have special attire for cycling which they use while cycling and usually change upon arriving at their destination, thus carrying an extra pair of clothes at all times.

o Competition Cyclists (Helmet Wearing)
When riding in the city, these cyclists also cycle on a regular basis. However they have a cycling kit comprising of tights and a colour coordinated outfit. They have the professional cycling kit and have a high spending budget for cycle equipment. Aerodynamics plays a huge factor when dealing with equipment and helmets. Safety comes secondary to aerodynamics and style.

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o Occasional Cyclists (Helmet Wearing)

These are the cyclists who cycle occasionally through the city. Cycling is a recreation sport rather than a means to exercise. Equipment and attire are casual as is the frame of mind during cycling. Helmets are used as a precaution and for safety. However the bulky helmets prove to be a hassle when concerned with ease of travel and post cycling use.

o Non Helmet Wearing cyclists

These are the group of cyclists who don’t bother to deal with the trouble of wearing a helmet because of post cycling storage and/or discomfort. They are cyclists who include everyday cyclists as well as occasional riders. They prefer the ease of cycling without the hassle of carrying around a helmet with them all day during Work/ School etc. They feel freedom without a helmet on their head.

o Non Cyclists (Fear of cycling)

These are the group of people who have a fear of cycling through the busy streets of London. They don’t believe that a helmet and other safety devices available today can protect them during a crash. They prefer to travel by tube/ bus since they feel its safer and less tiring. However they would like to cycle if the streets were less crowded and if there was better cycling protection.

Design Brief

The brief was set taking the above research into consideration. The following were developed as the needs for helmets today:

- A helmet, which would provide better absorb forces during high impact collisions.
- A helmet, which indicates when it needs to be replaced
- A helmet, which fits a person’s head properly.
- A helmet, which can be recycled easily.

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Design Brief and Product Specification

"To develop an innovative, lightweight outdoor sports activity helmet that will revolutionize the helmet market through improved safety, recyclability and break-through industrial design"

A new cycling helmet would have to deliver the following factors to make an impact on the market, namely:

Safety:
Above all a cycling helmet needs to protect your head during impact. That is the core value of the product. The current cycling helmets today don't fulfill this criteria. A helmet need to be able to absorb high amounts of impact energy

Standards Specification
The helmets should at a bare minimum conform to the various standards such as Snell, EN1078, etc.

Size and Fit:
A helmet has to provide a good fit for the user. This increases the amount of protection by increasing the impact area thus dispersing the force.

Weight:
The helmet should not increase the weight of the head by a large value as this would cause more injuries to be focused

Aesthetics:
In order to be identified the helmet would need to have its own design language. There exist thousands of helmets today and a large percent of them look almost similar to each other. Thus by having a different look of its own it would be able to send its own safe and attractive eco-friendly message.

Environment.
With the growing need of reducing landfill, the helmet should be sustainable in its model. IT should be made from eco friendly materials so as to reduce its impact on the environment.

Exploration

Upon identifying the brief, the explorational research phase was split into two different phases, namely:

Biomimicry : Nature as a model

Material / Structural Exploration

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Biomimicry: Nature as a model

After identifying the brief, the first research was conducted in the field of biomimicry. There exist several examples in nature where high forces are absorbed during collisions and impacts, namely:

- **Woodpecker**

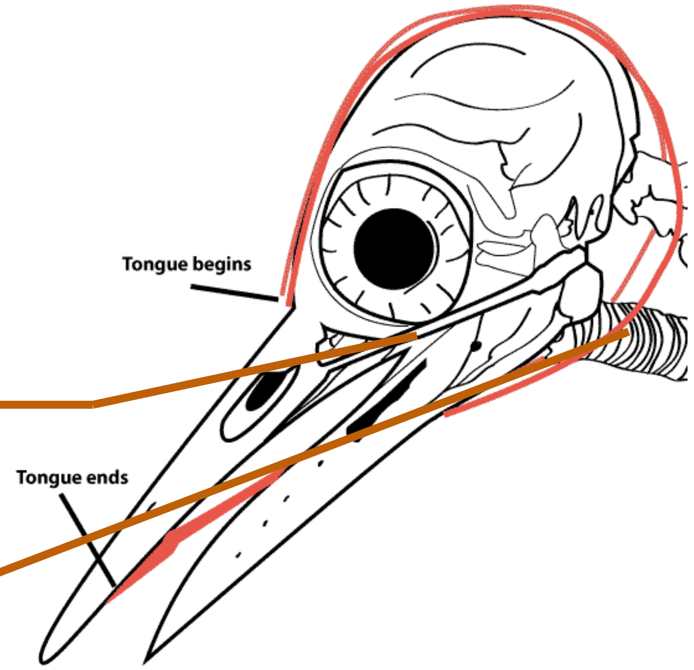
"The Creator has greatly reinforced the woodpecker's skull with bone"[xi] says David Juhasz, in his article for Science and Technology .
The woodpecker is truly a unique bird. Apart from an industrial strength beak it has several unique aspects, which make it withstand the high impact forces during pecking

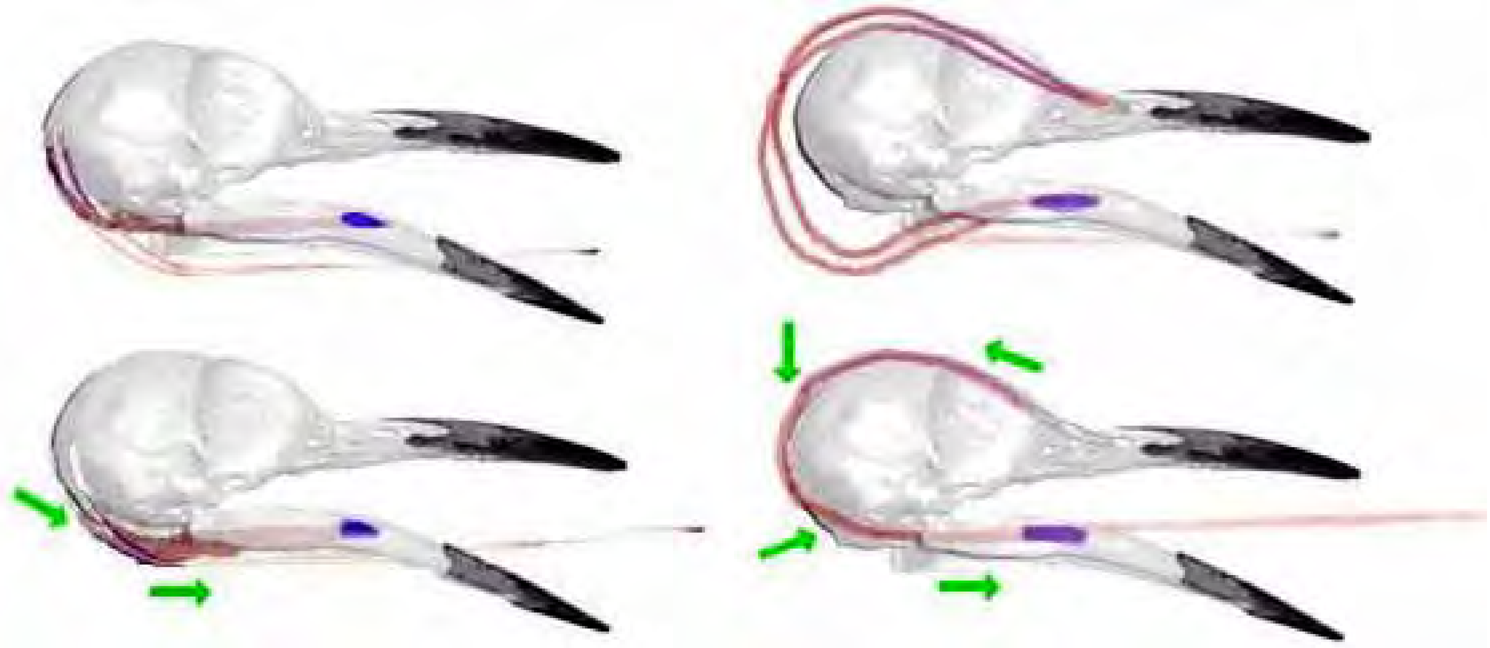
o The beak and the skull are not joined as in other birds. Instead a muscle cartilage structure is sandwiched between the two and acts as the perfect shock absorber

o The Hyoid Apparatus makes the woodpeckers tongue wrap around the brain and come through its bill. It wraps the brain and cushions it during impact

O Special muscles which pull its brain case away from its bill every time it strikes a blow

o The brain is completely fitted with the skull thus reducing rotational injuries. The tongue holds the brain to reduce injuries.





- **Red Deer**

During mating season the red deer compete against each other by head butting into each other. During this high amounts of impact forces are experienced. The skull of the deer is of a corrugated nature. This helps disperse the forces by crumpling and dampening the forces. The porous structure lies on the outer layer of the skull, which receives maximum impact.

- **Conifer Cones**

Conifer cones or Pinecones protect the seed within. The structure acts as a cushion during impact when the cone falls to the floor.
The conifer cone has two types of scale: The bract scales and the seed scales, one sub tending each bract scale. The bract scales develop first, and are conspicuous at the time of pollination; the seed scales develop later to enclose and protect the seeds.[xii]
They harden to form a protective layer. When the cone is ready to fall to the ground these scales swell out to form a dampening zone around the seeds. They absorb the force peak of the impact.

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Material And Structural Exploration

The next step was to look at a variety of manufacturing processes and structures to identify the replacement for EPS. This was done in two stages, namely:

- Existing material/structural Exploration
- Compound material exploration.

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Developed Samples

o Cork suspended in Glass rubber

- Composition : 80% Cork (granulated) + 20% polyurethane
- Cast into a cup with a cardboard spacer
- Properties: Retains the properties of cork; soft mouldable material; removes the non hygienic aspect of cork due to sweat.

o Triple wall (AAc) Cardboard

- Composition: Triple wall High Density Fibre Board.
- Thickness : 20mm, 30mm, 40mm
- Interlocking joinery, Interference fit
- Properties : Rigid and light weight Structure

PVA Dipped and water proof

o Paper Mache

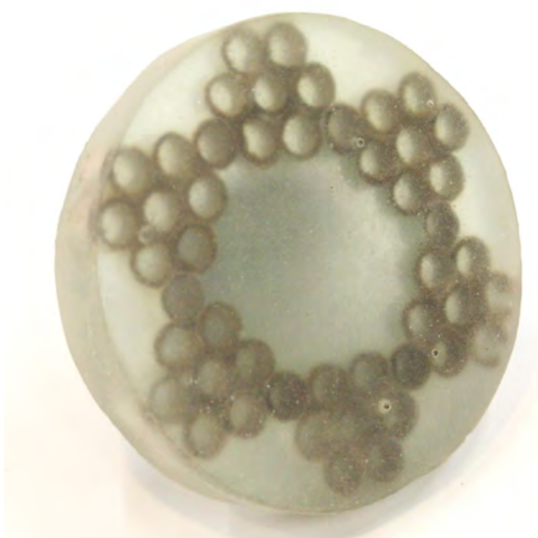
- Composition : Paper soaked in PVA + Water and layered
- Properties : Rigid structure which can be moulded
- Light weight with less compression capabilities

o Cardboard tubes / Piping

- Composition: Outer Diameter: 1inch
- Wall thickness : 3mm
- PVA (Wood Glue) Assembly followed by sanding
- Simple face to face joinery
- Properties:
- Organic forms obtained through changing the angles of contact
- Could use the air trapped within to crumple

o Cardboard Single Wall (A)

- Composition: Thickness : 2mm
- Interference fit
- Properties : Flexible and rigid structure



o Postal tubes suspended in glass rubber

- Composition: Diameter : 1cm
- Wall thickness : 1mm
- PVA assembly into a tessellated form followed by submersing into 150ml of glass rubber; spaced 2mm from the base
- Properties: Rigid structure with high elasticity; low compression

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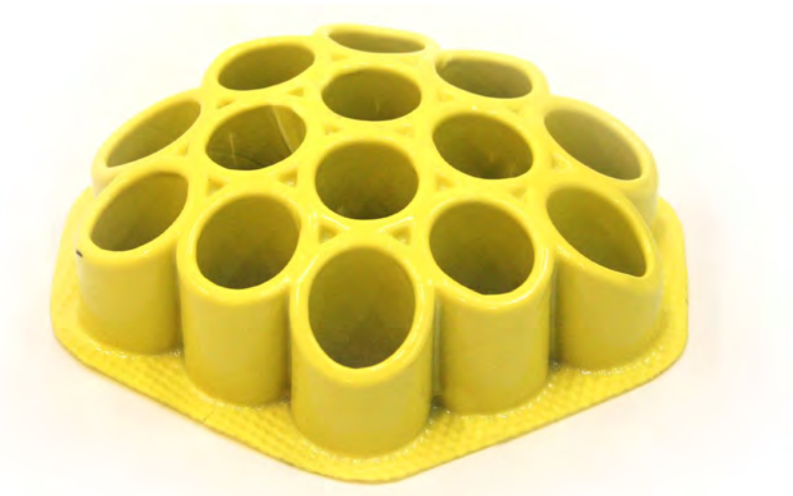
o Cardboard Tubes + Acrylic Cover

- Composition: Cardboard tubes stuck together and sanded into an organic profile
- Vacuum formed over the cardboard tube lattice
- Properties :Protects the cardboard from moisture
- Secures the cardboard in place but makes it more stiff than desired.

