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# Natural and loose-fill impact attenuating surfaces for use in children's playgrounds

**Previously presented in Vienna 22 October 2013 at: 'International Conference Playground fall impacts: are the Standards providing adequate safety?'**

**Prof. Ing. Dr. David Eager**

**University of Technology Sydney, Australia**

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# Acknowledgement of Country

**I acknowledge the traditional owners of all the lands on which we reside and pay respect to our respective elders past, present and future**

The Gadigal of the Eora Nation are the traditional custodians of my place which is currently called Sydney

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Open Access Article

# Additional Criteria for Playground Impact Attenuating Sand

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## Abstract

Falls within children's playgrounds result in long bone and serious injuries. To lower the likelihood and severity of injury, impact attenuating surfaces (IAS) are installed within the impact area (fall zone). There are three primary IAS materials used, namely: granulated rubber products, wood fibre products, and sand. There is a deficiency with existing IAS test methods in that they do not take account of sand degradation over time. When children use the playground, sand degradation can occur when sand produces fines and smaller particles with low sphericity and angular which fill the voids between the sand particles. These fines and smaller particles tend to bind the sand and lower its impact attenuating performance. This paper proposes an additional IAS test to eliminate sands that degrade above an established threshold rate after installation due to normal usage. IAS degradation properties of fifteen IAS sands were tested including sand particle shape, sand particle distribution, percentage fines and sand particle degradation. This accelerated ageing test method is applicable only to sands and not rubber or wood fibre IAS products. The best IAS sands were sourced from quarries located on rivers that had eroded volcanic outcrops. These sands were shown to degrade the least and had little to no fines, and their particle shape was rounded to well-rounded. The most reliable source for good quality IAS sands on these rivers was on specific bends. The sand mined at these locations consistently had a tight particle size distribution. View Full-Text

*Keywords:* children's playground; injury prevention; child falls; long bone injuries; serious injuries; impact attenuating surface; IAS; HIC; $g_{max}$

https://www.mdpi.com/2076-3417/11/19/8805

# Introduction

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- ✔ **Natural and loose fill**
  - Advantages – disadvantages
  - IAS behaviour during impact
- ✔ **Properties of loose fill materials**
  - Force v displacement hysteresis curves
  - Sand – size, shape, grading and degradation…
  - Bark – depth, sharps…
- ✔ **Maintenance of sand and bark**
- ✔ **Consequences for EN 1177 and other IAS Standards**

# Natural and loose-fill surfaces

## IAS Bark

| Advantages | Disadvantages | Comments |
|---|---|---|
| Low initial cost | Easily displaced in high traffic and near forced movement devices | Reduces ongoing maintenance if designed and installed to 400 mm minimum |
| Retains excellent impact attenuation properties for many years | Some barks are not suitable for disability access | Only purchase bark that has no sharps (timber contamination) |
| Does not cause skin burns on a hot day (high Specific Heat 1400 J/kg.K) | Requires regular inspection | Can conceal hazardous objects (broken bottles, syringes) |
| Easy to install | Requires raking | |
| Readily available | Requires topping up | |
| Long life | | |
| Natural surface | | |
| Difficult to vandalise | | |

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# Natural and loose-fill surfaces

## IAS Sand

| Advantages | Disadvantages | Comments |
| --- | --- | --- |
| Low initial cost | Easily displaced in high traffic and near forced movement devices | If sand gets contaminated with fines it loses impact attenuation properties and will need to be sieved in-situ or removed and replaced |
| Easy to install | Requires regular inspection | Can conceal hazardous objects (broken bottles, syringes) |
| Retains excellent impact attenuation properties for many years | Can get very hot and cause skin burns on a hot day (low Specific Heat 795 J/kg.K) | Mixing two different IAS can cause contamination if their grading curves are different |
| Readily available | Requires raking | Reduces ongoing maintentance if designed and installed to 400 mm minimum |
| Long life | Requires topping up | |
| Natural surface | Not suitable for disability access | |
| Difficult to vandalise | Conceals animal faeces | |

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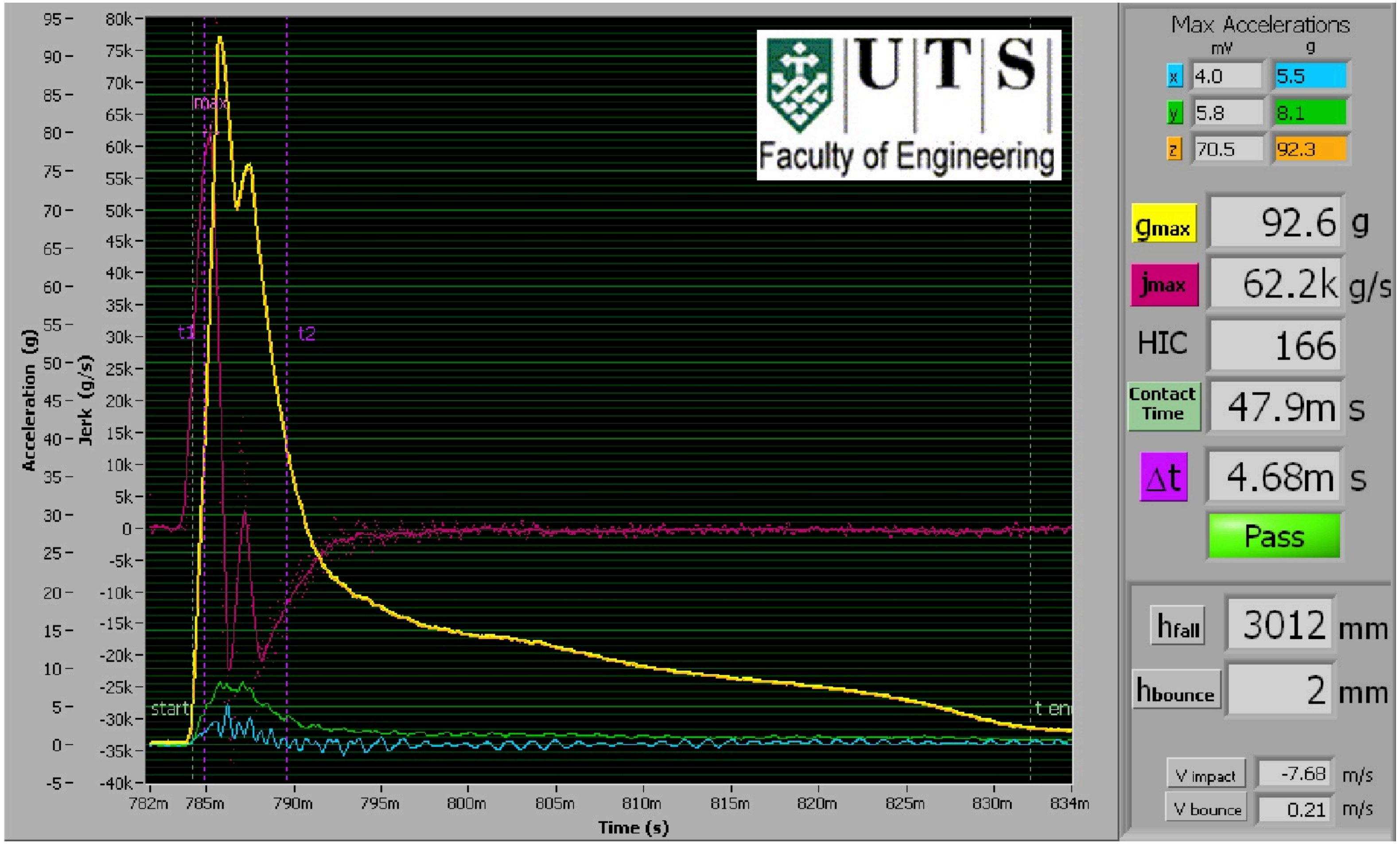
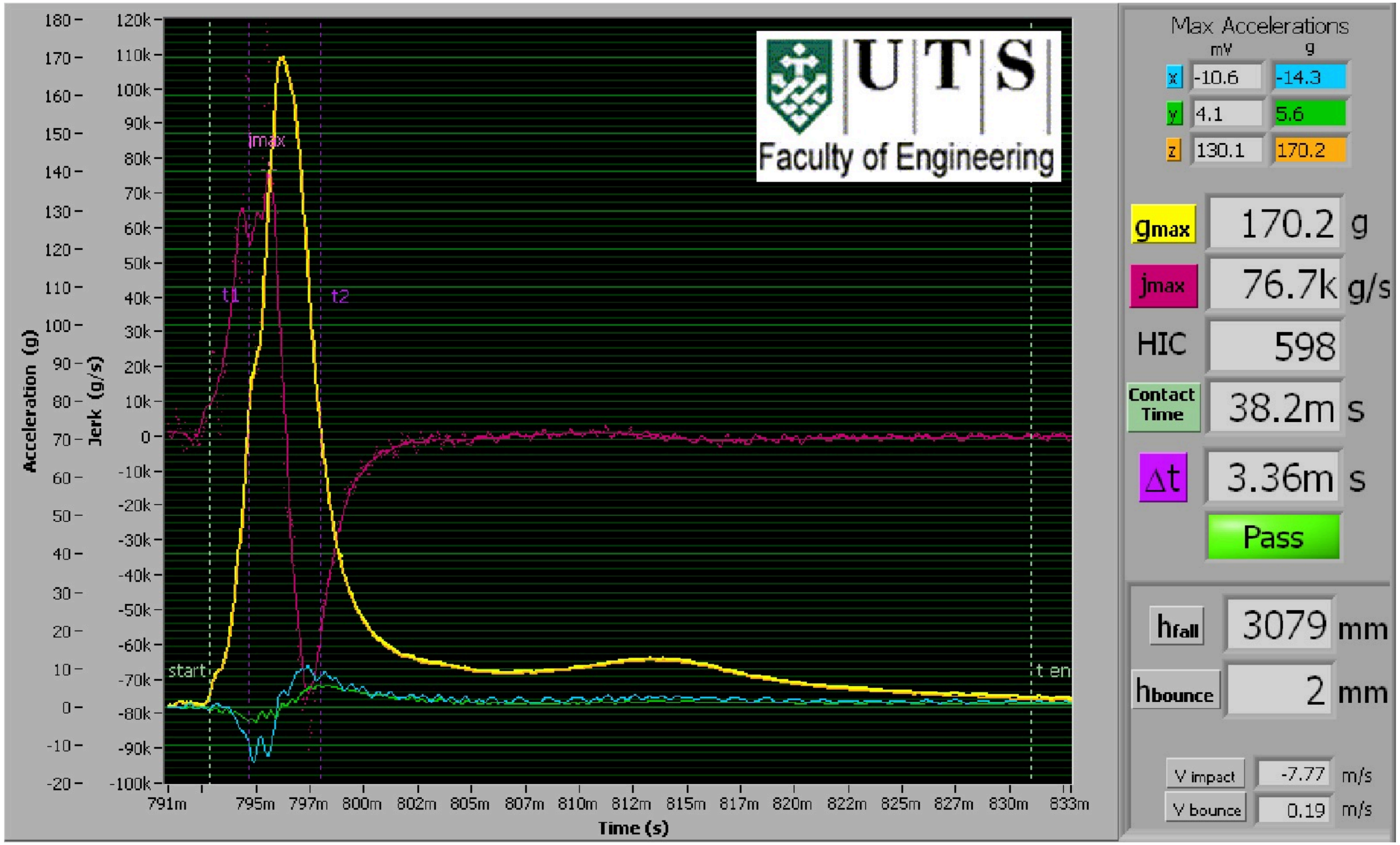
# IAS behaviour during impact – dry fine sand