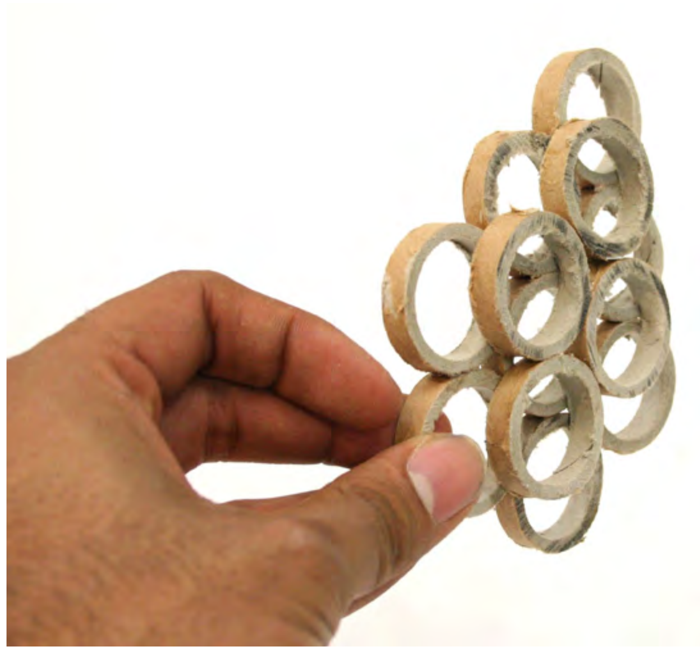


o Cardboard lattice suspended in Glass rubber

- Mimics the shock absorption system of the woodpecker
- Composition: 150ml of Glass rubber
- Rigid along the grain of the card-board and flexible against the grain

o Board Weave

- Composition : White high impact 2-ply fibre board
- The ply has been removed to ex-pose the lattice and is woven
- Properties : Exposes the lattice to impact
- Weave structure creates crumple zones but can only be used on a flat sur-face



o Ring Lattice

- Composition : Postal Tube Rings (Diameter: 1inch; Length: 5mm)
- Properties: Crumple zones can be built where needed with spacing
- Lengthy manufacturing process
- Organic shapes require complex manufacturing methods.

o Cardboard filings soaked in Silicon

- Composition: cardboard filings soaked in PLATSIL GEL 10 for 1 hour and cast in a mould.
- Properties: paper assumes the quali-ties of rubber
- High Elasticity and Water proof
- Can be moulded

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Testing

The testing phase is done in three phases:

Initial Drop Testing
Gforce Calculation test
Tube Compression Test

Primary Property Comparison:

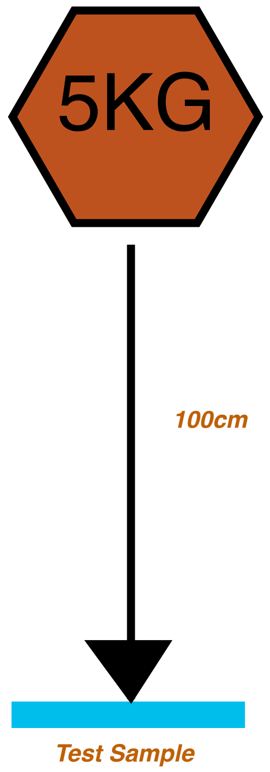
Initial Drop Test (Avg Weight of head = 5kg)

This was the initial phase of testing. By drop testing a 5kg weight onto the samples from varying heights of 1m, 1.5m and 2m, initial crumple analysis was done. The results are as follows.

Materials	Hieght	Crumple	Reusability
Cork suspended in Glass rubber	2m	No	Yes
Paper Mache	1m	Yes	Yes
Cardboard Single Wall (A)	1m	Yes	No
Triple wall (AAc)	1m	Yes	Yes
	2m	Yes	Yes
Cardboard tubes / Piping	1m	No	No
Postal tubes suspended in glass rubber	2m	No	No
Cardboard Tubes + Acrylic Cover	1m	No	Yes
	2m	Yes	Yes
Cardboard lattice suspended in Glass rubber	2m	Yes	Yes
Board Weave	1m	Yes	No
Cardboard filings soaked in Silicon	2m	No	yes

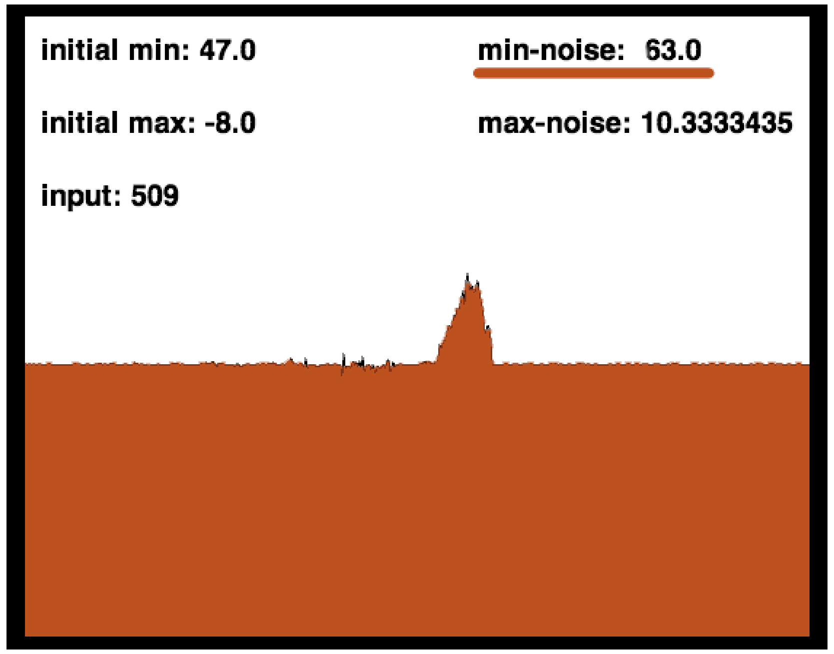
Materials	Properties
Cork suspended in Glass rubber	No impact on a 1m test, Good elastic compression
Paper Mache	Imact is absorbed by dampening, plastic compression in the outer layers
Cardboard Single Wall (A)	Weight goes through all, compresses but is weak to take the force peak
Triple wall (AAc)	Crumples down to absorb forces, Plastic compression
	Breaks the structure(absorbs force), weight doesn't go through sample
Cardboard tubes / Piping	Structure breaks on impact, lack of structural strength
Postal tubes suspended in glass rubber	Tubes rip throught the rubber layer
Cardboard Tubes + Acrylic Cover	Survives impact but does little compression thus not absorbing focre
	Cracked outer shell, compression is seen on the tubes (negligible)
Cardboard lattice suspended in Glass rubber	Signs of the damage are seen through the lattice
Board Weave	Weight goes through all, compresses but is weak to take the force peak
Cardboard filings soaked in Silicon	Elastic properties dampen the force peak, good compression strength

G Force Testing



This testing constitutes a 5Kg weight dropped from a height of 1 meter onto the test sample. The 5Kg weight is connected to an accelerometer ADXL193. Via the use of an Arduino the analog output from the accelerometer is transmitted digitally which the computer can understand. The digital code is then converted into a graph with Gforce on the x-axis and time on the y-axis. The code is provided in the appendix.

Cork suspended in Glass rubber



Single Wall (A) Cardboard

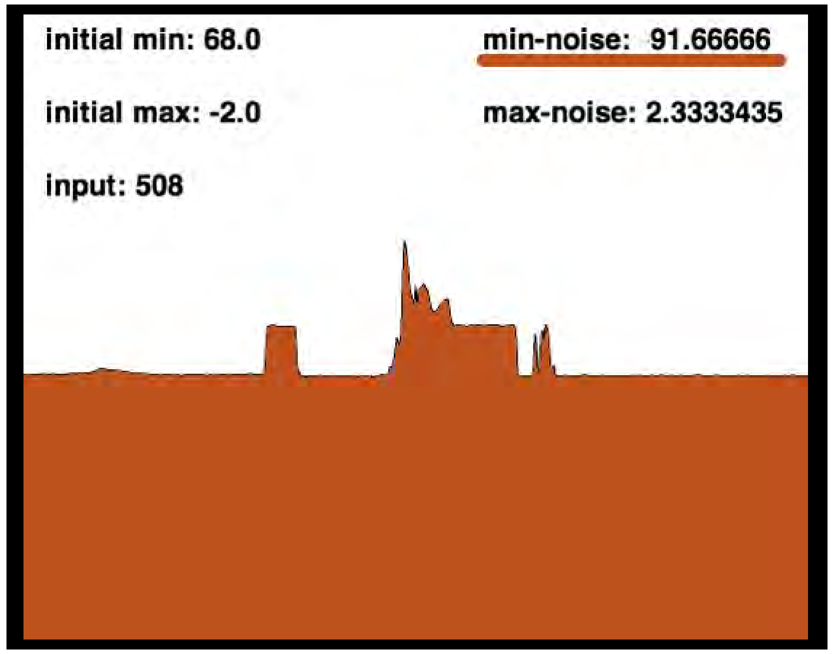


Fig 0.1

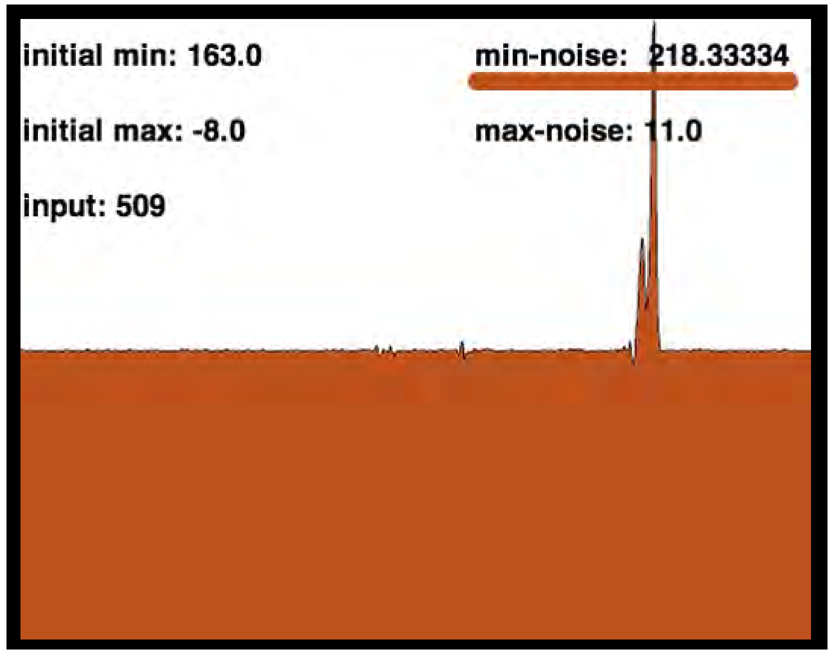


Fig 0.4

Postal Tubes in Glass rubber

Triple Wall (AAc) Card-board

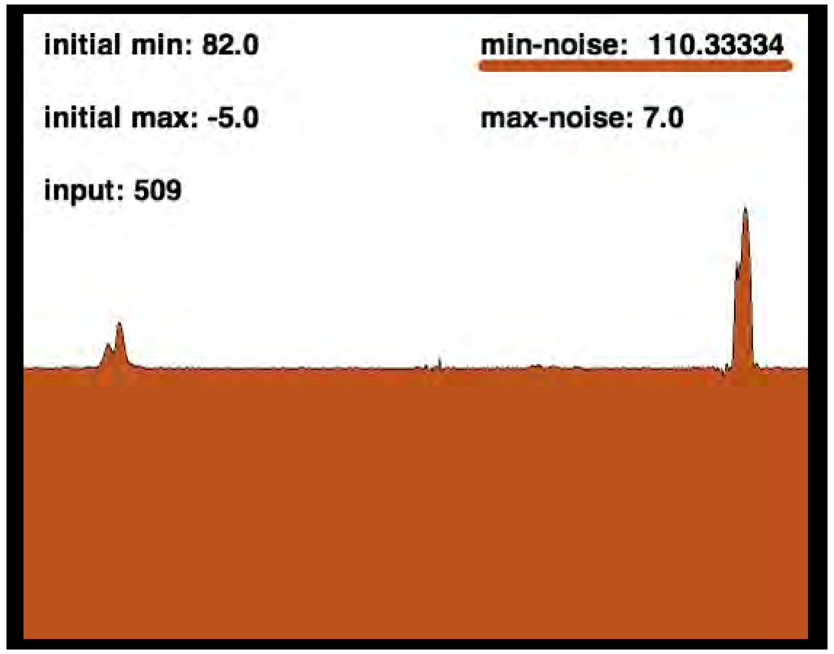


Fig 0.2

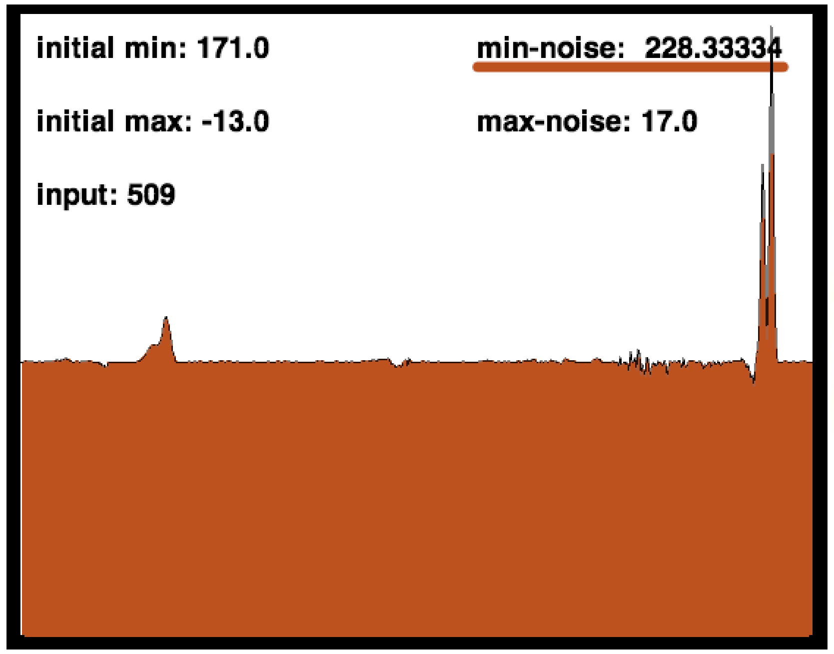


Fig 0.5

Cardboard Tubes + Acrylic Cover

Cardboard Tube Piping

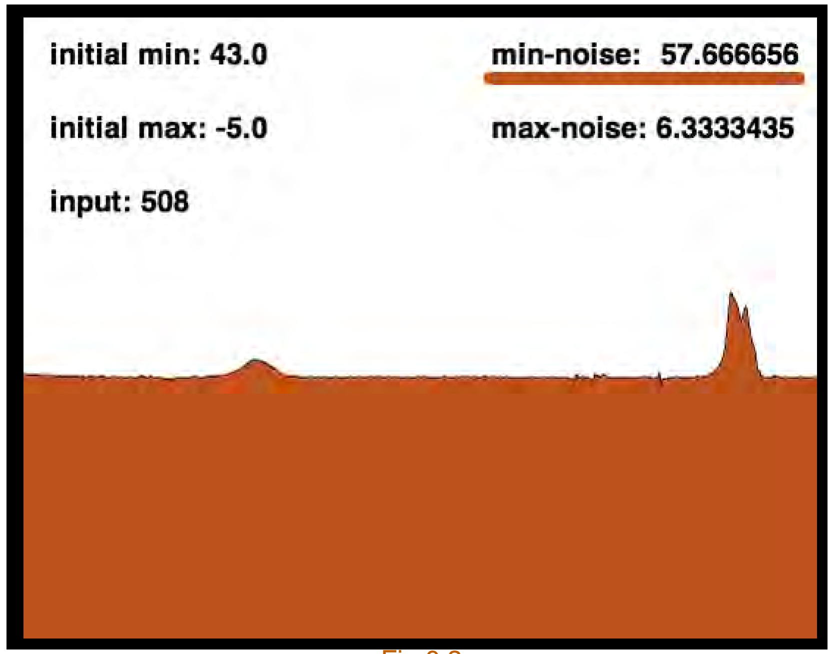


Fig 0.3

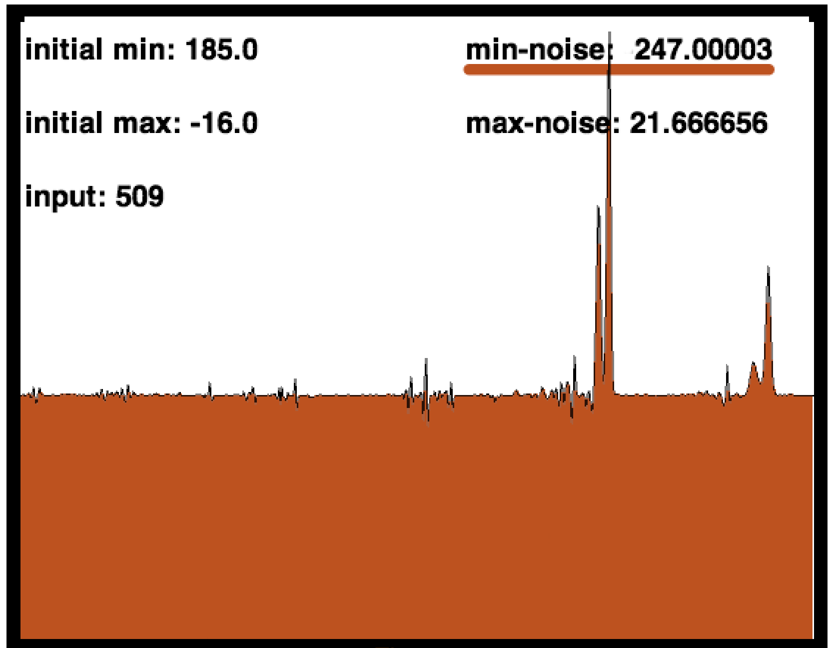
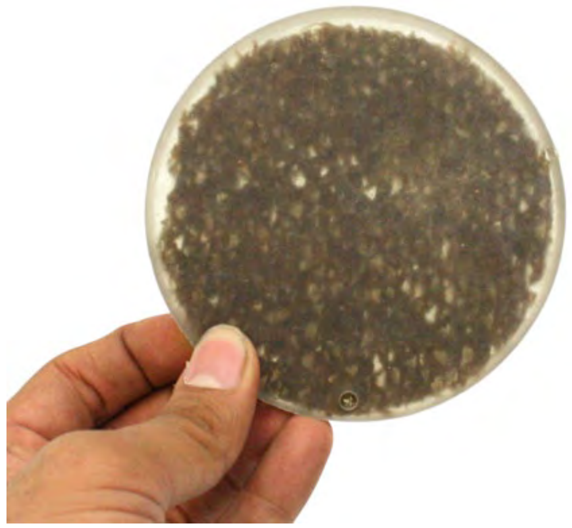
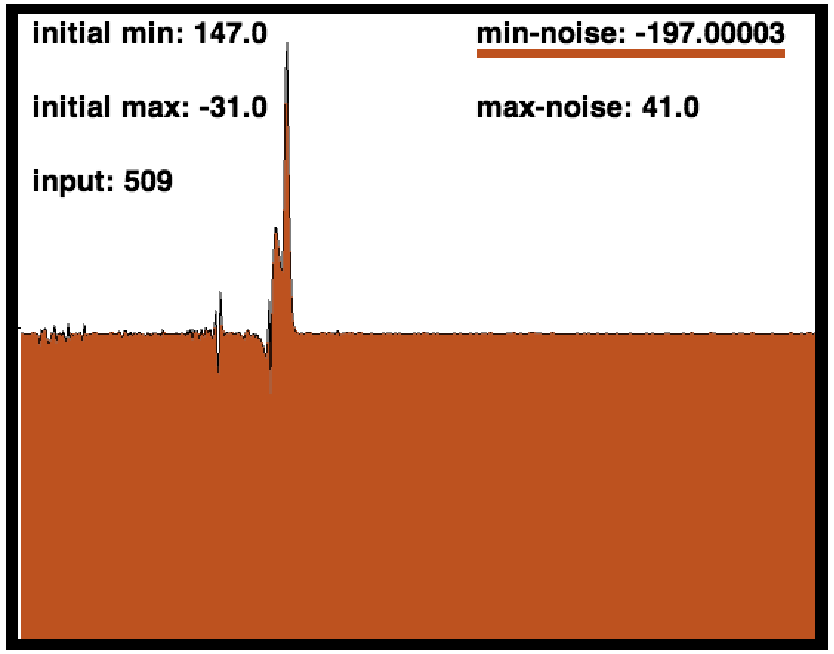


Fig 0.6

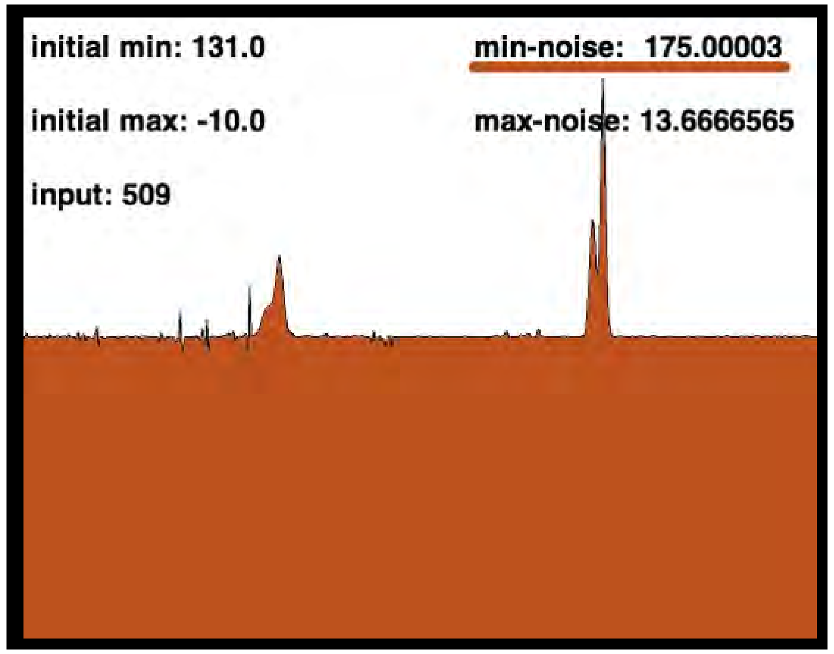


Lattice in Glass Rubber

Ring lattice



Cardboard Filings in Silicon



Tube Compression Test

As seen above tubes posed to be very strong during impact but at the same time they have several advantages. Cardboard tubes provide excellent strength along both its axis, along its circumference as well as its top face. However the strength along its top surface is far too strong to act as a crumple zone. These were the results based on impact drop tests developed crumple samples (Fig 1).

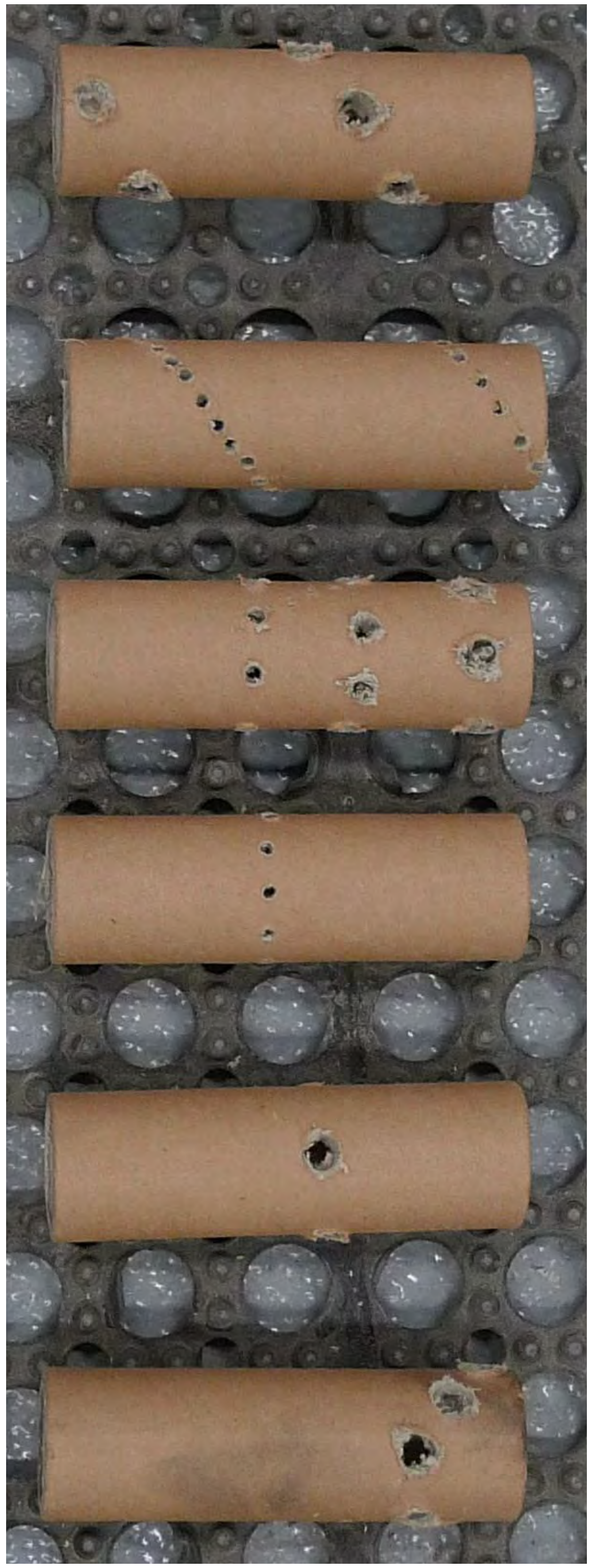


Fig 1 Crumple Zones

Tube Sample 01:

Crumple Structure :

- 8mm drill spaced at 1cm apart.
- Helical structure

Tube Sample 02:

Crumple Structure:

- 3mm drill spaced at 3mm apart
- Helical Structure

Tube Sample 03:

Crumple Structure:

- 3mm, 6mm and 8mm drill spaced at 5mm from each other
- Consecutive Cylindrical ring structure

Tube Sample 04:

Crumple Structure:

- 3mm drill spaced at 3mm apart

Tube Sample 05:

Crumple Structure:

- 6mm drill spaced at 5mm apart
- Circumference ring structure

Tube Sample 06:

Crumple Structure:

- 8mm drill spaced at 5mm apart
- V shaped structure

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Result of Tube Compression Test:

Sample 02 (top result in Fig 1.1), hereby named as "Helical Tube", proves to be the solution. The helical holes create a breakable structure as a result of which the tube breaks into a spring structure and provides compression capabilities. The structure coils in the direction of impact thus creating a dampening spring on impact.
This is also the most viable solution in terms of manufacturing. During production of paper tubes the tubes are spiralled as the paper wraps itself around the cylinder. The helical drill structure can be simply made by introducing a drill or hole puncher in the manufacturing process. As the tubes spiral the stationary hole puncher punches in the crumple holes.