**Sand (fine & dry): Acceleration v Time**

**1st drop in same location @ 3 m FHoF**

# IAS behaviour during impact – dry fine sand




**Sand (fine & dry): Acceleration v Time**

**2nd drop in same location @ 3 m FHoF**

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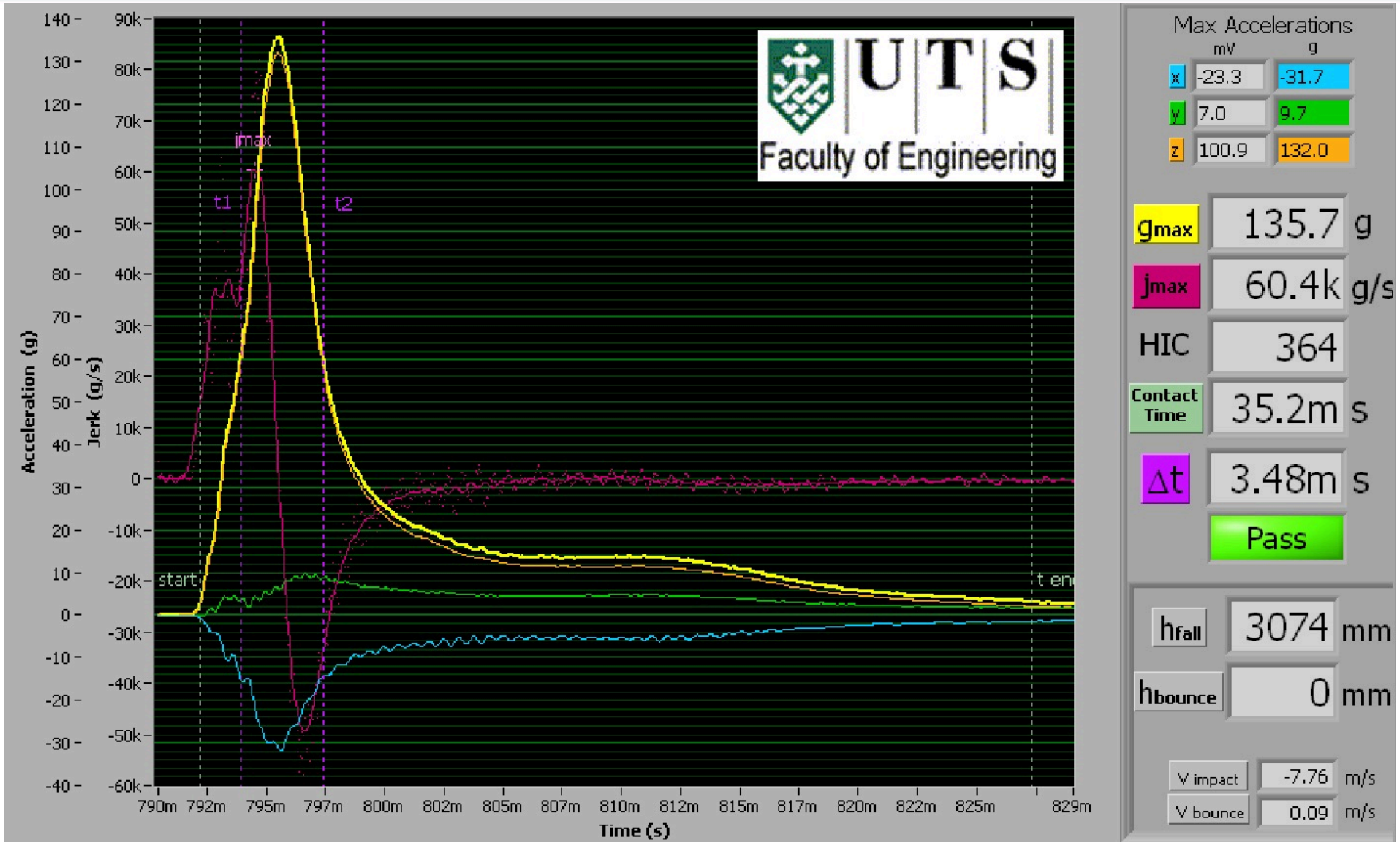
# IAS behaviour during impact – dry fine sand




**Sand (fine & dry): Acceleration v Time**

**3rd drop in same location @ 3 m FHoF**

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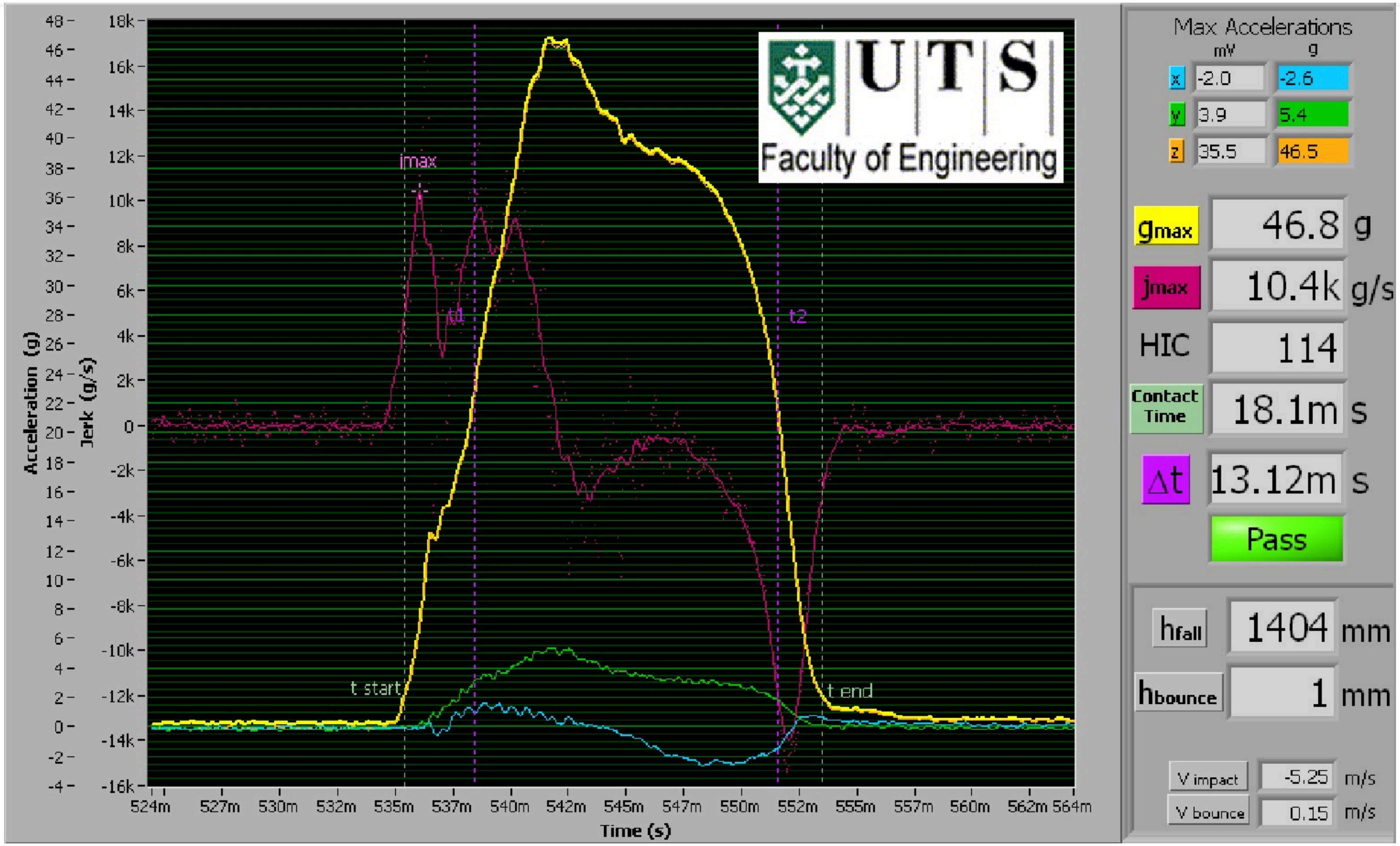
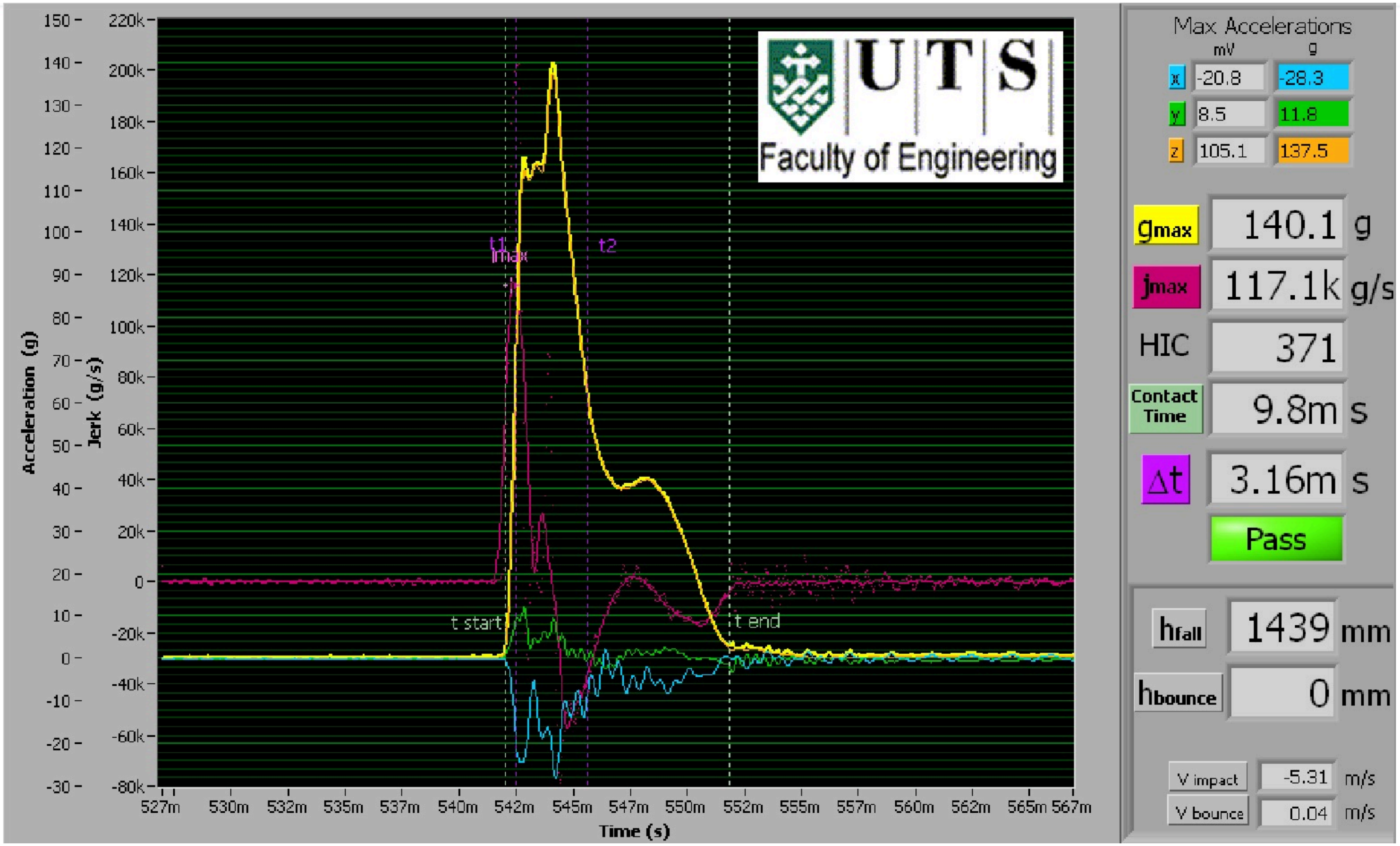
# IAS behaviour during impact – wet fine sand




**Sand (fine & wet): Acceleration v Time**

**1st drop in same location @ 1.4 m FHoF**

# IAS behaviour during impact – wet fine sand




**Sand (fine & wet): Acceleration v Time**

**2nd drop in same location @ 1.4 m FHoF**

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# IAS behaviour during impact – wet fine sand