Tube Sample No.	Crumple Dist
Tube Test 01	14mm
Tube Test 02	27mm
Tube Test 03	12mm
Tube Test 04	4mm
Tube Test 05	8mm
Tube Test 06	12mm

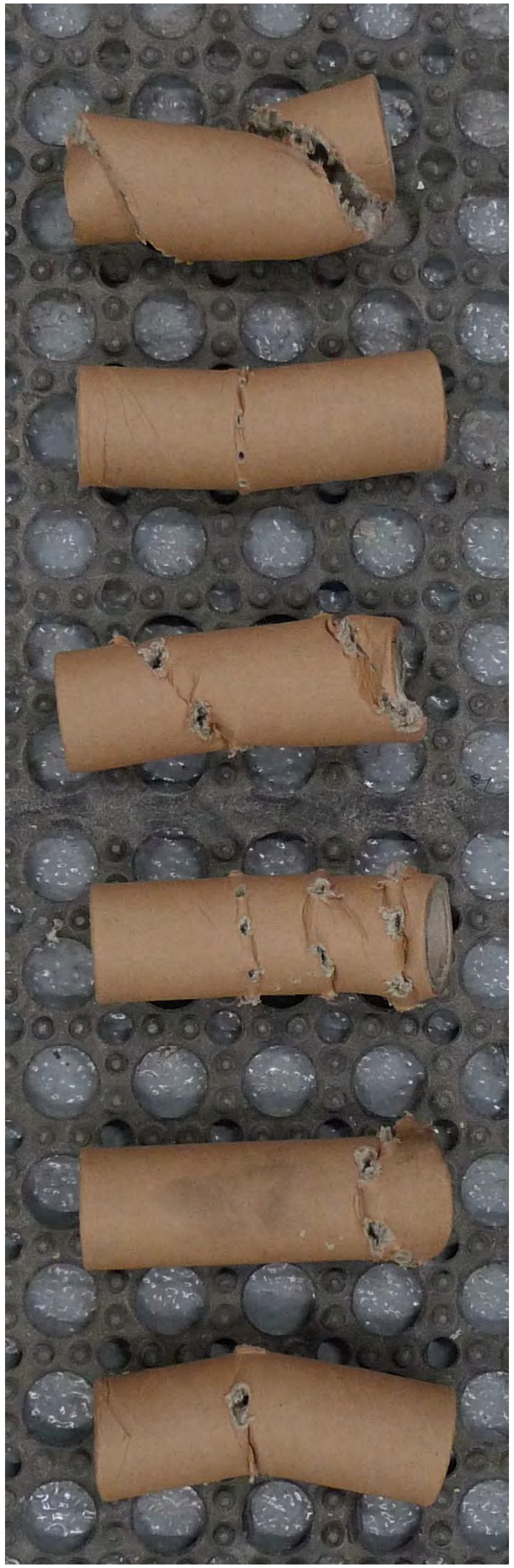

Fig 1.1 Tube test Samples

Summary Of Tests:

Cardboard Matrix

From the test results it is evident as to why the eliminated samples have been so done. The most prominent solution is the cardboard matrix. Its shows a Gforce reading of 110.33g as shown in fig 0.2. This is haf the amount of gforce experienced with a EPS helmet. Cardboard has the property of absorbing he amounts of energy by crumpling. This is done along the direction of the flutes. However cardboard has the property of unidirectional strength. The strength of cardboard is high only when impact is received across the flutes. When the impact is given perpendicular to the flutes its coefficient of stiffness is far too small to absorb the force peak and thus compresses too quickly thus transmitting the remaining force through to the adjoining body (the head in this case). Thus the structure would have to be constructed in such a way that the flutes are facing every direction so as to absorb impact from any angle.

Tubes

The tubes also prove to be a viable solution during impact. The Helical Tube solves the problem of excess strength by crumpling into a helical spring. As stated above, this also gives rise to ease of manufacturing. The tubes could be joined together by PVA and can be placed into a CNC. Thus by treating the cardboard matrix as a block of material one can create an outer shell for the helmet.

Evolution of Design

This phase is based on the results from the test samples. Cardboard matrixes were developed to provide optimum safety. The matrix underwent 4 stages of evolution

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Fig 2.0

Design 01 (D01):

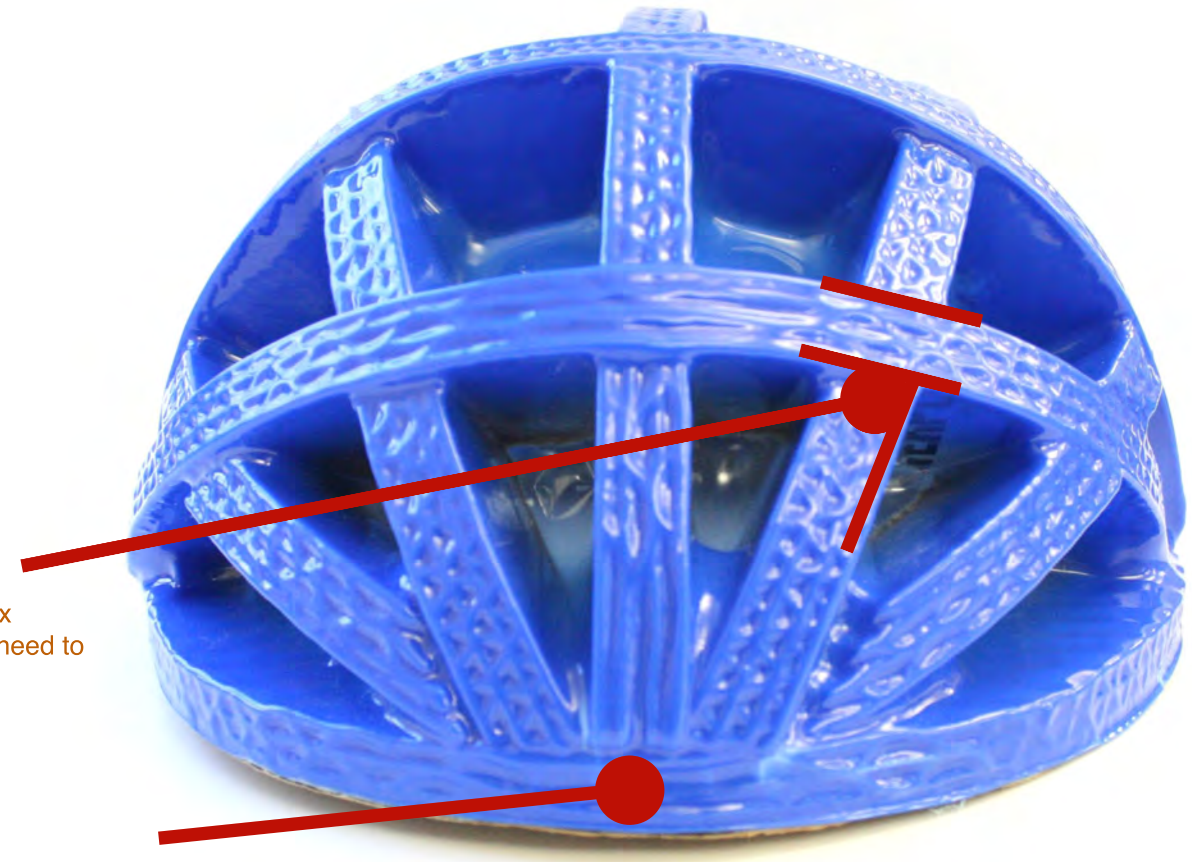
The first exploration was done using AAc board, which has thickness of 14mm. First exploration was done in collaboration with David Graham, an IDE alumni who has been working in the cardboard industry for the past few years.
Measuring the head, using metal wire to make the templates, was the first step. The templates were then plotted onto a stiff piece of card and the joinery sections were marked out. They were then translated onto the AAc board.
By pivoting the ribs along two points along the x and y axis, a multi directional structure was achieved with atleast 3 ribs with facing flutes in every direction thus giving protection to the head from all angles. This structure was lighter than existing helmets by 45grams and breathable.

Problems with D01

- Stress is concentrated along the pivot points (Fig 2.1)
- Angles needed to be cut into the cardboard to create angular slots, which complicates manufacturing process (Fig 2.1)
- Difficult to assemble as the parts look alike
- The thickness of the board restricts the form building possibilities.
- The base of the helmet has to be flat for construction thus restricting design.

Fig 2.1

Fig 3.1



Design 02 (D02):

This was the evolution of D01. The method of construction was the exactly similar to D01. However the D02 solved the problem of the joints and stress via vacuum forming over the cardboard. This resulted in several iterations due to the complexity of vacuum forming over such a complex surface and the plastic tending to burst upon reaching its maximum limit.

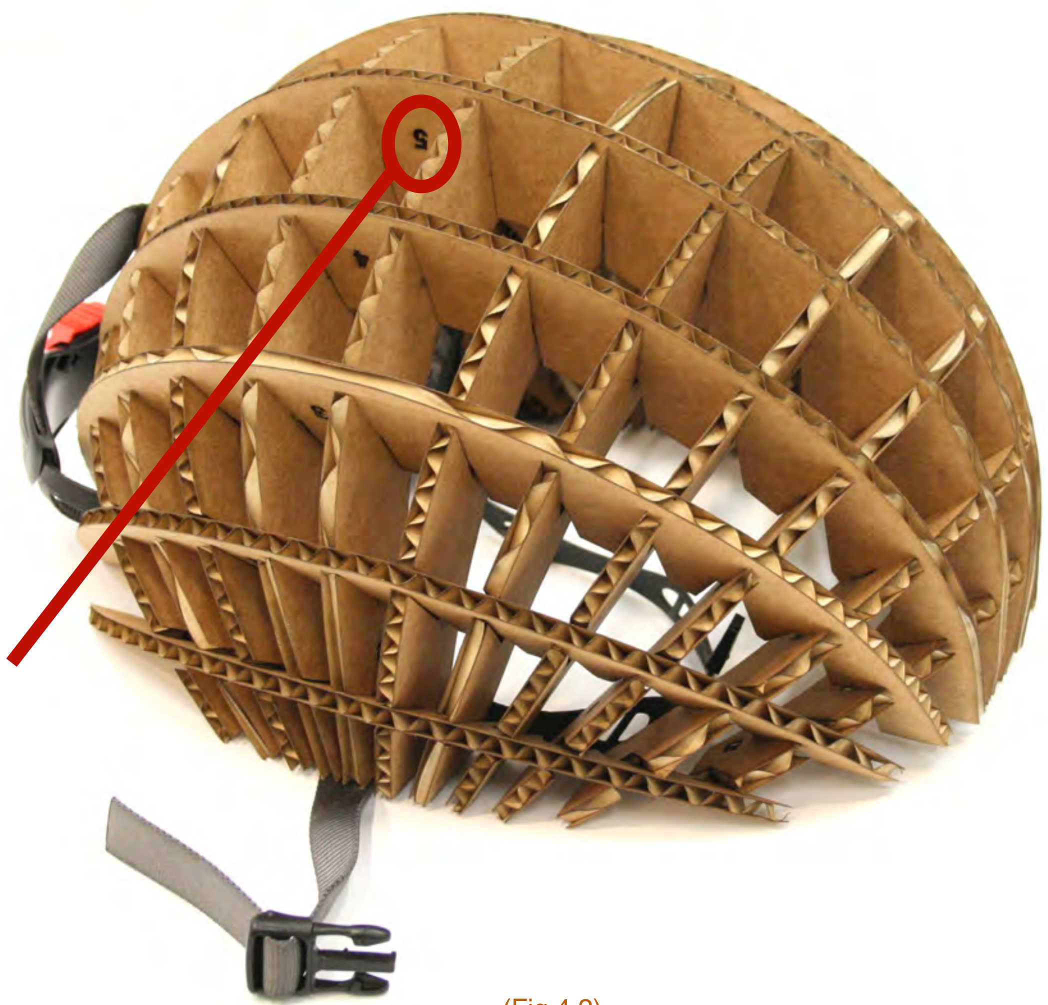
Taking a plaster mould of the head itself solved this by using that as a limit for the vacuum formed plastic. By taking an initial cast of the human head, a perfect fit could be attained. The vac-formed plastic would then undergo several drill procedures (Fig 3.1) to provide adequate suction at the joints of the ribbed structure. This model also largely solves the waterproofing aspect.

Problems with D02 (Fig 3.2)

- Stress although lowered is still focused on the pivot points
- Complex angle issue still exists
- Difficult to assemble as the parts look alike
- Base has to be flat giving the helmet a very bulky appeal.

Fig 3.2

(Fig 4.2)



(Fig 4.2)

Design 03 (D03):

D03 uses Single Wall (A) Cardboard with a thickness of 5mm, which is one third that of the (AAc) board. This gives rise to a whole new set of opportunities. The number of ribs in every direction has been increased to 12. The maximum width of the ribs on the top of the helmet is 40mm and that on the base of the helmet is 30mm.
The pivot point of the ribs was shifted below the base plate thus giving room for each rib to touch the surface independently and thus distribute the surface of contact. Thus on impact the force gets dispersed along a wider area and reduces the stress on the base plate.
Each rib is numbered (Fig 4.2) so as to provide ease of assembly.
The ribs are laser cut and thus upon slotting the first 3 ribs in place, all the other groves align themselves.

Problems with D03:

- Bulky due to the 40mm thickness, which has to be maintained due to single wall cardboard.
- Flat base plate adds to the bulky nature of the helmet (Fig 4.3).

(Fig 4.3)

(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

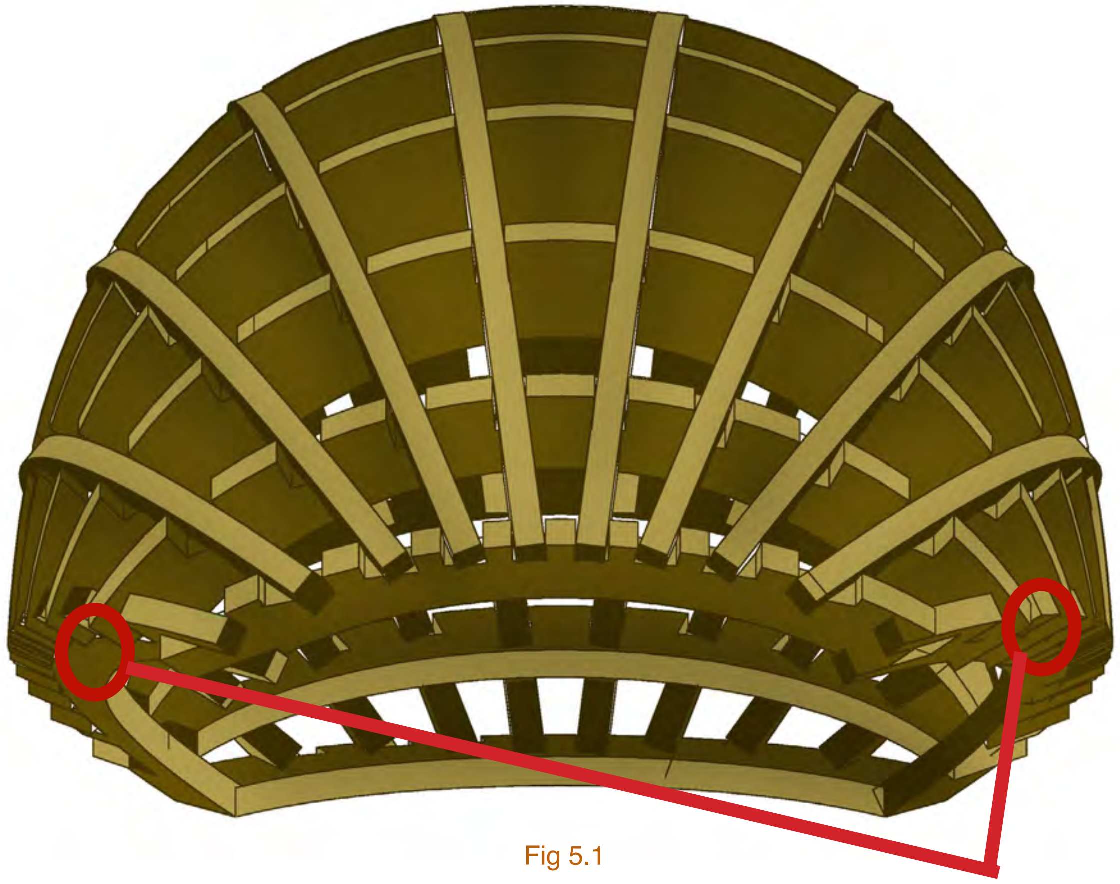
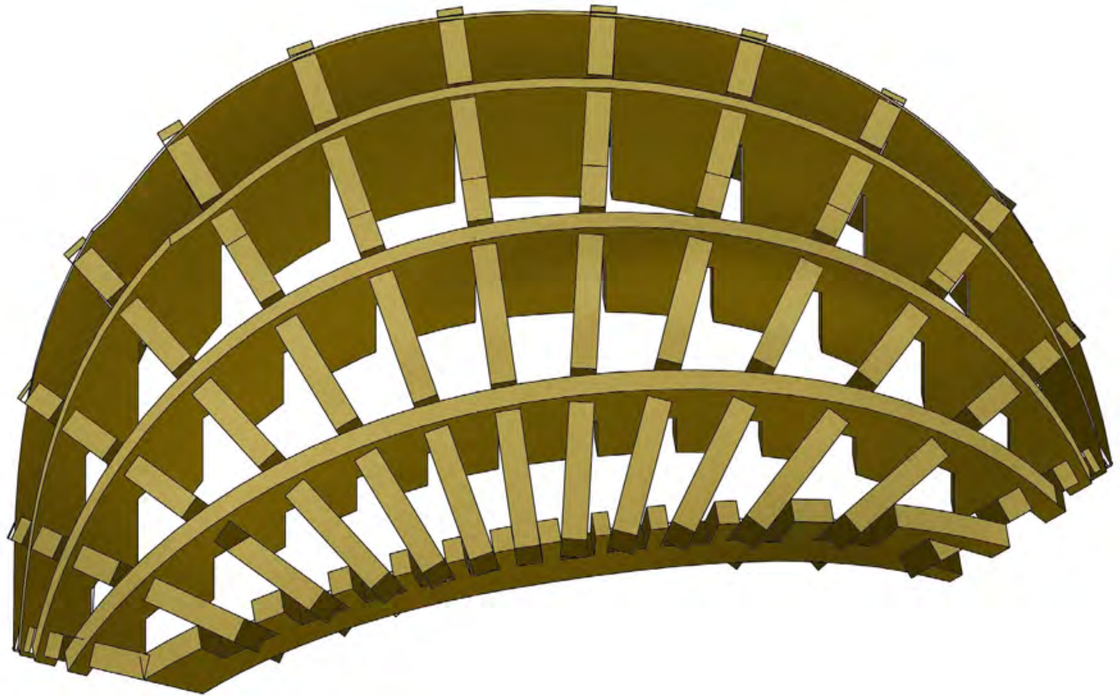


Fig 5.1



Design 04 (D04):

Taking the development of D03, D04 uses the shift in pivot point to its advantage. The thickness of the ribs is also reduced to 30mm and 20mm thus giving the helmet a sleeker design. This is brought about by the use of Double wall (Bc) cardboard with a thickness of 6mm. BY increasing the ply of the board more strength can be achieved in a smaller width. This is a significant improvement as this now gave rise to more appealing helmets by moving away from the bulky “mushroom like” helmets. The D04 also steps away from the flat base plate to hold the ends of the ribs. Instead the penultimate ribs act at the end plates for the helmet (Fig 5.1). Thus giving a unique profile to the helmets. The inclined penultimate plates also make the helmet look visually thinner. The stress during impact is better distributed over the entire plate rather than a concentrated point. Thus the D40 overcomes the problems leading to structural stress as well as design.

The inner surfaces of the ribs, which are in contact with the head, have airshafts running through the entire length of the helmet (Fig 5.2). This allows air to go through and thus ventilate the helmet and avoid sweating.

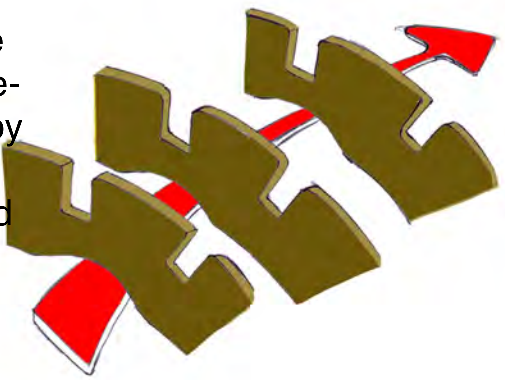
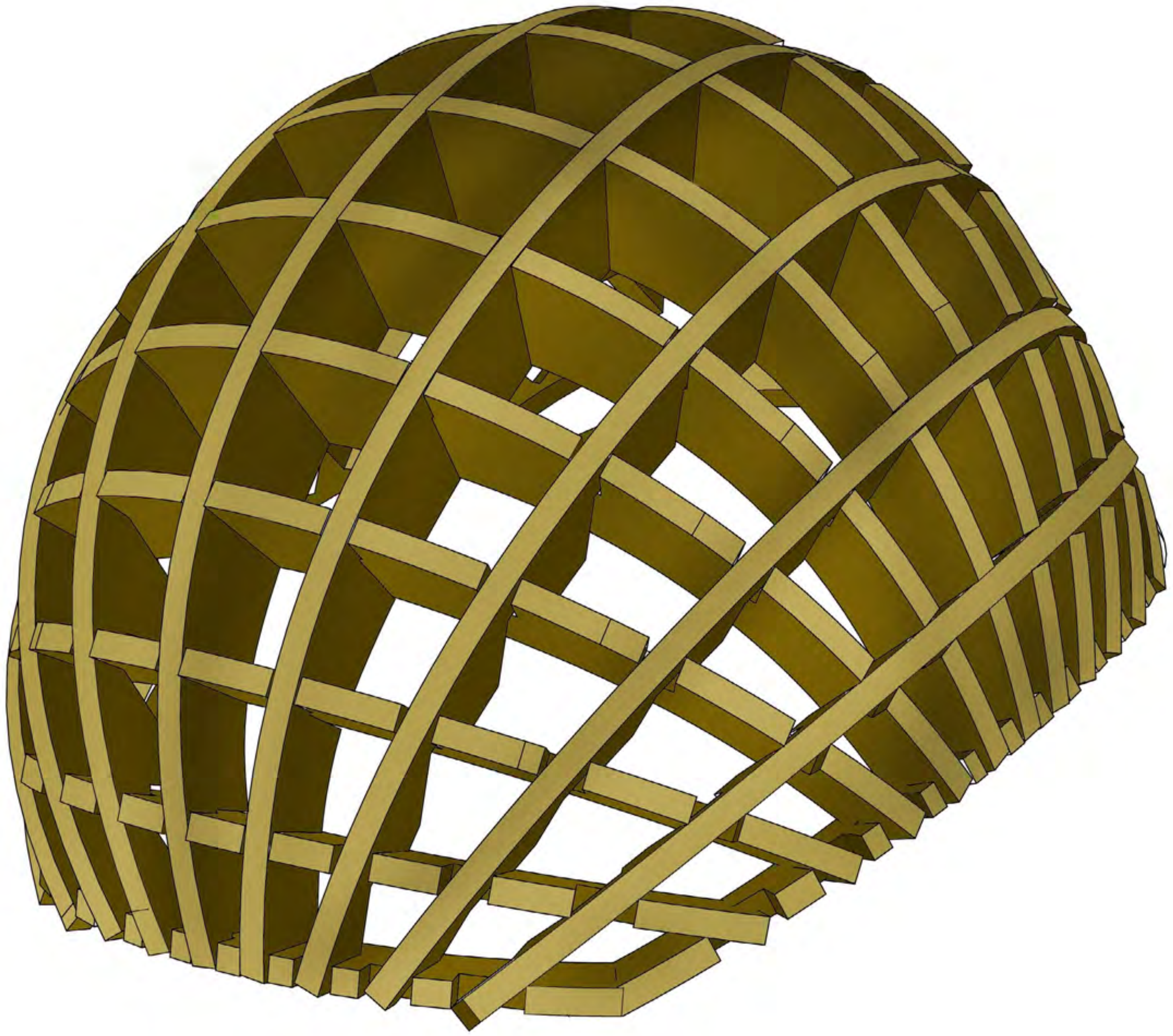


Fig 5.2 Air Flow



Waterproofing Cardboard:

"Because cardboard is paper, it is susceptible to humidity and water damage. Continual exposure to water causes the cardboard to become a soggy mess."[xiii]
However there exist several methods to solve this problem. One of the most prominent methods used today is laminating cardboard. This is done for most packaging boxes. However this doesn't protect the inner flutes of corrugated cardboard. The following methods are the new ways of protecting cardboard from water.

Wax Impregnation

Wax dipping is dipping the cardboard into a wax preparation. This is done so as to get the wax to penetrate to all the layers of cardboard. It is a further step from wax cascading where the cardboard is just coated with wax. However this destroys the recycling properties of cardboard.