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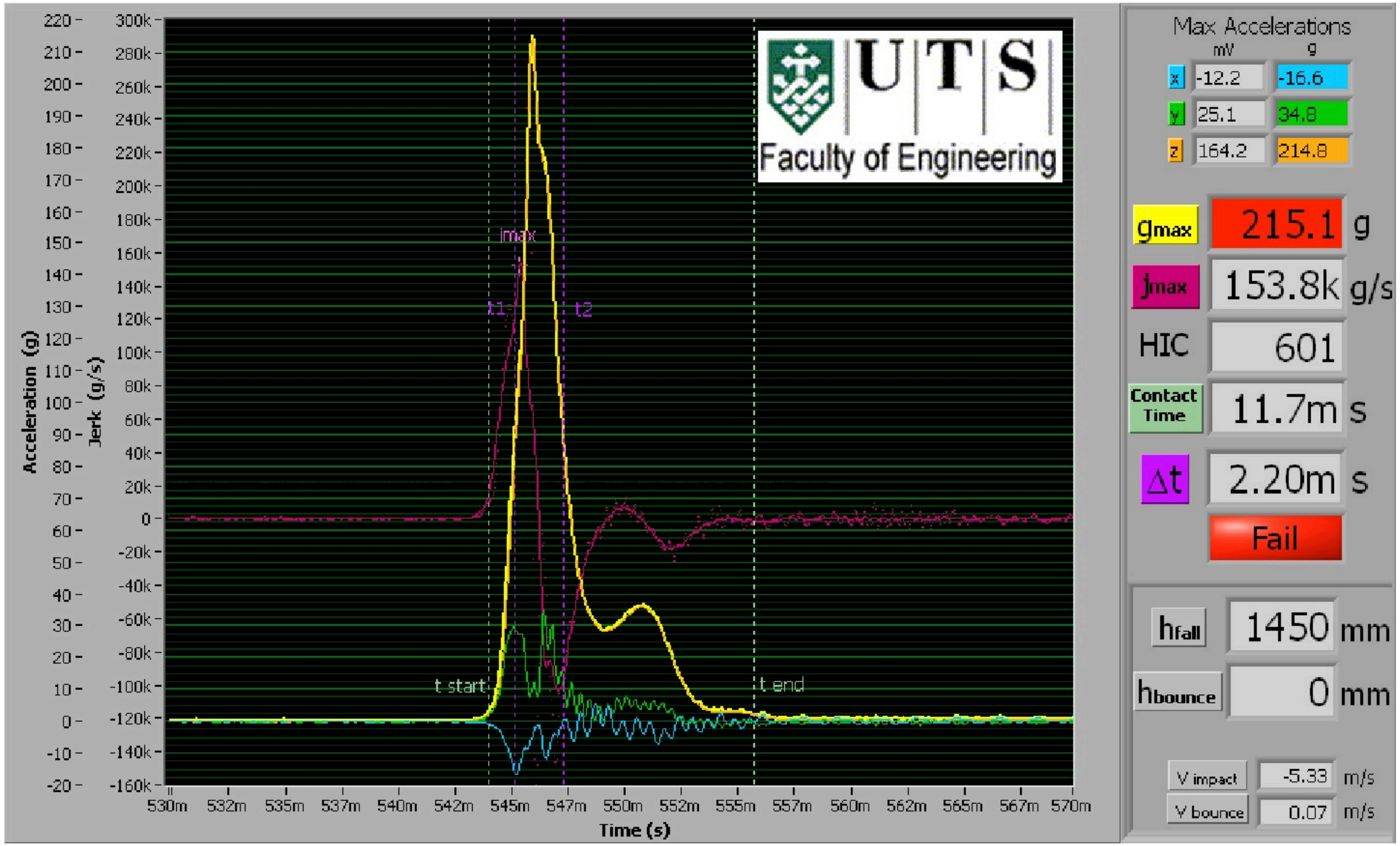
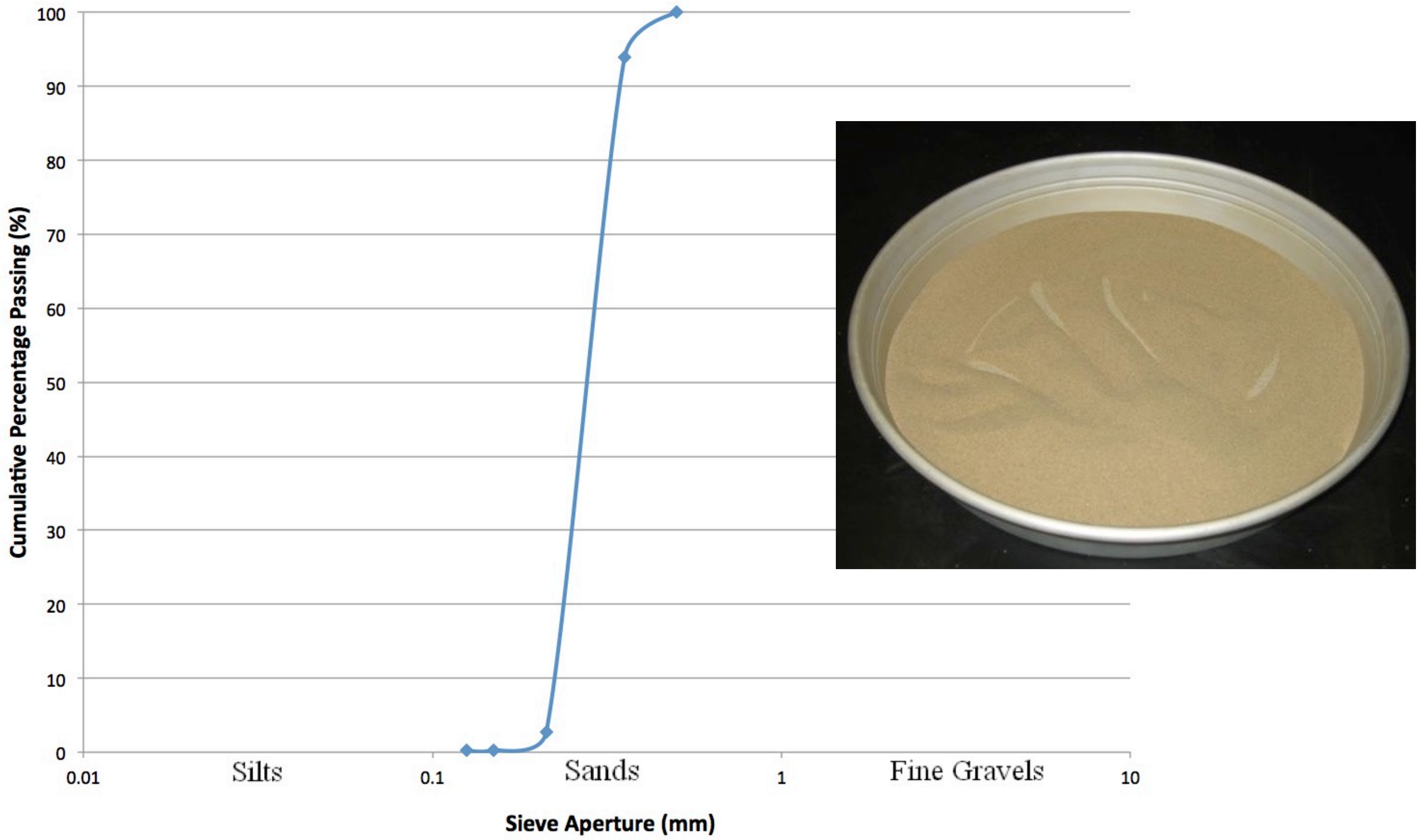



**Sand (fine & wet): Acceleration v Time**

**3rd drop in same location @ 1.4 m FHoF**

# Sieve grading curve of the tested ‘fine’ sand

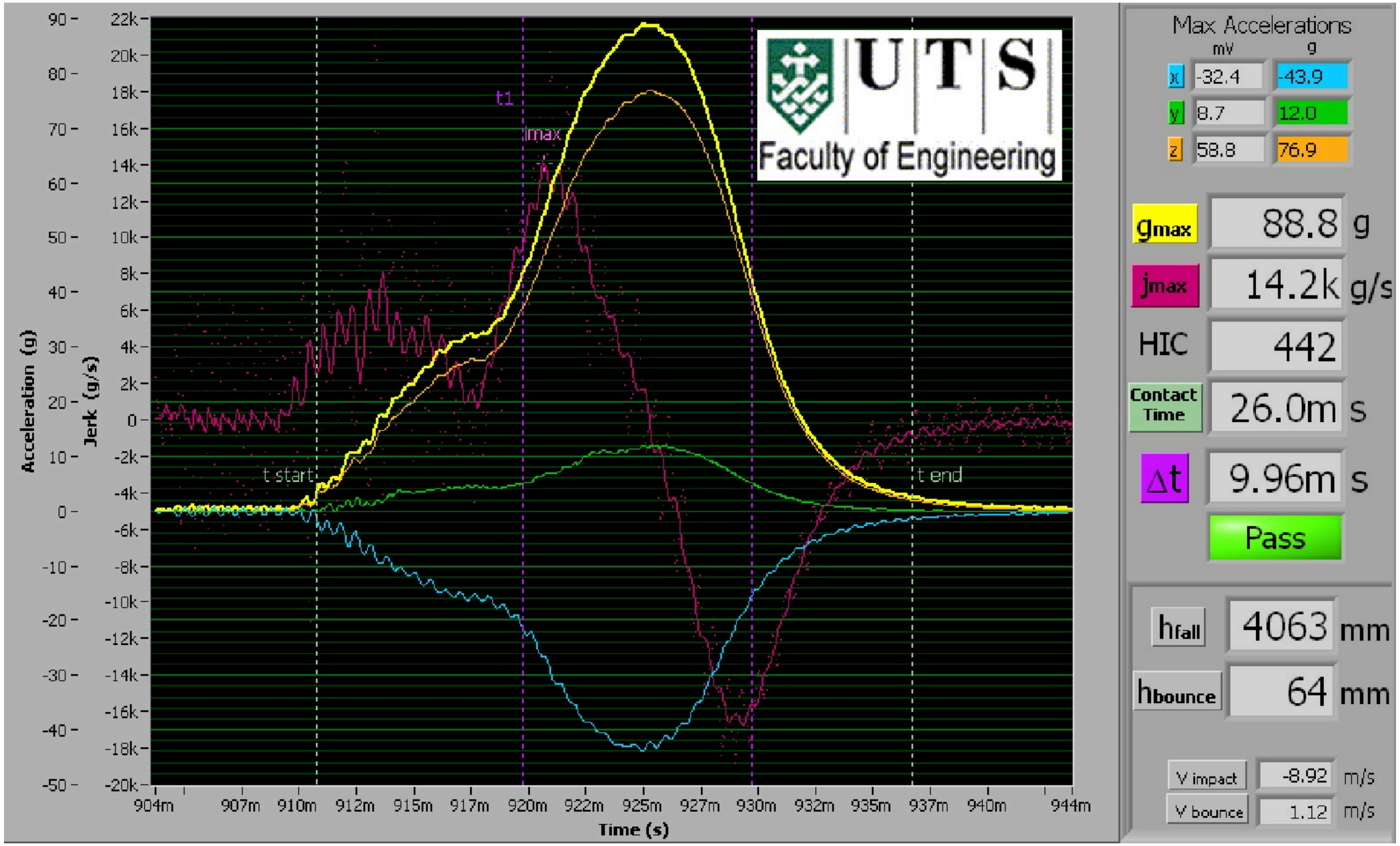





**Sand (fine): Sieve grading curve**

**Cumulative passing (%) v Sieve aperture (mm)**

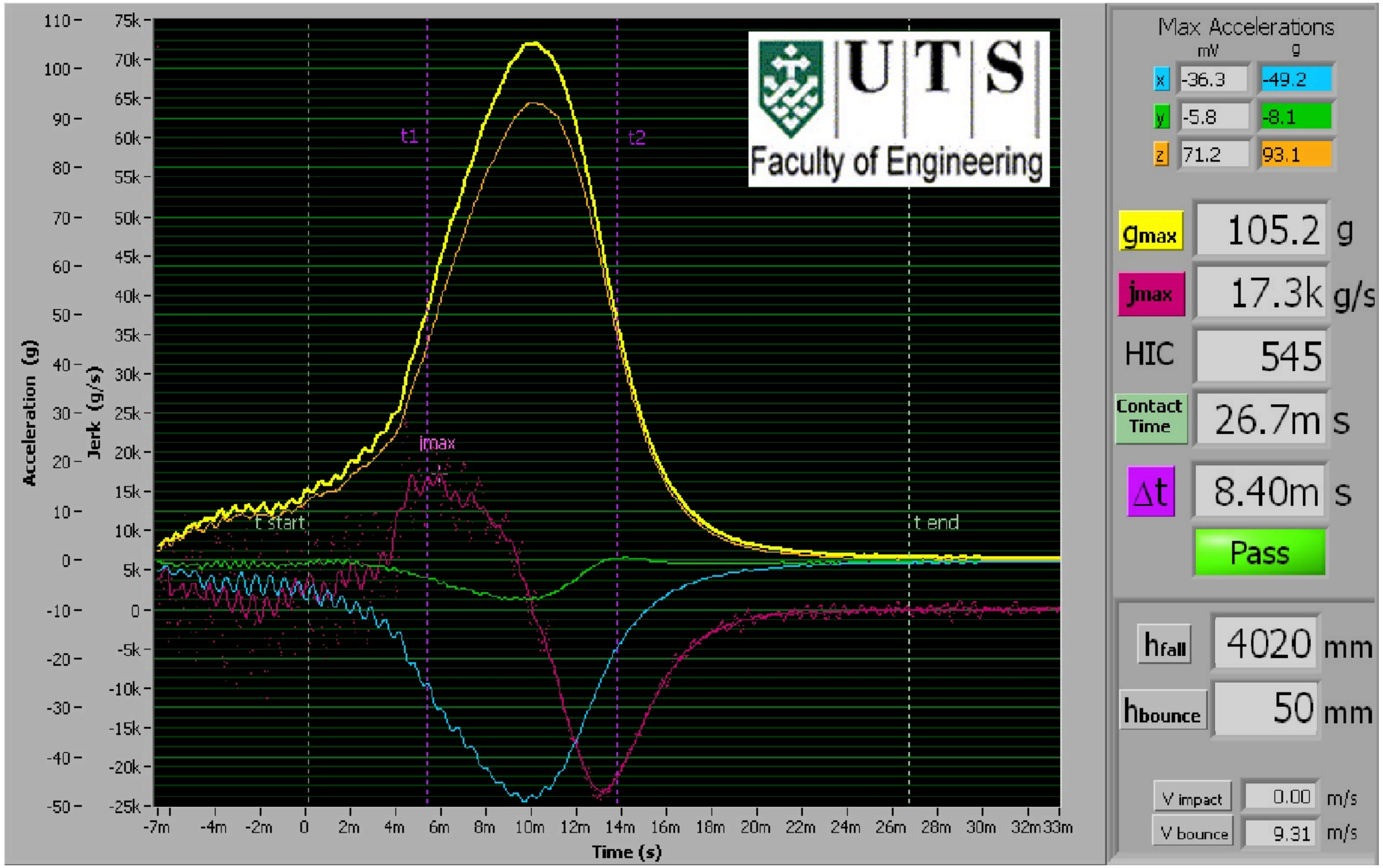
# IAS behaviour during impact – dry bark