Acrylex 100 (data Sheet in Appendix)

Acrylex 100 is also the solution for the problem. "It is a water based and acts as a perfect solution for waterproofing cardboard" , says David Graham Of Move It Solutions. Acrylex can be sprayed on or can even be used for dipping. Cardboard would need to be Flash dipped and this would ensure that the liquid seeps through the paper and makes it completely waterproof. Thinning ACRYLEX 100 to 10 to 20% with water will facilitate application by brush or roller, or in other applications where a thinner consistency is desired.[xv]This solution also has adhesive properties and would hold the ribs of card together. This would thus remove a step of dipping into a PVA solution during manufacture. The data sheet for Acrylex 100 has been included in the Appendix

Standards testing

Tested against British Standards
EN1078 as well as SNELL stndards.

(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

Aim:

To determine the Gravitational Force experienced by the head due to sudden deceleration due to impact.

Experiment:

- The EN 1078 (Refer to Appendix) test constitutes a drop test of a head weighing 5Kg (Avg. Weight of the Human Head) onto a flat base. A cast of my face was made using Lifeform Silicon. A plaster model was cast using 5kg of plaster. This was done to ensure that the head form fit the testing helmets perfectly(Fig 6.3)

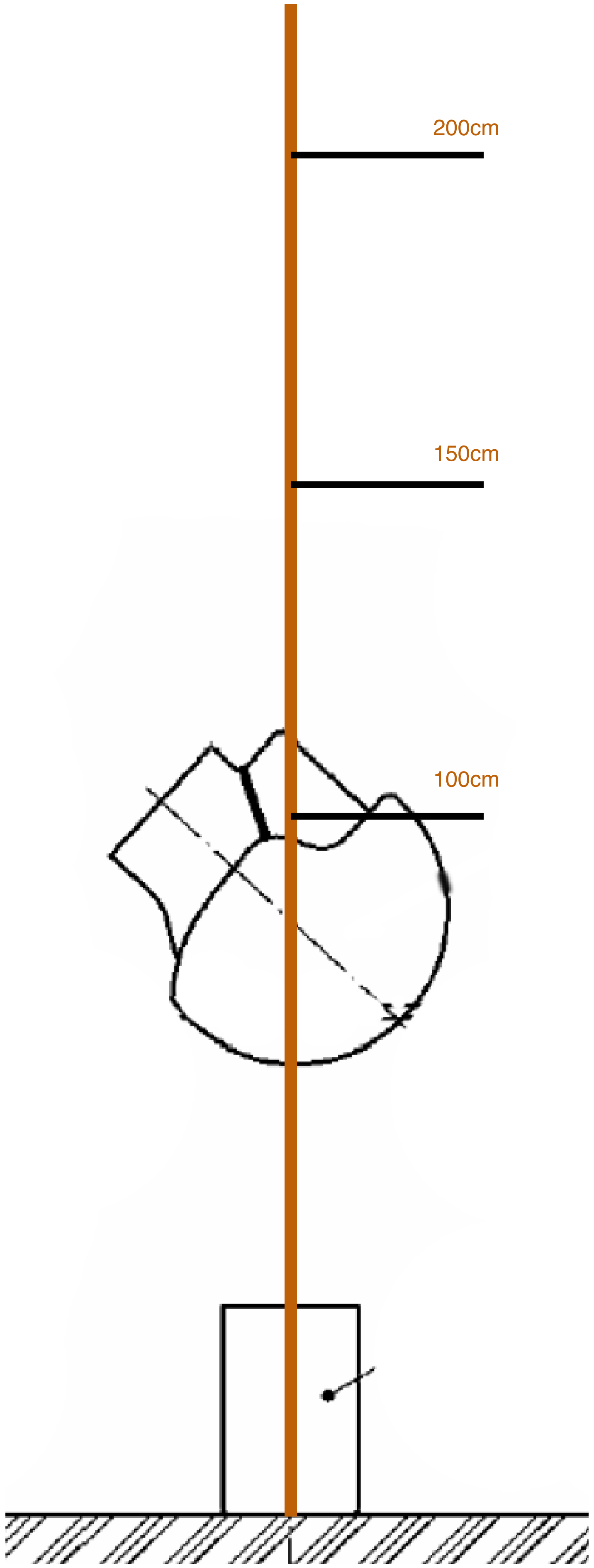
- The head was fitted with and accelerometer ADXL193 to measure the deceleration during impact. This was then transmitting an analogue output, which was translated by the Arduino as shown in Fig 6.2. A processing code was used to calculate the maximum and minimum G Values during the testing process. This can be found in the Appendix.

- A rig was constructed to maintain path and guide the head as it collided with the base.

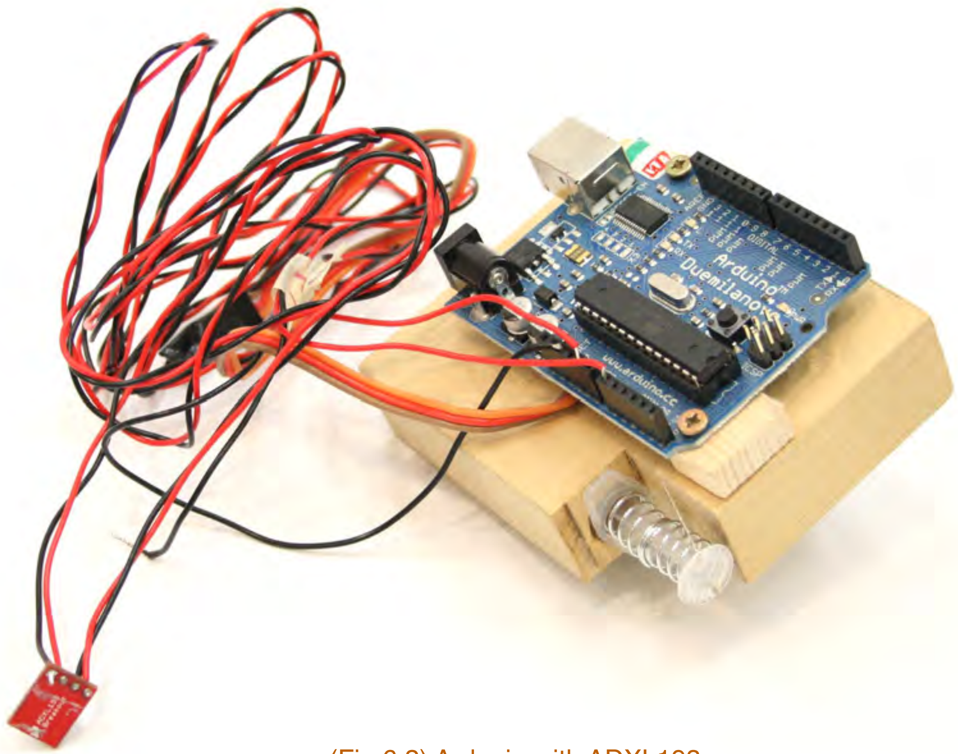
- The head was drilled through to accommodate the guide rail.

- The guide rail was measured and marked with the test heights, namely, 1metre, 1.5 m and 2m.

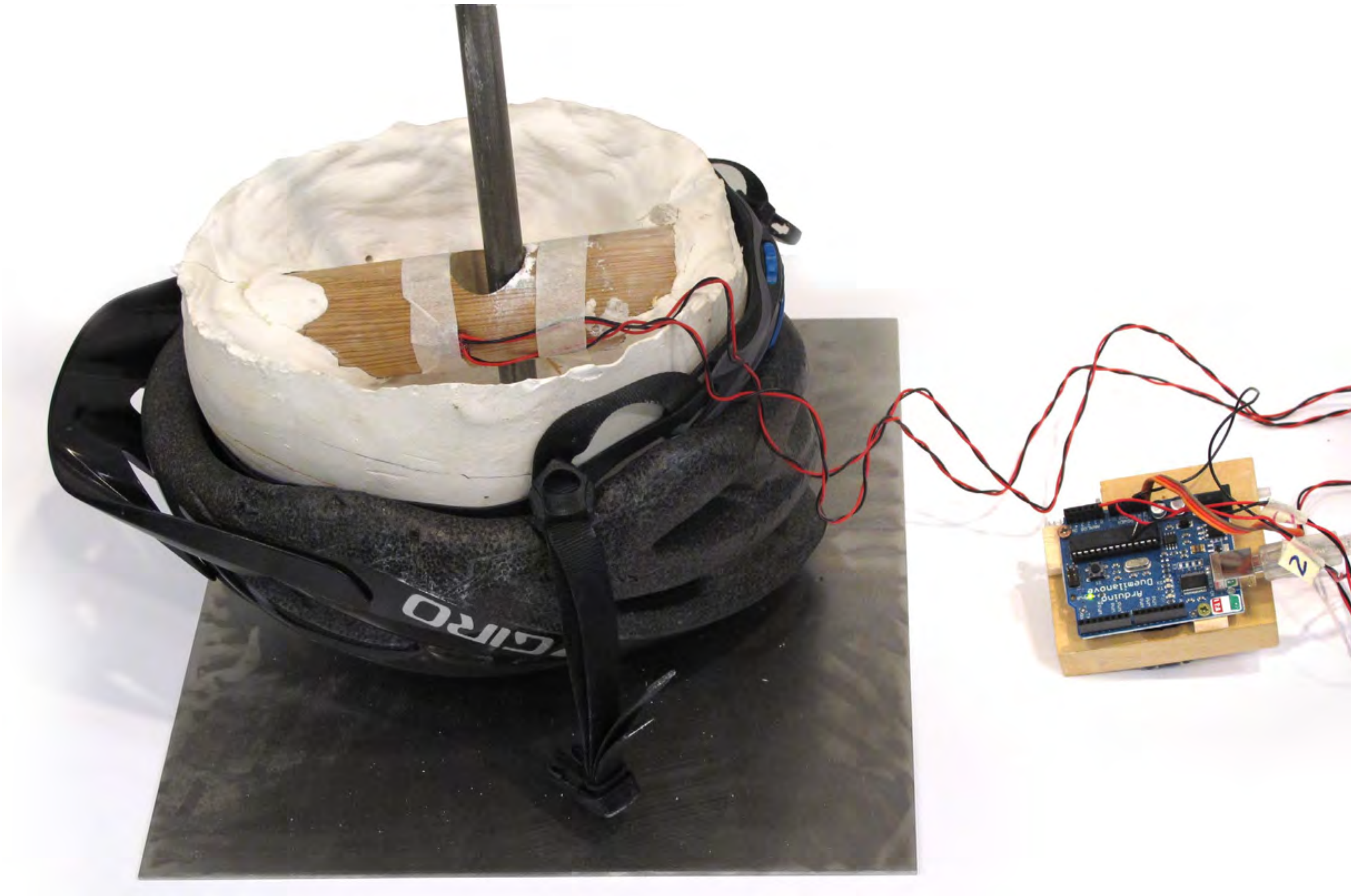
- The process was recorded via the use of a video camera for future reference.



(Fig 6.1) Gforce Testing Rig



(Fig 6.2) Ardunio with ADXL193



(Fig 6.3) Gforce Testing Rig

(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

Results:

Sample Name	Materials	Height	Gforce Meter Reading
Giro	EPS	0.5m	200.33
Giro	EPS	1m	220.33
Design Sample 01	Tripple Wall Aac Cardboard	1m	98.9
Design Sample 02	Aac + Arcylic	1m	131.8
Design Sample 03	Single Ply (A) heavy Cardboard	1m	99.66
Design Sample 03	Single Ply (A) heavy Cardboard	1.5m	145.66
Design Sample 04	Double Ply (Bc) Light Cardboard	1m	63.65
	Double Ply (Bc) Light Cardboard	1.5m	91.66

Multiple tests

After the testing phase, D04 proved to be the most impact absorption structure.
The D04 underwent further testing to determine if the D04 can be reused. Upon testing the D04 held its structural and impact absorption capability until the fifth test after which the ribs split and thus rendered the helmet unusable.

A regular polystyrene helmet only survived the first test after which it cracked, whereas the D04 can be re used a couple of times before it can be put away.

HPE Test Labs

The Kraniums llners have been tested at HPE Test Labs in Surrey, UK by Paul Walker who has been testing helmets since 30 years.