**Bark (WA dry): Acceleration v Time**

**1st drop in same location @ 4 m FHoF**

# IAS behaviour during impact – dry bark




**Bark (WA dry): Acceleration v Time**

**2nd drop in same location @ 4 m FHoF**

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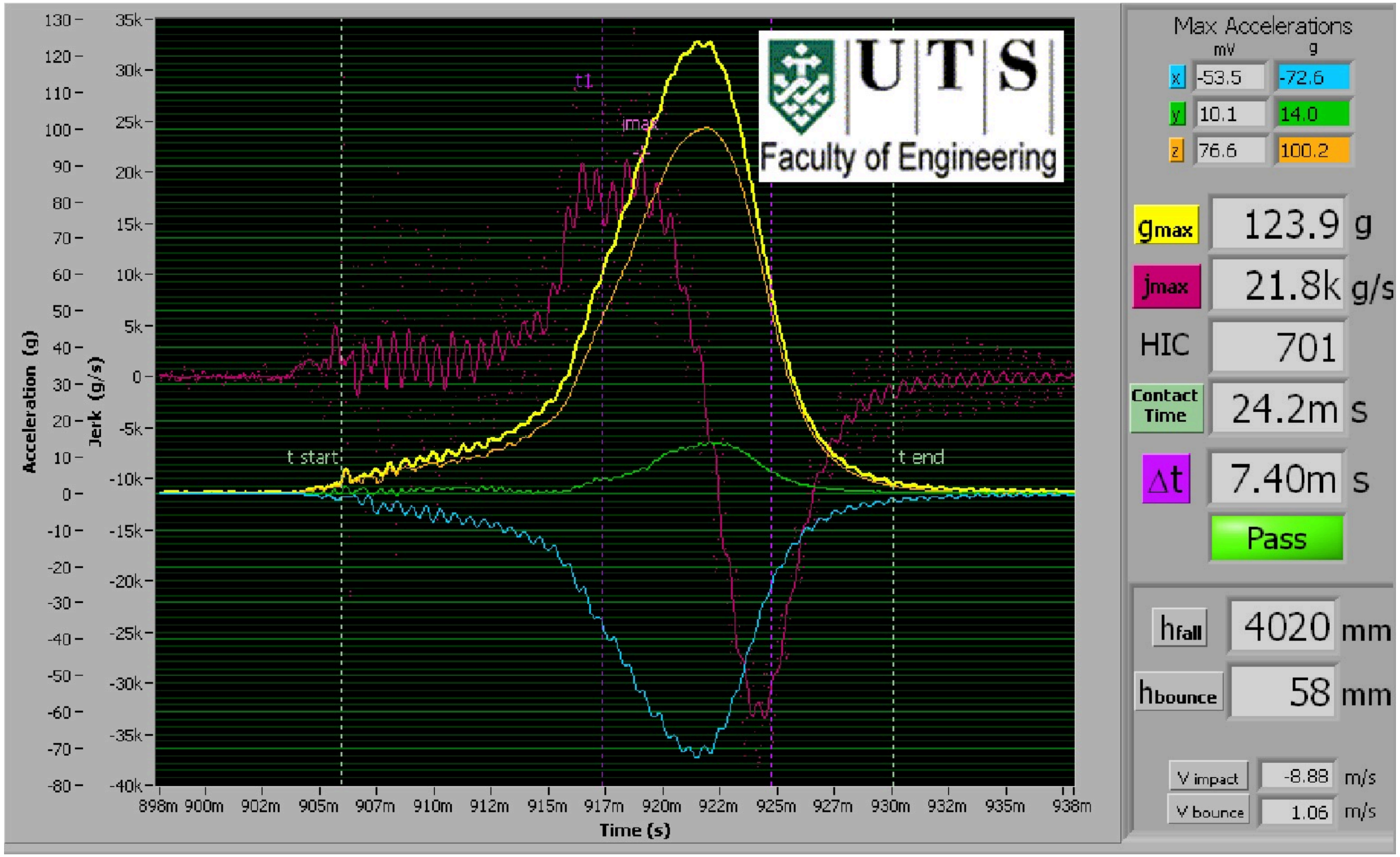
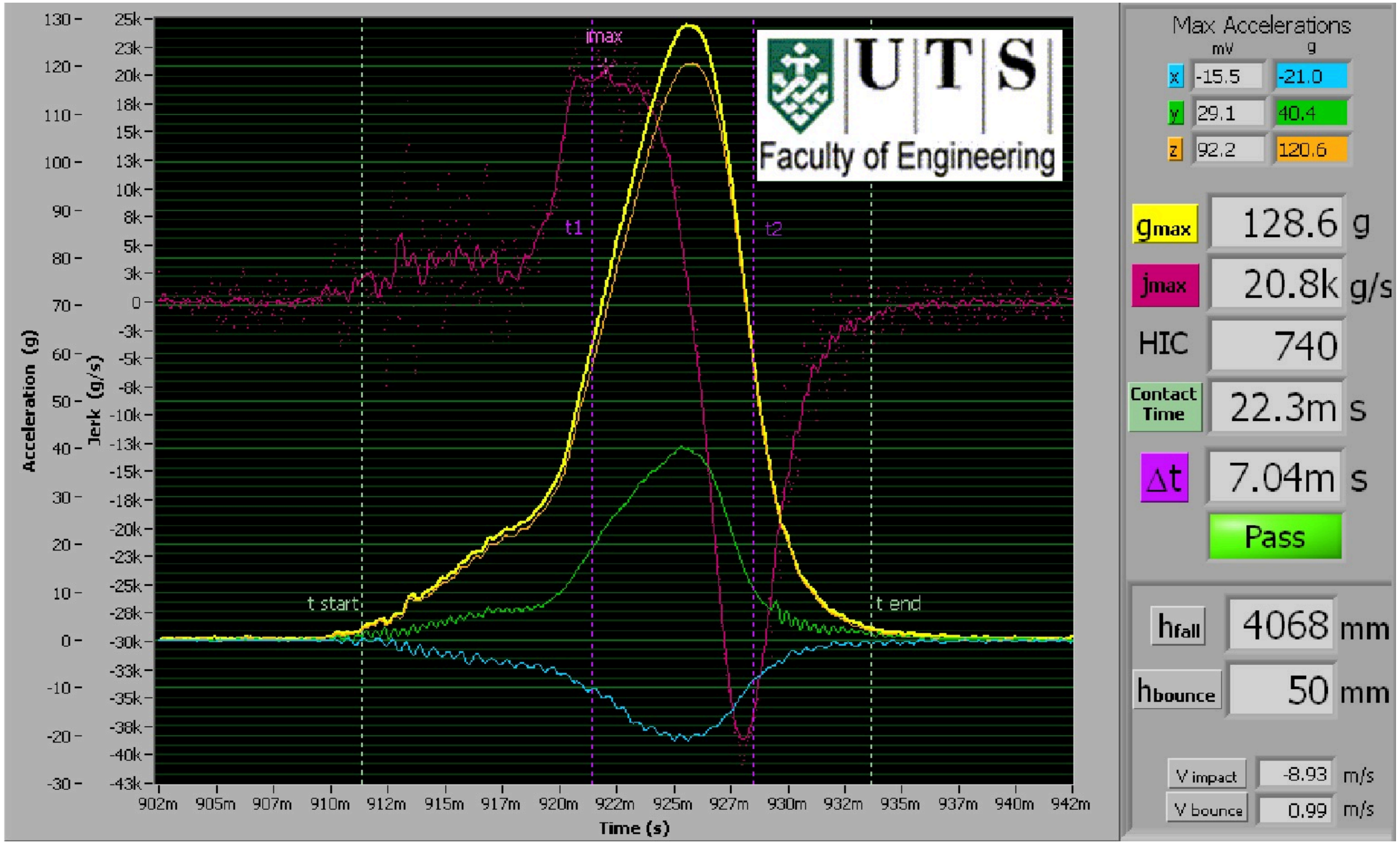
# IAS behaviour during impact – dry bark




**Bark (WA dry): Acceleration v Time**

**3rd drop in same location @ 4 m FHoF**

# IAS behaviour during impact – dry bark




**Bark (WA dry): Acceleration v Time**

**4th drop in same location @ 4 m FHoF**

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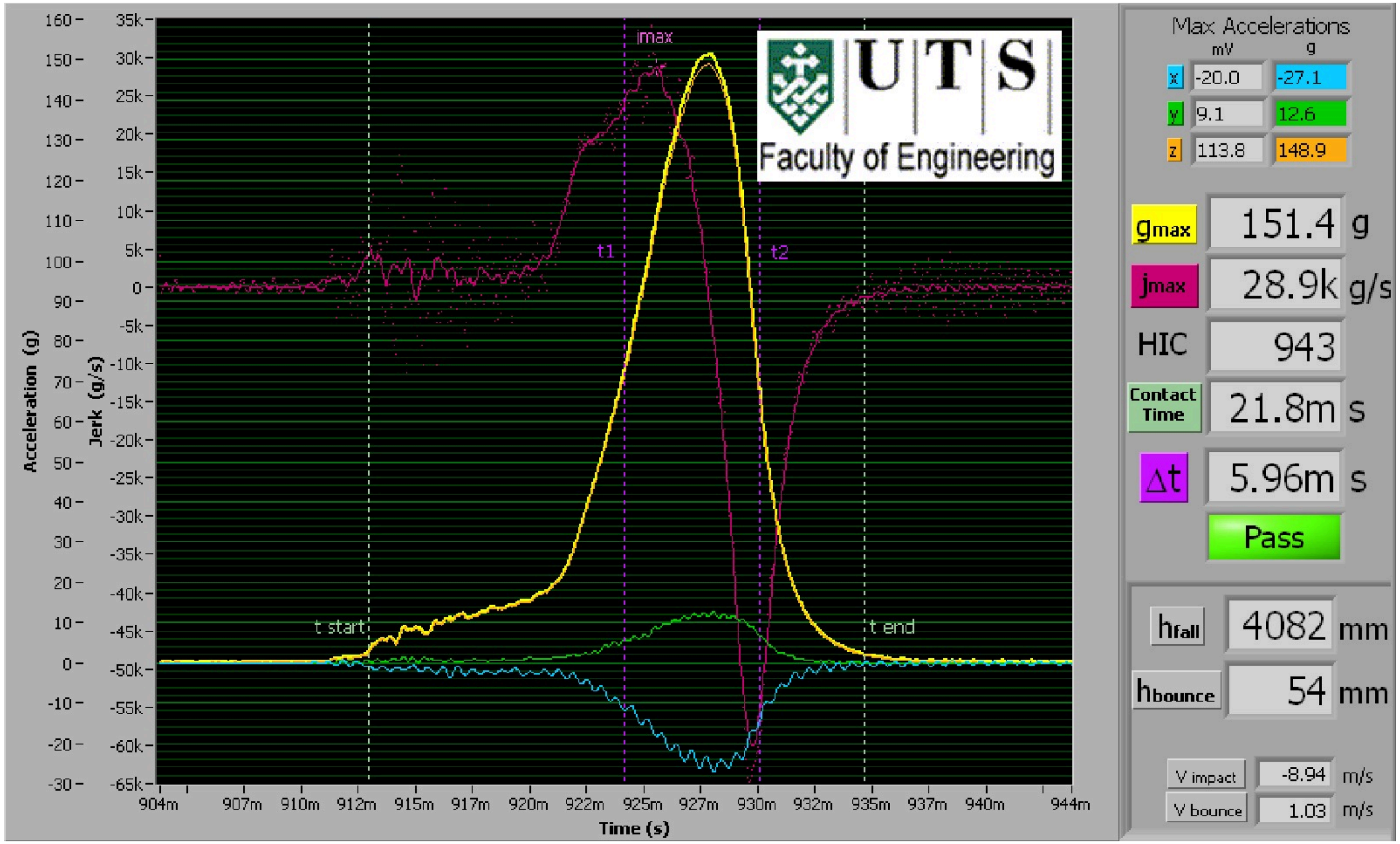
# IAS behaviour during impact – dry bark




**Bark (WA dry): Acceleration v Time**

**5th drop in same location @ 4 m FHoF**

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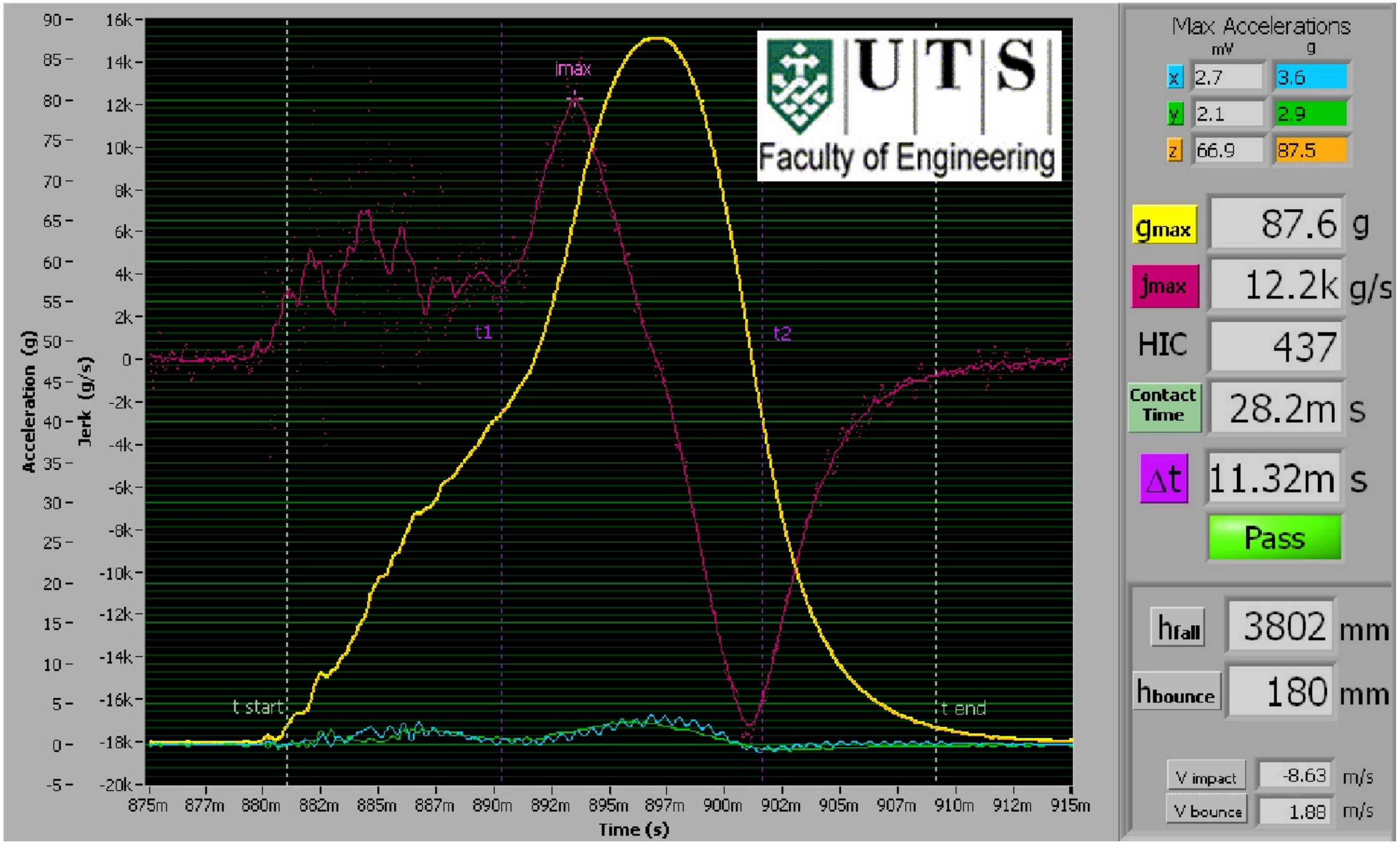
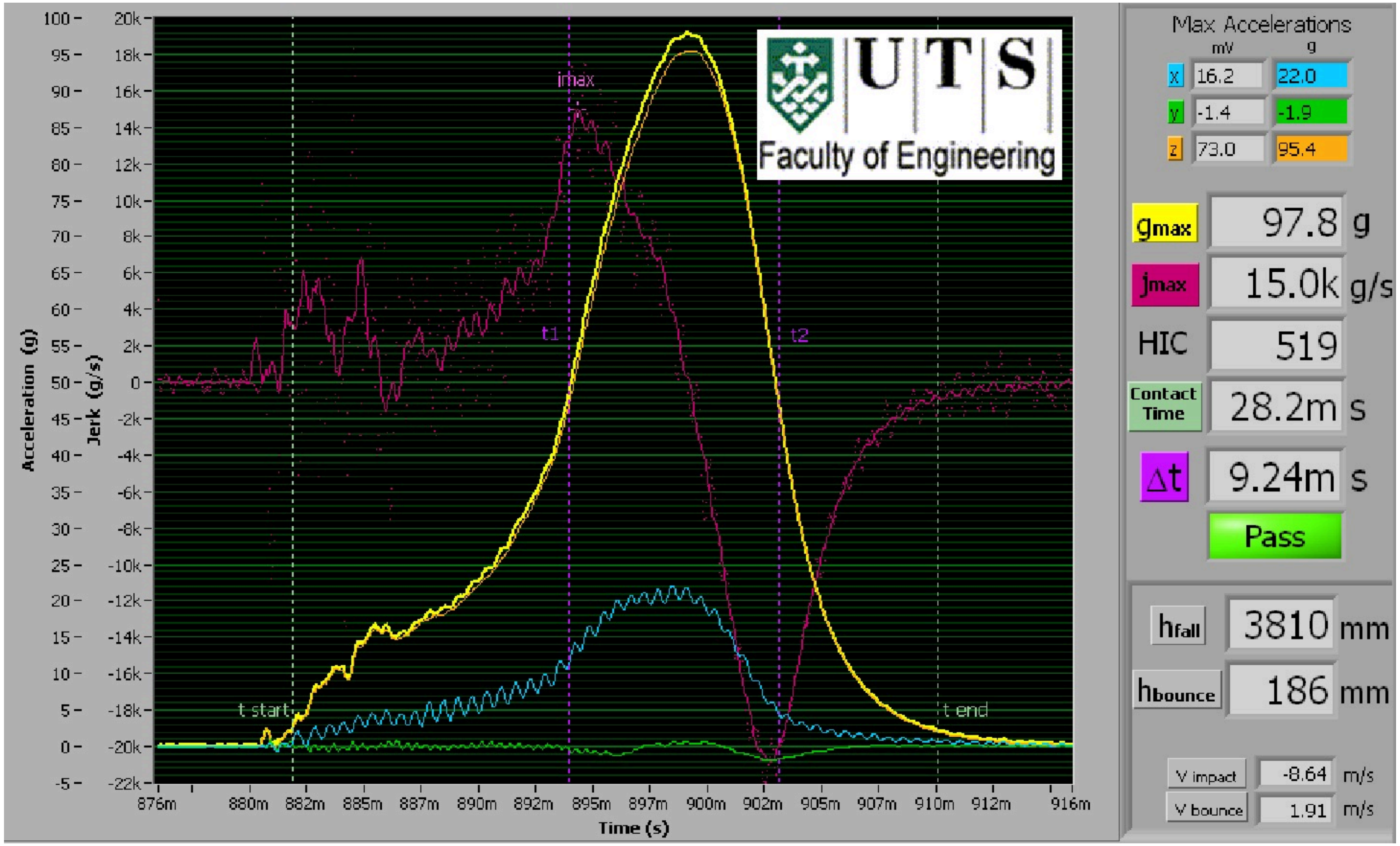
# IAS behaviour during impact – wet bark




**Bark (WA wet): Acceleration v Time**

**1st drop in same location @ 3.8 m FHoF**

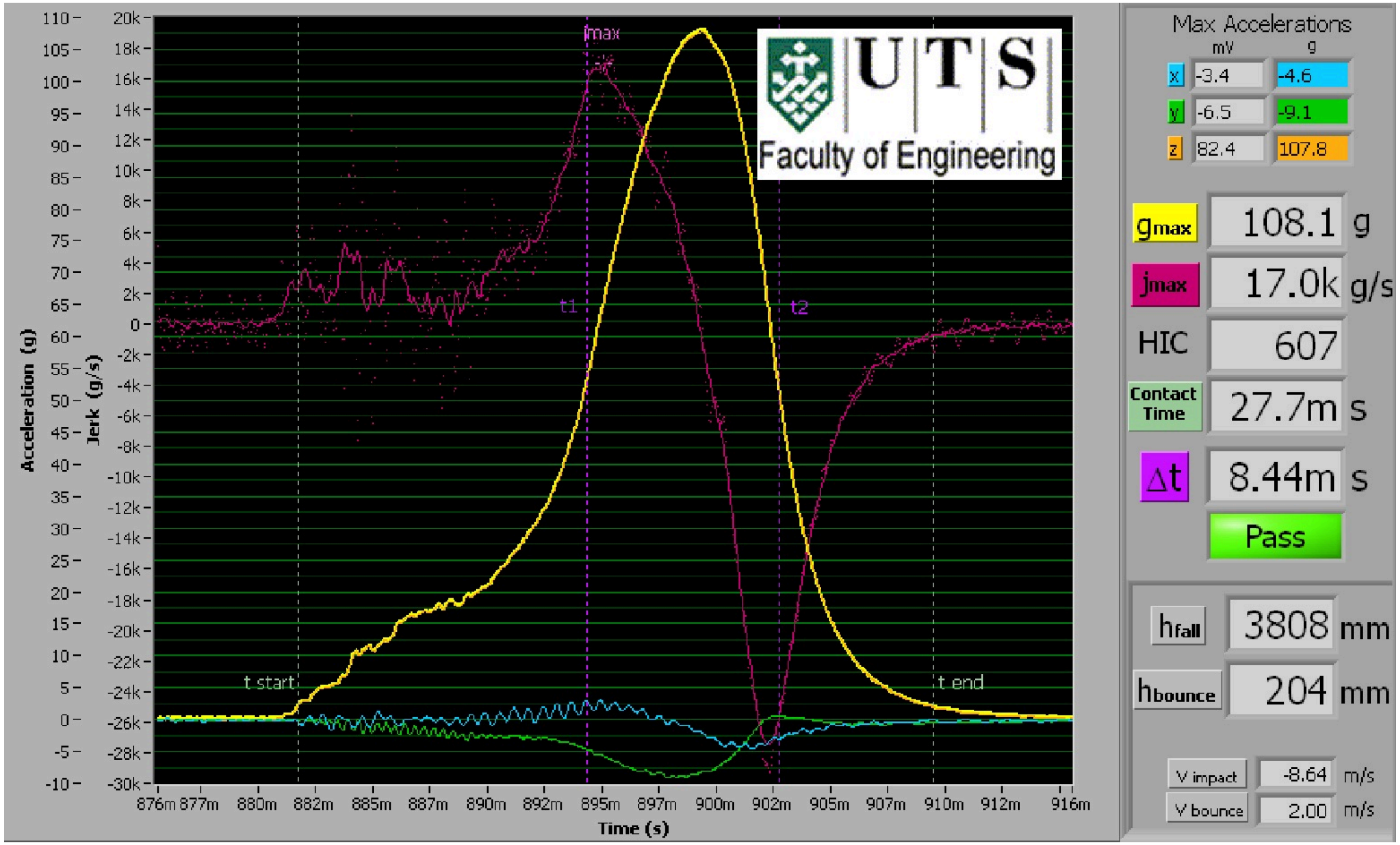
# IAS behaviour during impact – wet bark




**Bark (WA wet): Acceleration v Time**

**2nd drop in same location @ 3.8 m FHoF**

# IAS behaviour during impact – wet bark




**Bark (WA wet): Acceleration v Time**

**3rd drop in same location @ 3.8 m FHoF**

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# Properties of loose-fill surfaces

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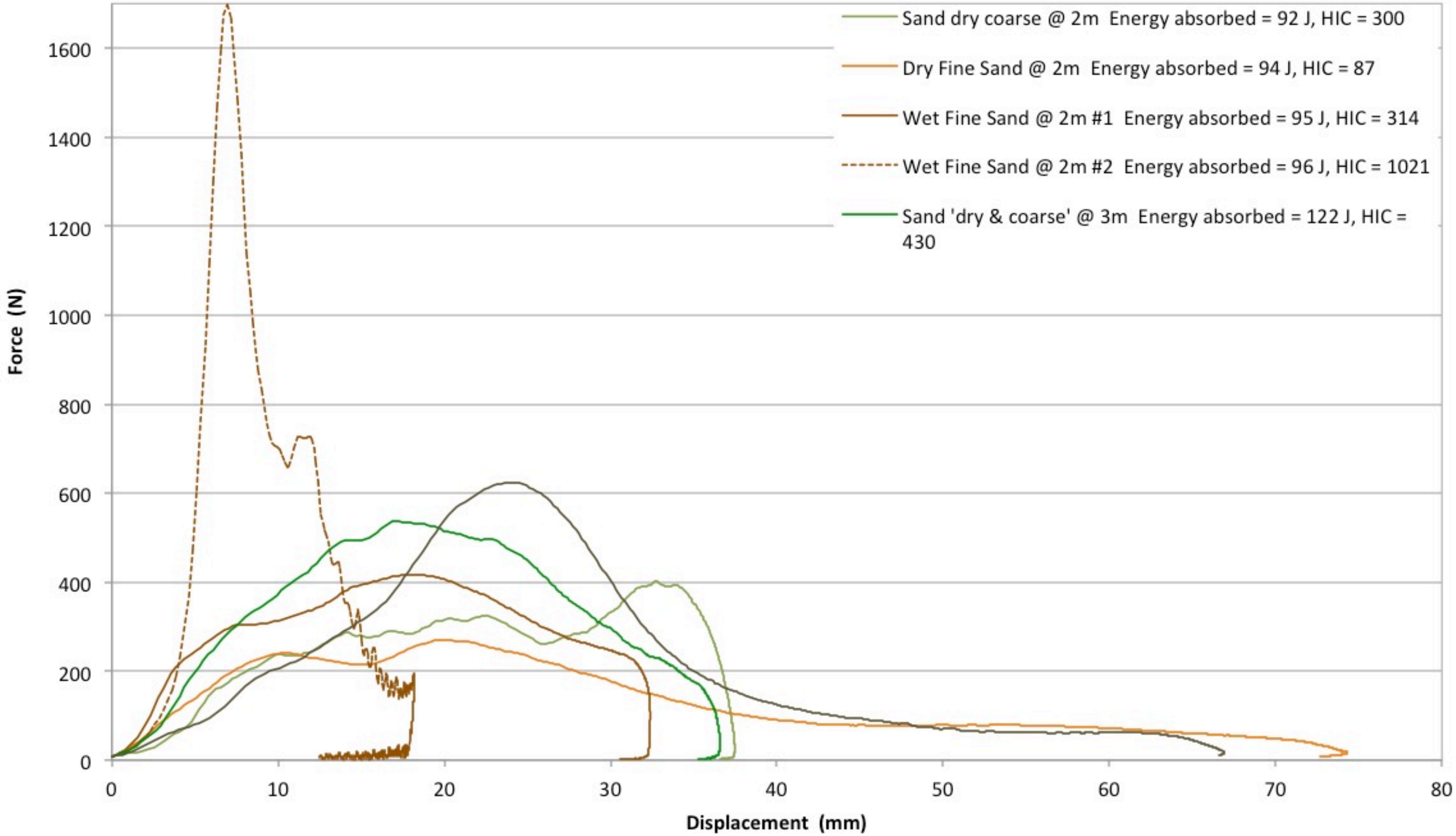