Given ahead are the results of the testing

(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

Test Date: **07/06/11** Test Number: **7820-11**

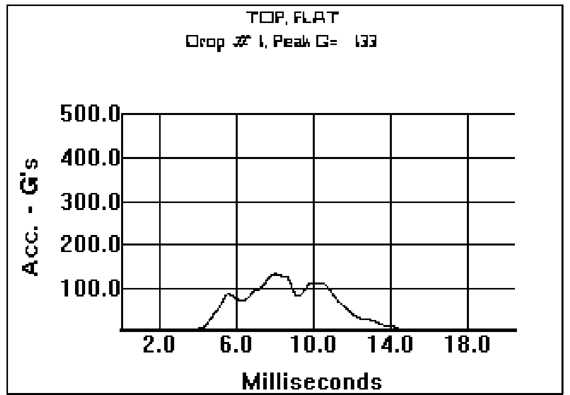
MANUFACTURER: **Kranium Ltd.**
MODEL: **Single**
SIZE: **Large**
DATE ACQUIRED: **07/06/11**
FILE: **UK7820**
SAMPLE WEIGHT: **N/A**
CONSTRUCTION: **Cardboard technology**

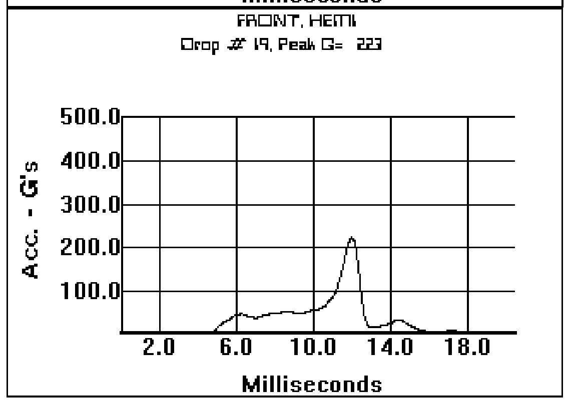
SNELL #: **N/A**
P.O. #: **via B. Vero/Design**
DATE OF MANUF: **N/A**
CONFIGURATION: **Open Face**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	FLAT	0.00	0.00	3.645	133
FRONT	HEMI	0.86	0.44	4.145	223





Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result**
RETAINING SYSTEM: **N**
CHIN GUARD: **N**
PENETRATION-SHELL: **No Result**
POSITIONAL STABILITY: **No Result**

VISUAL FIELD: **No Result**
ELONGATION: **--**
DISTORTION: **--**
PENETRATION-SHIELD: **No Result**

SAMPLE **No Result**

NOTES

Fitted with Design Headwear composite shell.
Evaluation impacts.

Test Tech: PMW
Approved By: ______________________ **Laboratory Manager** Date: 20/6/2011

Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

Test Date: **07/06/11** Test Number: **7821-11**

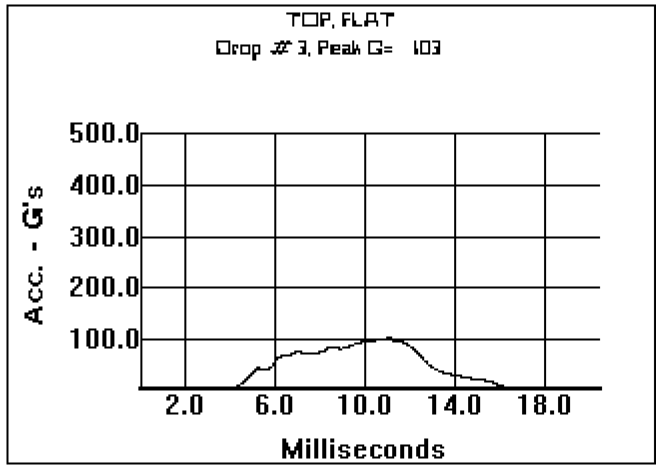
MANUFACTURER: **Kranium Ltd.**
MODEL: **Single**
SIZE: **Large**
DATE ACQUIRED: **07/06/11**
FILE: **UK7821**
SAMPLE WEIGHT: **N/A**
CONSTRUCTION: **Cardboard technology**

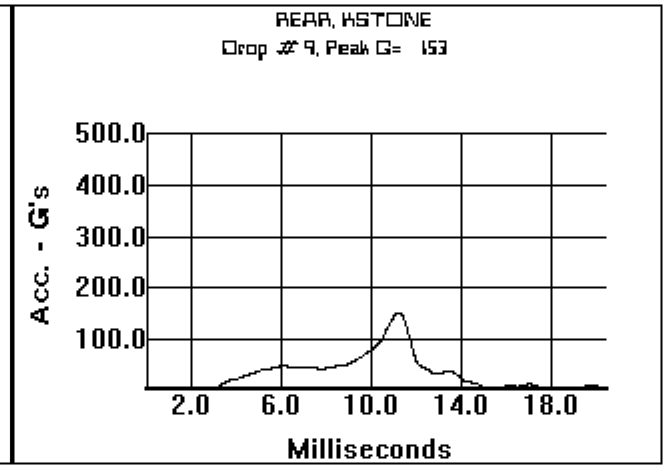
SNELL #: **N/A**
P.O. #: **via B. Vero/Design**
DATE OF MANUF: **N/A**
CONFIGURATION: **Open Face**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	FLAT	0.00	0.00	3.683	103
REAR	KSTONE	0.20	0.00	4.351	153





Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result**
RETAINING SYSTEM: **N**
CHIN GUARD: **N**
PENETRATION-SHELL: **No Result**
POSITIONAL STABILITY: **No Result**

VISUAL FIELD: **No Result**
ELONGATION: **--**
DISTORTION: **--**
PENETRATION-SHIELD: **No Result**

SAMPLE **No Result**

NOTES

Fitted with an ABS shell.
Evaluation impacts.

Test Tech: PMW
Approved By: ______________________ **Laboratory Manager** Date: 20/6/2011

Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

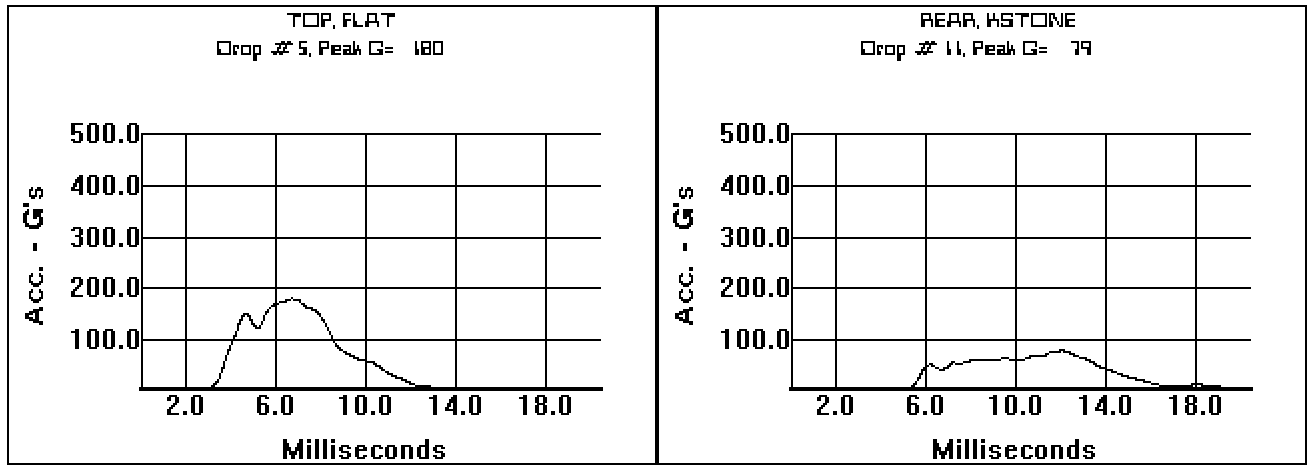
Test Date: **07/06/11** Test Number: **7822-11**

MANUFACTURER: **Kranium Ltd.**
MODEL: **Light**
SIZE: **Large** SNELL #: **N/A**
DATE ACQUIRED: **07/06/11** P.O. #: **via B. Vero/Design**
FILE: **UK7822** DATE OF MANUF: **N/A**
SAMPLE WEIGHT: **N/A** CONFIGURATION: **Open Face**
CONSTRUCTION: **Cardboard technology**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	FLAT	2.46	0.00	3.208	180
REAR	KSTONE	0.00	0.00	4.381	79



Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result** VISUAL FIELD: **No Result**
RETAINING SYSTEM: **N** ELONGATION: **--**
CHIN GUARD: **N** DISTORTION: **--**
PENETRATION-SHELL: **No Result** PENETRATION-SHIELD: **No Result**
POSITIONAL STABILITY: **No Result**
SAMPLE **No Result**

NOTES

Fitted with Design Headwear composite shell.
Evaluation impacts.

Test Tech: PMW
Approved By: **Laboratory Manager** Date: 20/6/2011

Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

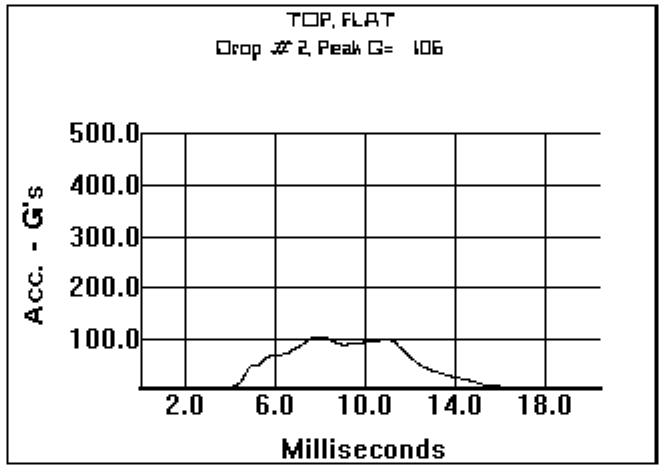
Test Date: **07/06/11** Test Number: **7823-11**

MANUFACTURER: **Kranium Ltd.**
MODEL: **Light**
SIZE: **Large** SNELL #: **N/A**
DATE ACQUIRED: **07/06/11** P.O. #: **via B. Vero/Design**
FILE: **UK7823** DATE OF MANUF: **N/A**
SAMPLE WEIGHT: **N/A** CONFIGURATION: **Open Face**
CONSTRUCTION: **Cardboard technology**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	FLAT	0.00	0.00	3.683	106



Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result** VISUAL FIELD: **No Result**
RETAINING SYSTEM: **N** ELONGATION: **--**
CHIN GUARD: **N** DISTORTION: **--**
PENETRATION-SHELL: **No Result** PENETRATION-SHIELD: **No Result**
POSITIONAL STABILITY: **No Result**
SAMPLE **No Result**

NOTES

Fitted with an ABS shell.
Evaluation impacts.

Test Tech: PMW
Approved By: **Laboratory Manager** Date: 20/6/2011

Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

Test Date: **07/06/11** Test Number: **7824-11**

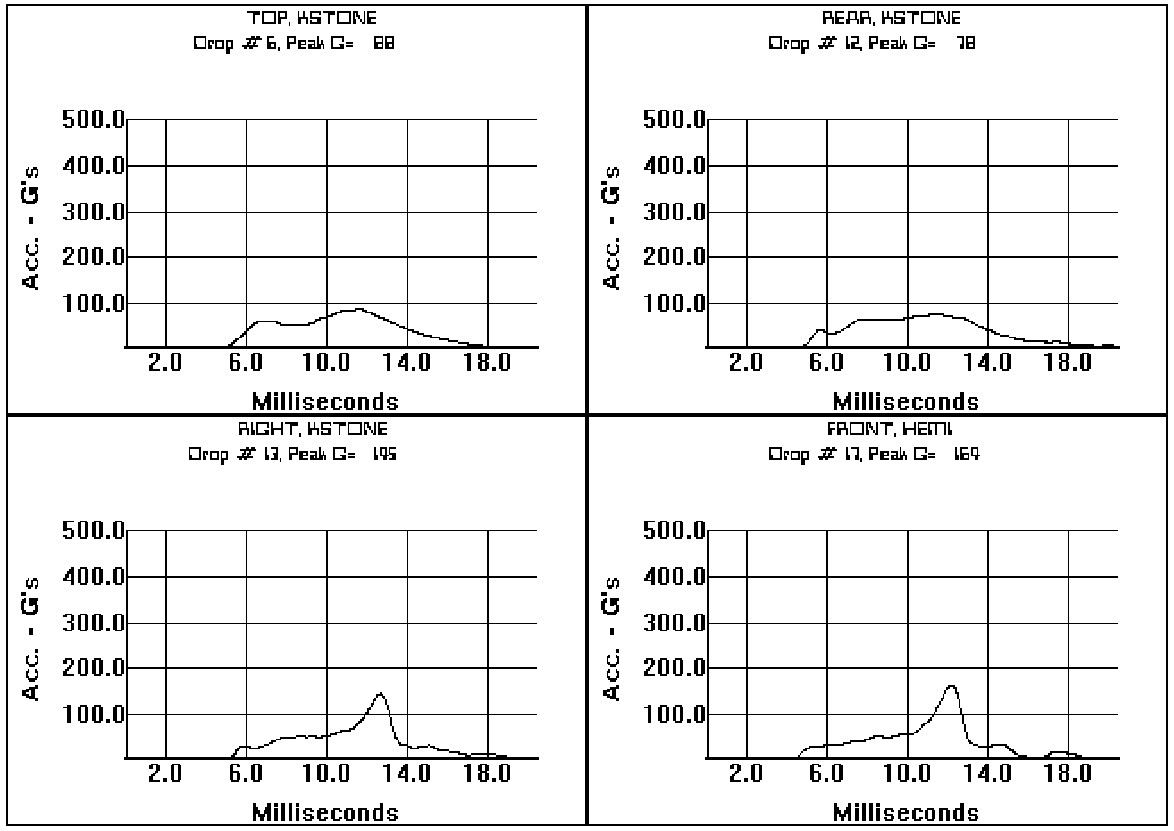
MANUFACTURER: **Kranium Ltd.**
MODEL: **Heavy**
SIZE: **Large**
DATE ACQUIRED: **07/06/11**
FILE: **UK7824**
SAMPLE WEIGHT: **N/A**
CONSTRUCTION: **Cardboard technology**

SNELL #: **N/A**
P.O. #: **via B. Vero/Design**
DATE OF MANUF: **N/A**
CONFIGURATION: **Open Face**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	KSTONE	0.00	0.00	4.373	88
REAR	KSTONE	0.00	0.00	4.370	78
RIGHT	KSTONE	0.00	0.00	4.378	145
FRONT	HEMI	0.54	0.00	4.151	164



Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result**
RETAINING SYSTEM: **N**
CHIN GUARD: **N**
PENETRATION-SHELL: **No Result**
POSITIONAL STABILITY: **No Result**

VISUAL FIELD: **No Result**
ELONGATION: **--**
DISTORTION: **--**
PENETRATION-SHIELD: **No Result**

SAMPLE **No Result**

NOTES

Fitted with an ABS shell.
Evaluation impacts.