**Force v Displacement hysteresis curves**

**Wet, dry, course & fine sand @ 2 m & 3 m FHoF**

# Properties of loose-fill surfaces

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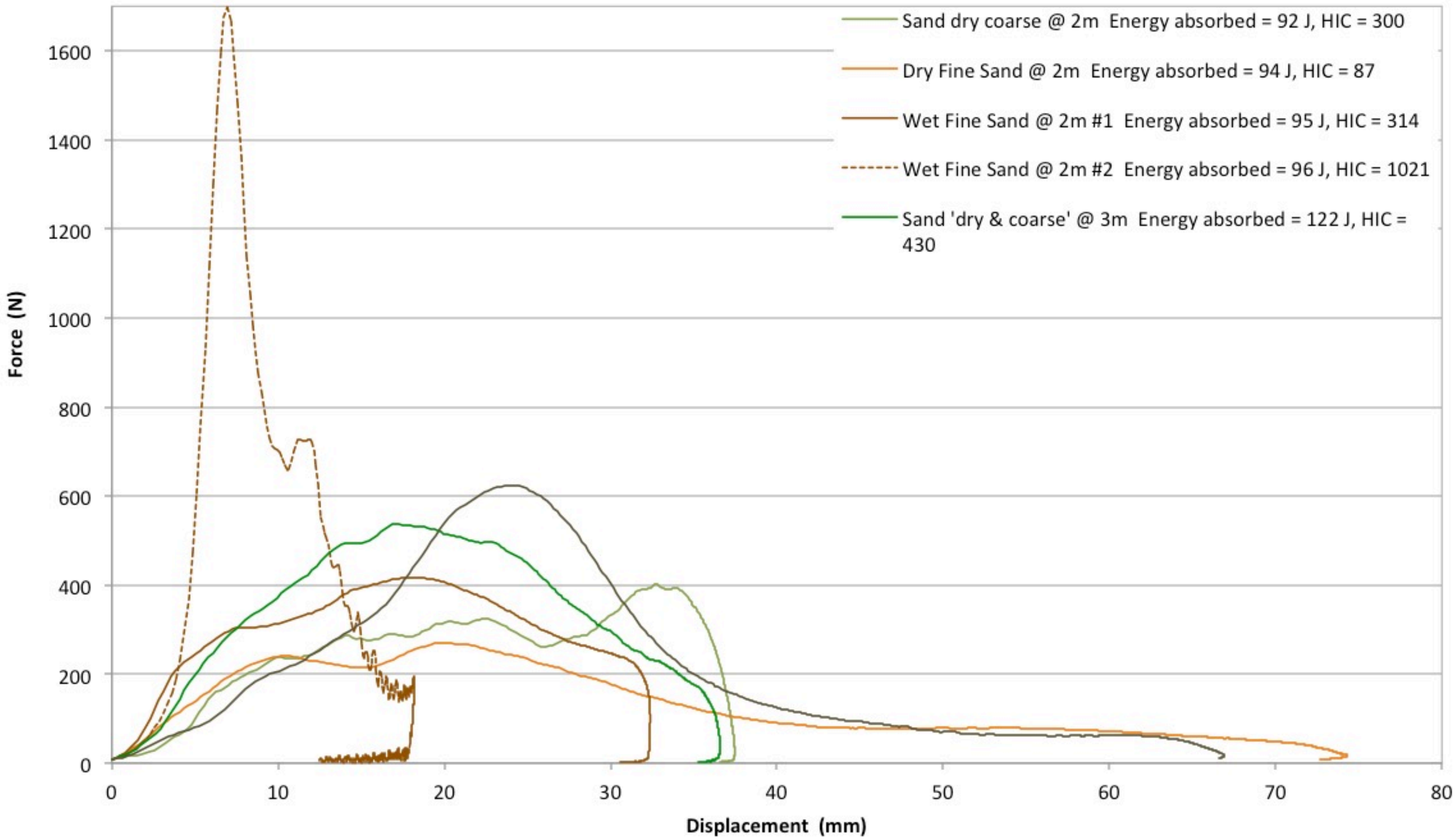


**Force v Displacement hysteresis curves**

**rubber & bark @ 1 m FHoF**

# Properties of loose-fill surfaces

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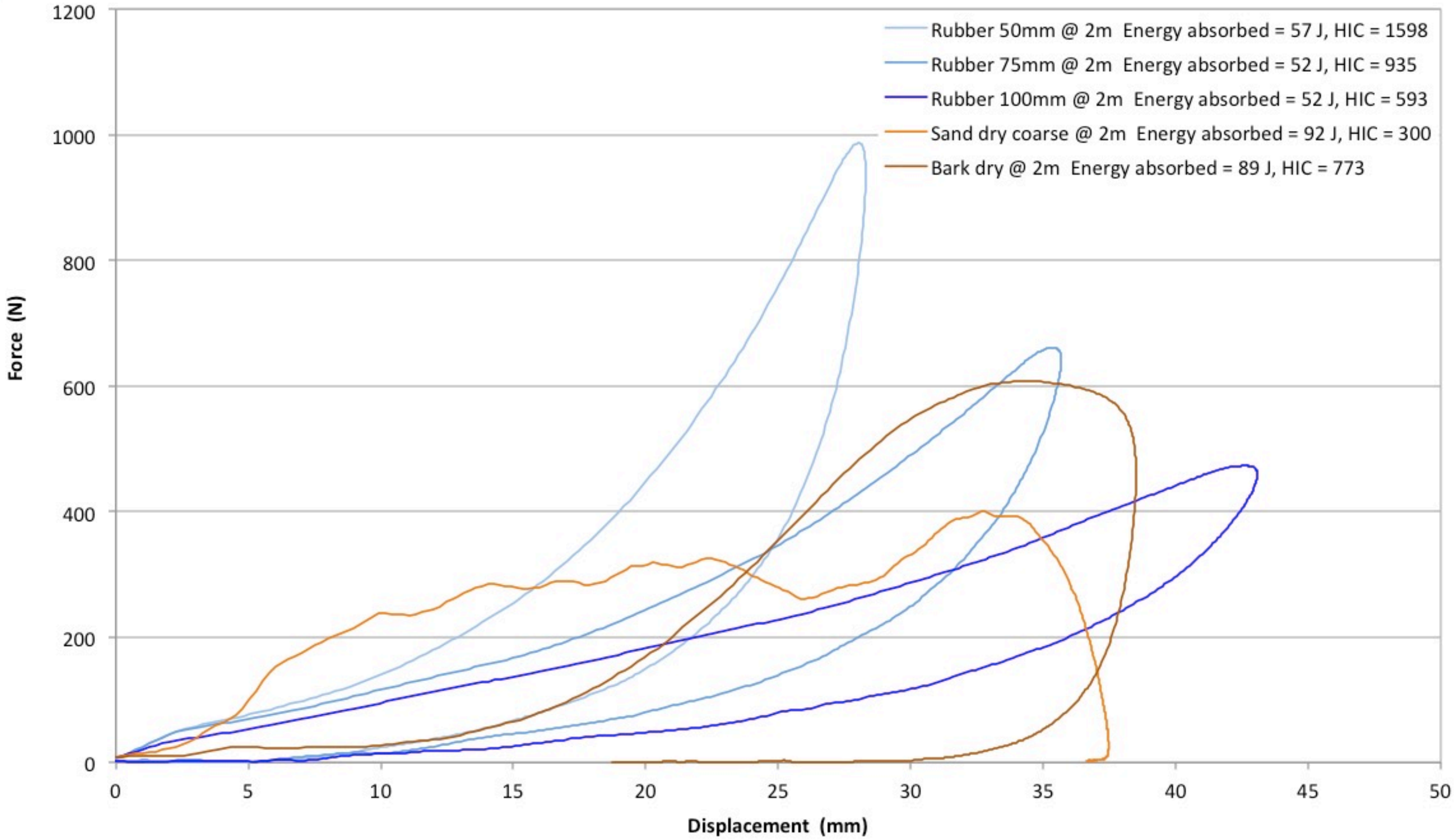
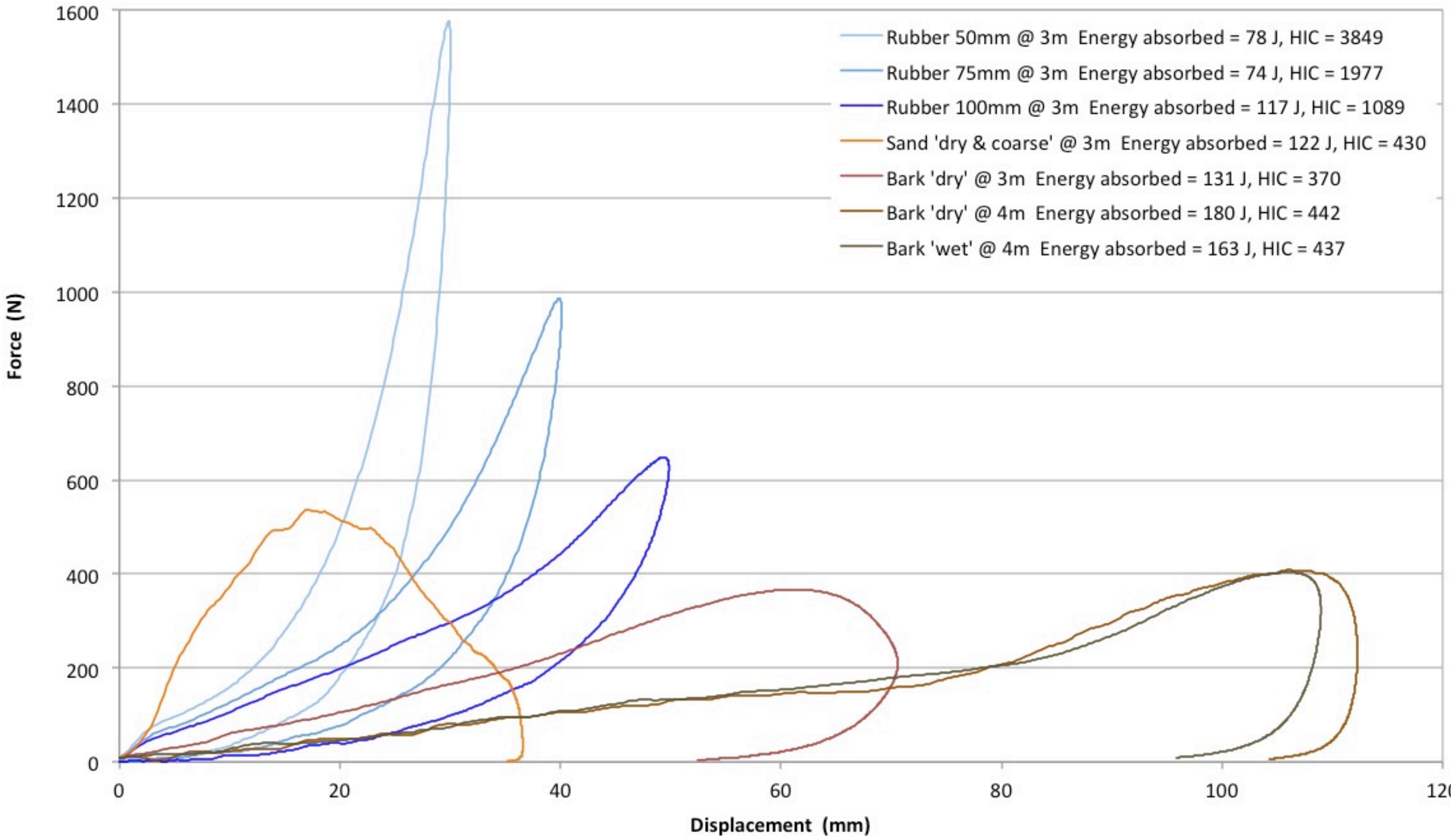



**Force v Displacement hysteresis curves**

**rubber & bark @ 2 m FHoF**

# Properties of loose-fill surfaces




**Force v Displacement hysteresis curves**

**rubber & bark @ 3 m & 4 m FHoF**



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# Properties of loose-fill surfaces

| IAS Product | FHoF | HIC | % work |
|---|---|---|---|
| Rubber 50mm | 1.0 | 511 | 0.51 |
| Rubber 100mm | 1.0 | 218 | 0.51 |
| Rubber 75mm | 1.0 | 307 | 0.53 |
| Rubber 75mm | 3.0 | 1977 | 0.55 |
| Rubber 75mm | 2.0 | 935 | 0.57 |
| Rubber 100mm | 2.0 | 593 | 0.57 |
| Rubber 50mm | 3.0 | 3849 | 0.58 |
| Rubber 50mm | 2.0 | 1598 | 0.63 |
| Rubber 100mm | 3.0 | 1089 | 0.86 |
| Sand dry course 200mm | 3.0 | 430 | 0.90 |
| Bark wet 200mm #1 | 3.8 | 437 | 0.95 |
| Bark dry 200mm #1 | 3.0 | 370 | 0.97 |
| Bark dry 200mm #1 | 2.0 | 773 | 0.97 |
| Bark dry 200mm #1 | 4.1 | 442 | 0.98 |
| Sand fine & dry 200mm #1 | 2.1 | 87 | 1.00 |
| Bark dry 200mm #1 | 1.0 | 597 | 1.00 |
| Sand fine & dry 200mm #3 | 3.1 | 364 | 1.00 |
| Sand fine & wet 200mm #1 | 2.1 | 314 | 1.00 |
| Sand fine & wet 200mm #2 | 2.1 | 1021 | 1.00 |
| Sand dry course 200mm | 2.0 | 300 | 1.00 |

**Percentage work performed by IAS**

**(rubber, bark & sand @ 1m, 2m, 3 m & 4 m FHoF)**

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# Properties of loose-fill surfaces – Bark

- **For bark IAS the following is recommended:**
  - Good site preparation
  - Only install on level ground
  - Install to minimum depth of 400 mm
  - Install over heavy duty geotextile membrane
  - Provide adequate sub-surface drainage
  - Fibrous bark has no sharp, pointed or large elements
  - Don’t rotary hoe as this disturbs subsurface stratum and can bury or mix contaminates
- **Research has confirmed that decomposition improves the impact attenuation properties – so don’t discard every year, let your bark decompose and mature like a good red wine**

# Manufactured wood IAS

**This is not an IAS material !!!**

# Natural and loose-fill surfaces



- ✔ **Many different types of sand exist and they are not all suitable for use as IAS within playgrounds**





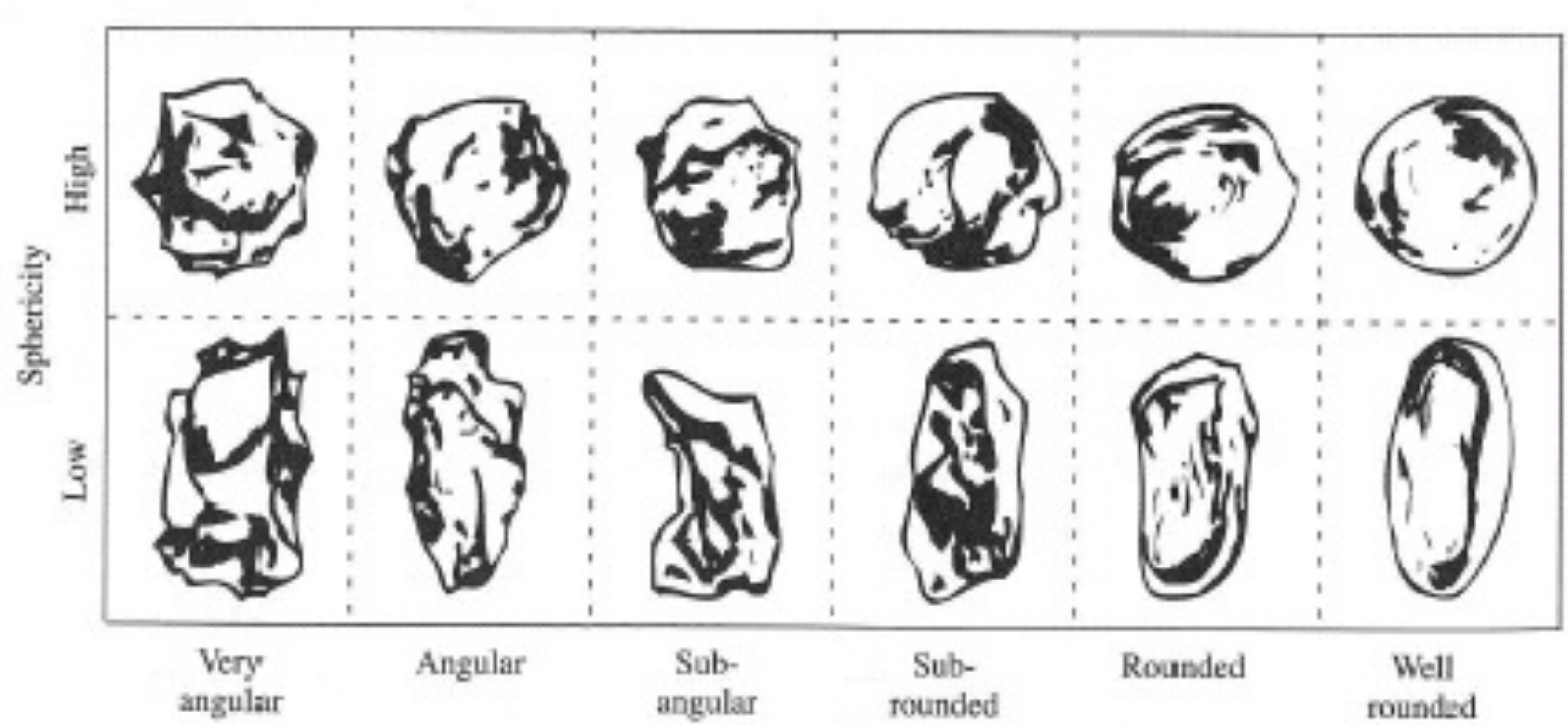


# Properties of loose-fill surfaces – Sand



✔ **Particle shape – roundness and sphericity are important**

- Angular particles compact and bind together
- Rounded particles flow when impacted



# Properties of loose-fill surfaces – Sand

✔ **Particles all the same size**

- The coefficient of uniformity must not exceed 2.75
- Recommend coefficient of uniformity  < 2.00
- IAS Sand can be contaminated when topping up during maintenance by mixing two high quality sands of different grading size ie fine sand with a coarse sand
- Assessment is by way of mechanical sieve analysis

# Properties of loose-fill surfaces – Sand

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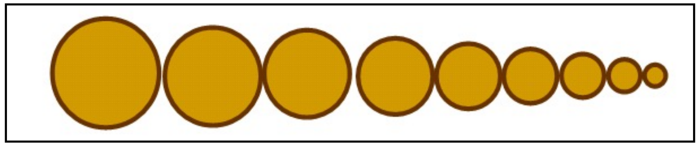
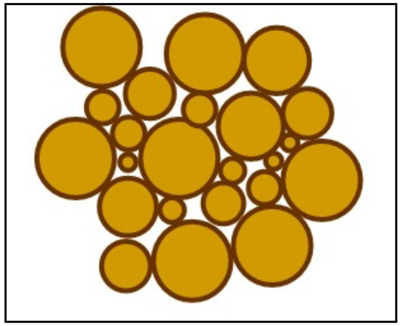
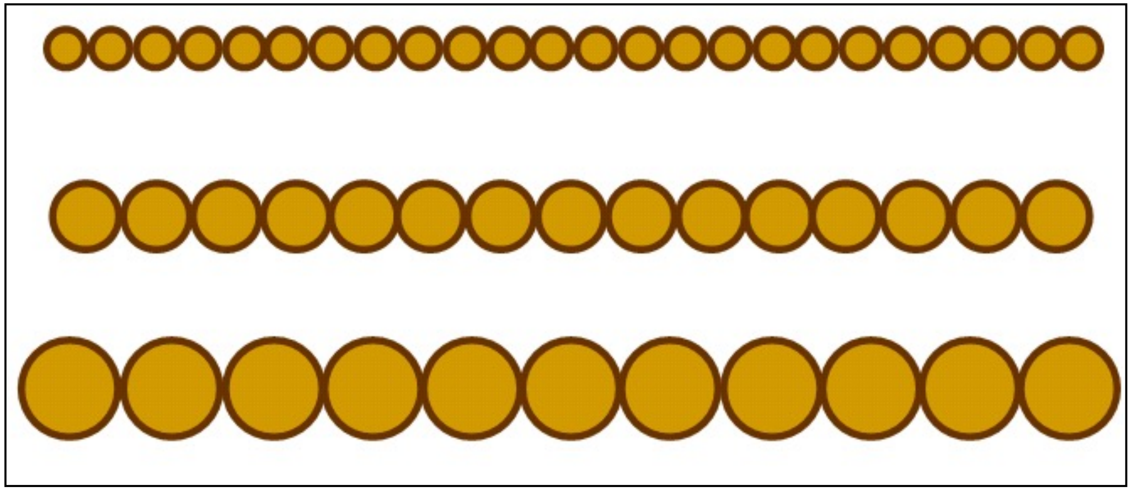
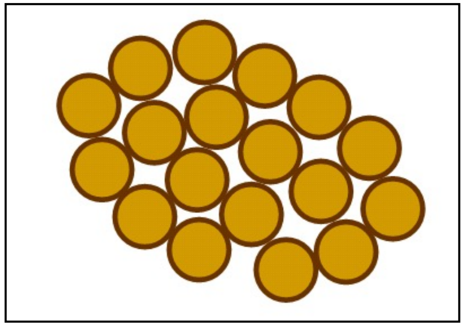
X **Well graded sand is undesirable as a playground IAS**





✔ **Uniformly graded sand is desirable as a playground IAS**





## Properties of loose-fill surfaces – Sand

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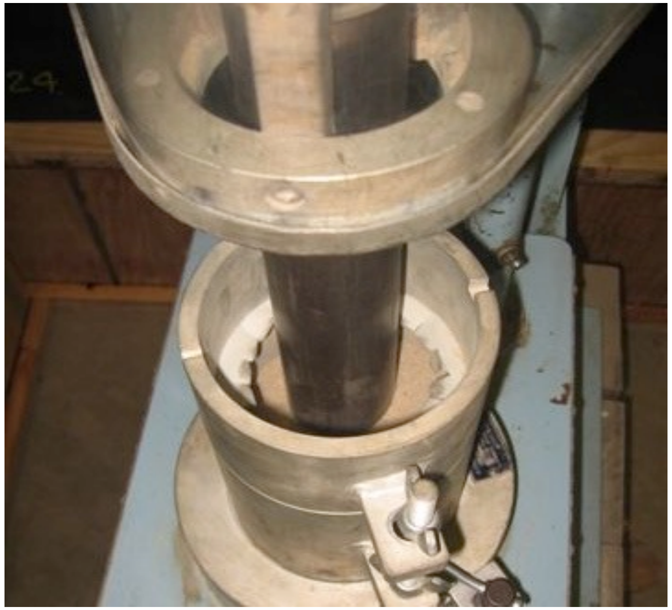
✔ **No fines**

- Fines cause agglomeration of particles
- Fines cause airborne dust
- Fines make hands and clothes dirty

# Properties of loose-fill surfaces – Sand

✔ **Low degradation**

- Degradation occurs over time through playground usage
- Changes the particle size distribution
- Increase the percentage of fines
- Increase the coefficient of uniformity
- Test by accelerated ageing