Test Tech: PMW
Approved By: **Laboratory Manager** Date: 20/6/2011

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Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

Test Date: **07/06/11** Test Number: **7825-11**

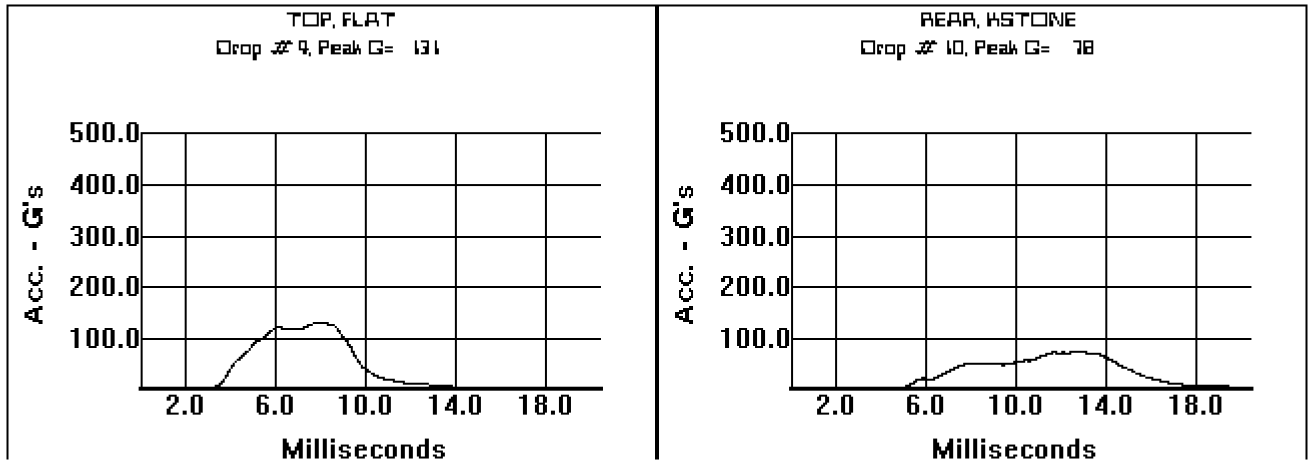
MANUFACTURER: **Kranium Ltd.**
MODEL: **Heavy**
SIZE: **Large**
DATE ACQUIRED: **07/06/11**
FILE: **UK7825**
SAMPLE WEIGHT: **N/A**
CONSTRUCTION: **Cardboard technology**

SNELL #: **N/A**
P.O. #: **via B. Vero/Design**
DATE OF MANUF: **N/A**
CONFIGURATION: **Open Face**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
TOP	FLAT	0.00	0.00	3.690	131
REAR	KSTONE	0.00	0.00	4.373	78



Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result**
RETAINING SYSTEM: **N**
CHIN GUARD: **N**
PENETRATION-SHELL: **No Result**
POSITIONAL STABILITY: **No Result**

VISUAL FIELD: **No Result**
ELONGATION: **--**
DISTORTION: **--**
PENETRATION-SHIELD: **No Result**

SAMPLE **No Result**

NOTES

Fitted with an ABS shell.
Evaluation impacts.

Test Tech: PMW
Approved By: **Laboratory Manager** Date: 20/6/2011

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Head Protection Evaluations

Test Data Sheet

Unit 4 Farnham Business Centre, Dogflud Way, Farnham, Surrey GU9 7UP
United Kingdom

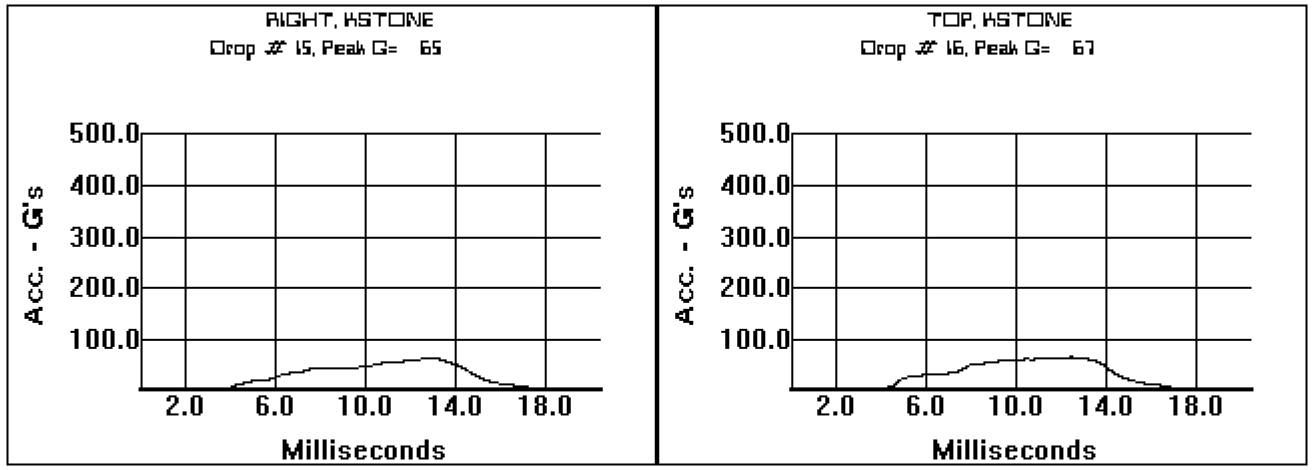
Test Date: **07/06/11** Test Number: **7830-11**

MANUFACTURER: **Kranium Ltd.**
MODEL: **Vacuum formed shell**
SIZE: **Large** SNELL #: **N/A**
DATE ACQUIRED: **07/06/11** P.O. #: **via B. Vero/Design**
FILE: **UK7830** DATE OF MANUF: **N/A**
SAMPLE WEIGHT: **N/A** CONFIGURATION: **Open Face**
CONSTRUCTION: **Cardboard technology**

TESTING INFORMATION

TEST TYPE: **Other Prototype Test**
TEST CONDITION: **AMB**
HEADFORM: **ISO M** HPI: **N/A** TEMP: **19°** HUM / PRESS: **52% / 1012 mb**
VELOCITY TAB WIDTH: **20 mm's** DROP MASS: **5.582 kg's**

SITE	ANVIL	Duration@150g	Duration@200g	TIME (ms)	PEAK G'S
RIGHT	KSTONE	0.00	0.00	4.366	65
TOP	KSTONE	0.00	0.00	4.359	67



Site- (a,Y): a = Angle clockwise from Reference Point(degrees); Y = Distance Up to Site (mm)

LABELING & MARKING: **No Result** VISUAL FIELD: **No Result**
RETAINING SYSTEM: **N** ELONGATION: **--**
CHIN GUARD: **N** DISTORTION: **--**
PENETRATION-SHELL: **No Result** PENETRATION-SHIELD: **No Result**
POSITIONAL STABILITY: **No Result**
SAMPLE **No Result**

NOTES

Vacuum formed shell covering.
Evaluation impacts.

Test Tech: PMW
Approved By: **Laboratory Manager** Date: 20/6/2011

These results apply only to items tested. This report shall not be reproduced except in full and then only with written permission from Head Protection Evaluations.

STG Test Labs

The Kraniums llners have been tested at STG test labs in China to make a direct comparison with an EPS liner.
Both the liners were placed into similar shells and dropped onto the same points in a controlled test environment.

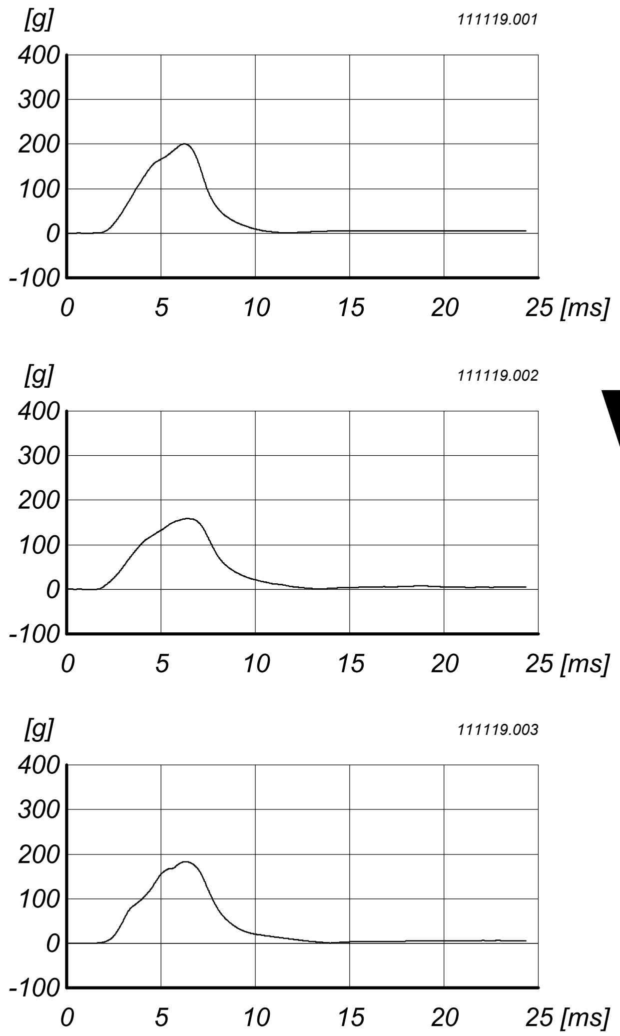
ADEngineering
DLS9000

TEST INFO		Date/Time :	2011-11-19 9:49
Temperature :	24	Operator :	JOHN
SAMPLE IDENTIFICATION		Manufacturer :	STRATEGIC
		Shock abs. mat. :	
Standard :	CE EN1078	Density :	
Min Speed [m/s]:	5.42	Helmet Size :	L
Max Peak [g]:	250	Helmet Mass :	
		Helmet Color	BLACK EPS

File	Ext.	Helmet Model	Sa. N#	Cond.	Height [cm]	Head. Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [g]
111119	001	SK-501(EPS)	01	AMB	158	60	TOP	FLAT	5.45	200
111119	002	SK-501(EPS)	01	AMB	158	60	FRONT/RI	FLAT	5.45	159
111119	003	SK-501(EPS)	01	AMB	158	60	RIGHT/RE	FLAT	5.45	183
111119	004	SK-501(D2)	02	AMB	159	60	TOP	FLAT	5.45	130
111119	005	SK-501(D2)	02	AMB	158	60	FRONT/RI	FLAT	5.45	146
111119	006	SK-50(D2)	02	AMB	158	60	RIGHT/RE	FLAT	5.40	136

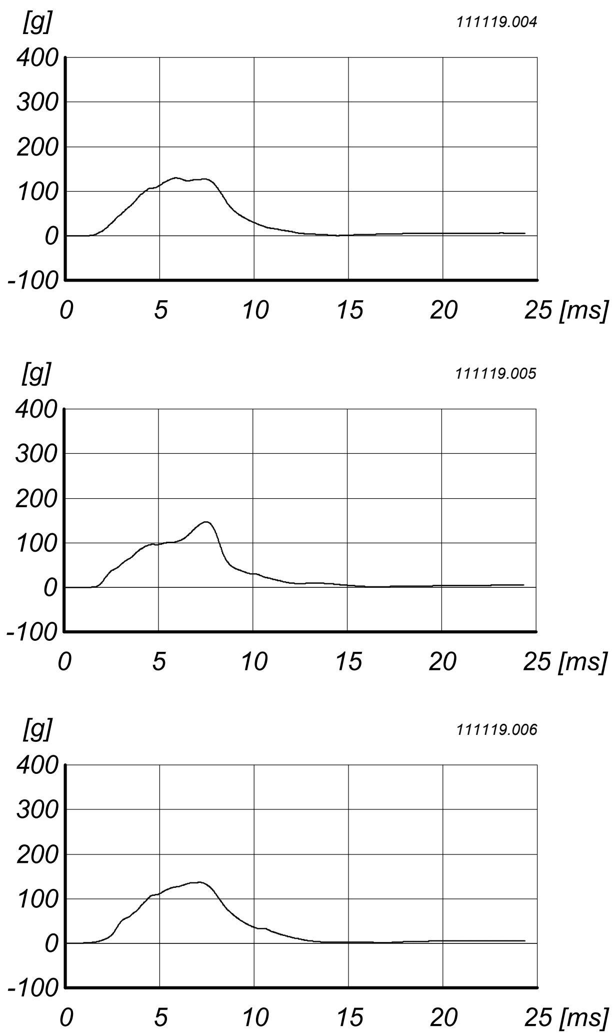
SHOCK TEST RESULTS

EPS Shell



Vs

Kranium Shell D2



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(c) Anirudha Surabhi, Royal College Of Art, Imperial College Of London

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