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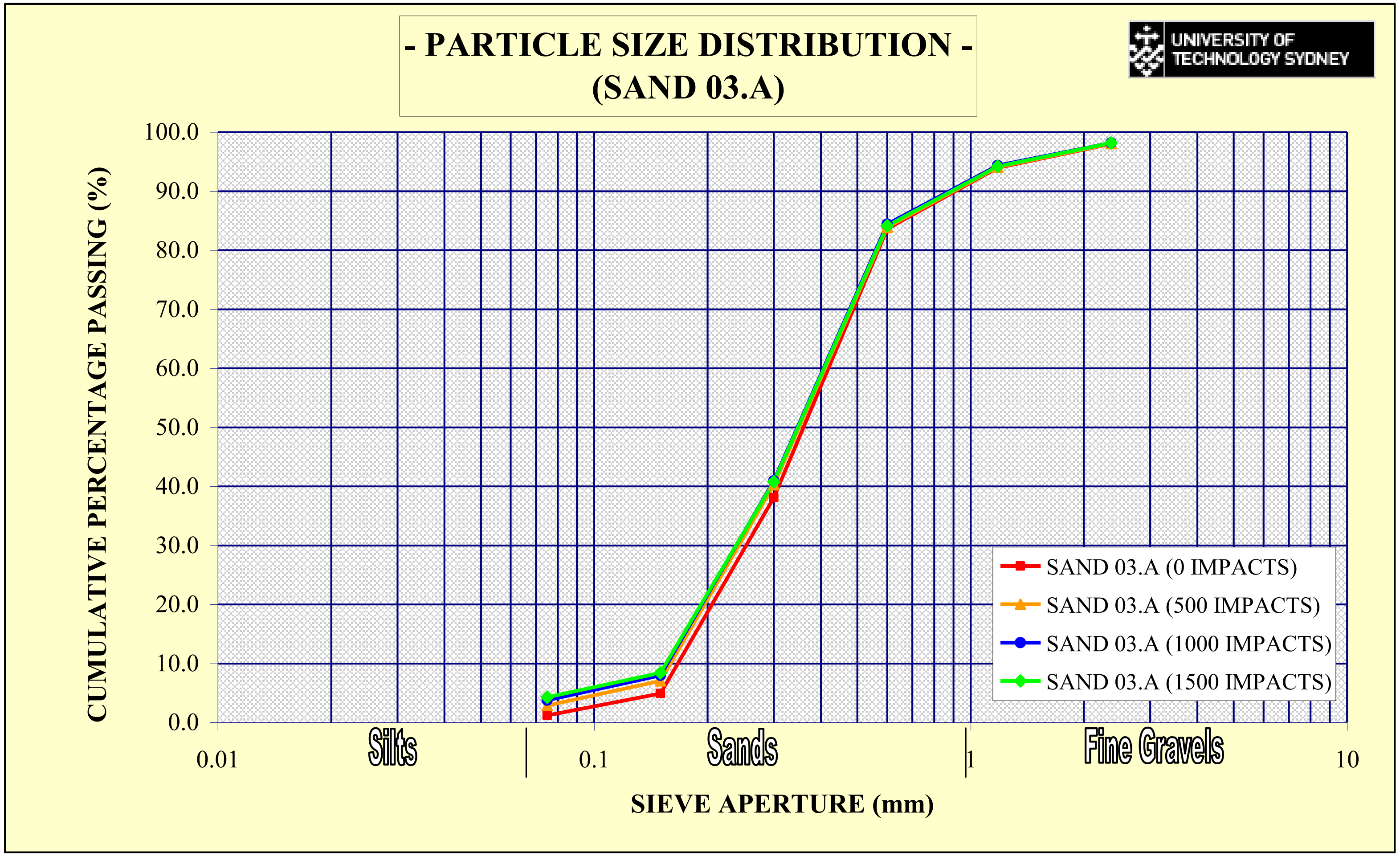
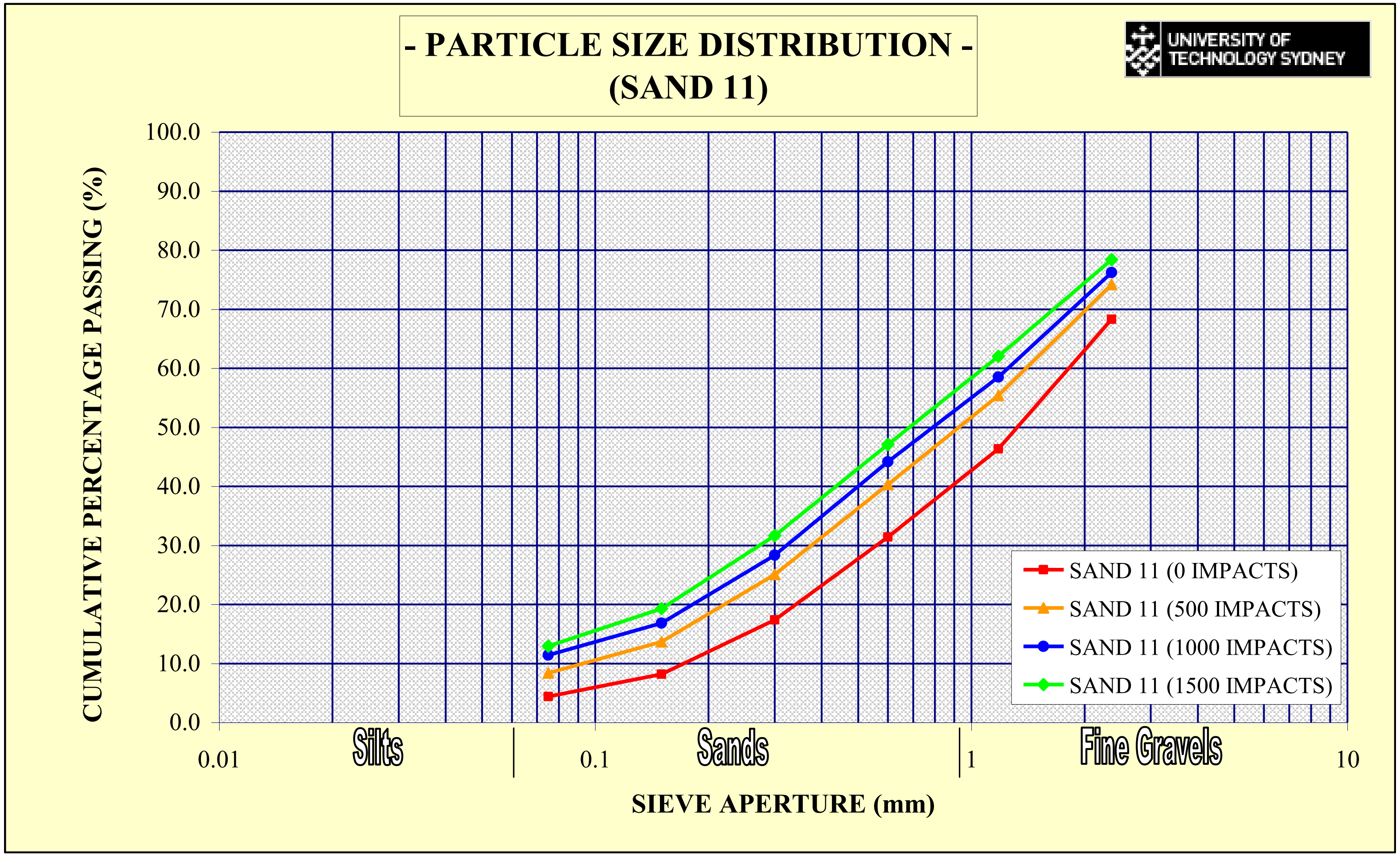
# Properties of loose-fill surfaces – Sand

## ✓ Low degradation – good example



# Properties of loose-fill surfaces – Sand

✔ **Low degradation – poor example**

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# Properties of loose-fill surfaces – Sand

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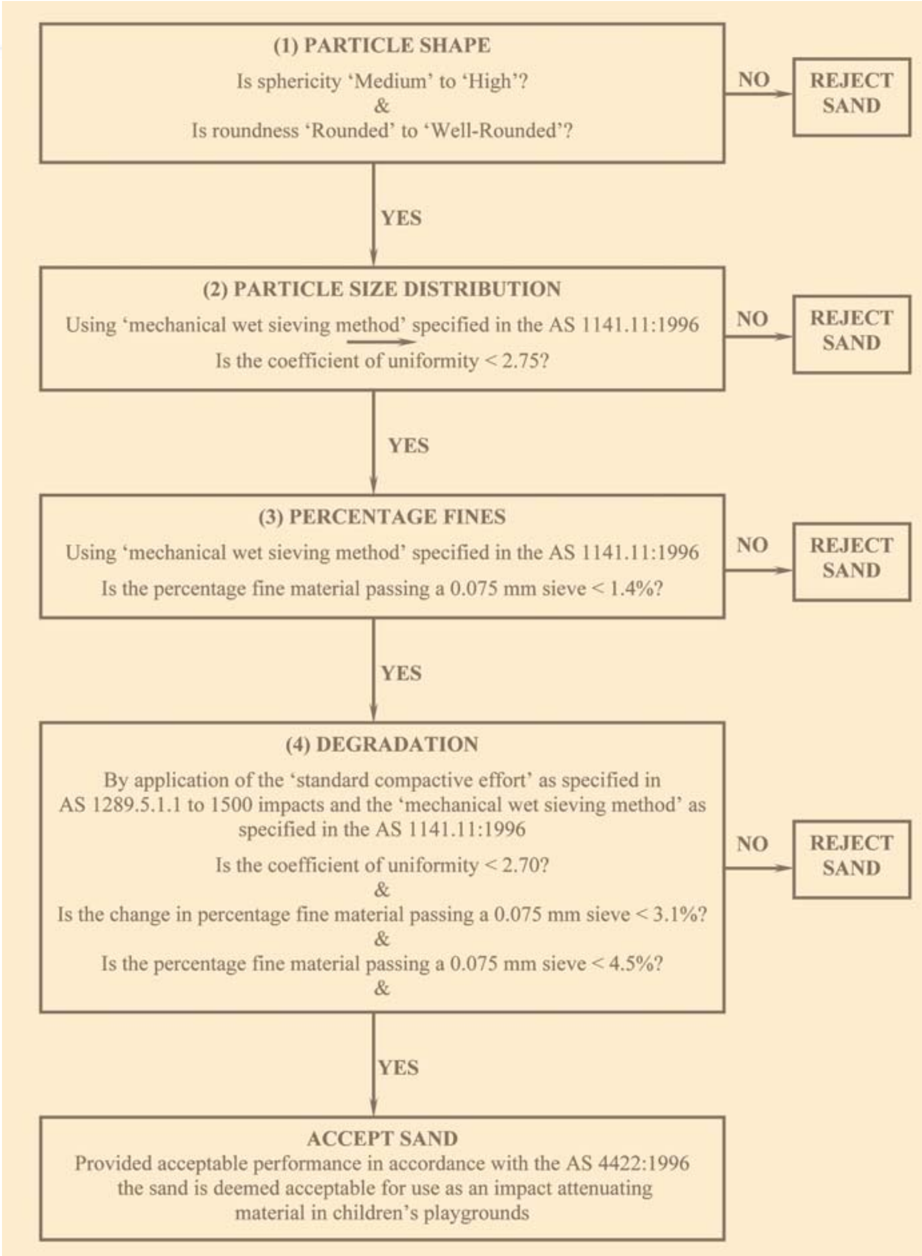
✔ **No solubles**

- Solubles cause agglomeration of particles
- Solubles act as a binder or glue
- Causes sand to crust and cake
- Washing reduces solubles
- Watch out for solubles created during degradation

# Sand selection process flow chart



# Maintenance of sand IAS

**In-situ sieving using portable vibrating sieve**

# Maintenance of sand IAS

**In-situ sieving using portable vibrating sieve**

# Maintenance of sand IAS


In-situ sieving using portable vibrating sieve

# Maintenance of sand IAS


**In-situ sieving using portable vibrating sieve**

# Maintenance of sand IAS


**In-situ sieving using portable vibrating sieve**

# Maintenance of sand IAS



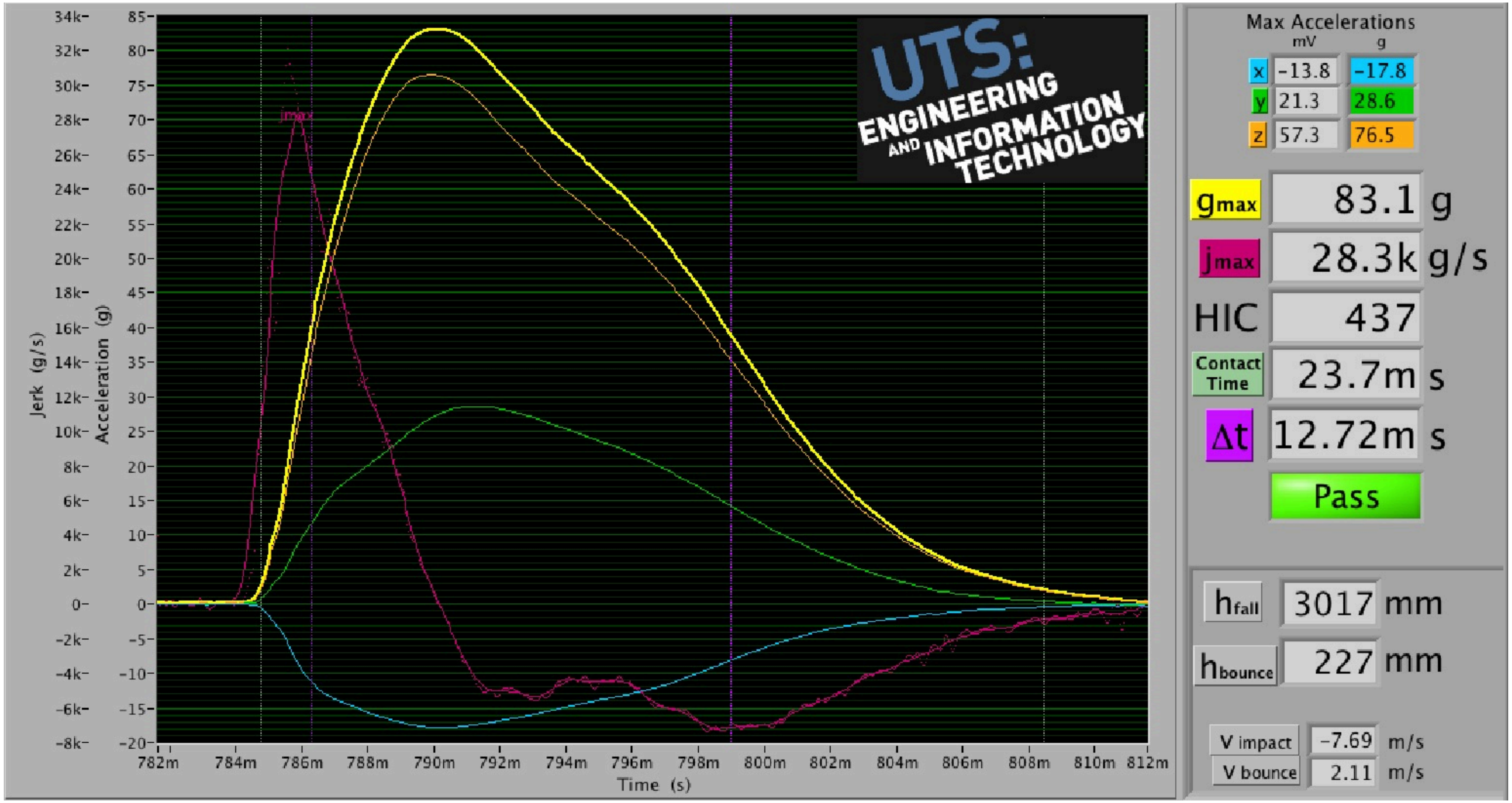

**In-situ sieving using portable vibrating sieve**

# Maintenance of bark IAS

**Bark only topped up & not 'fluffed' (compacted in better)**

**> 12 months low travel area**

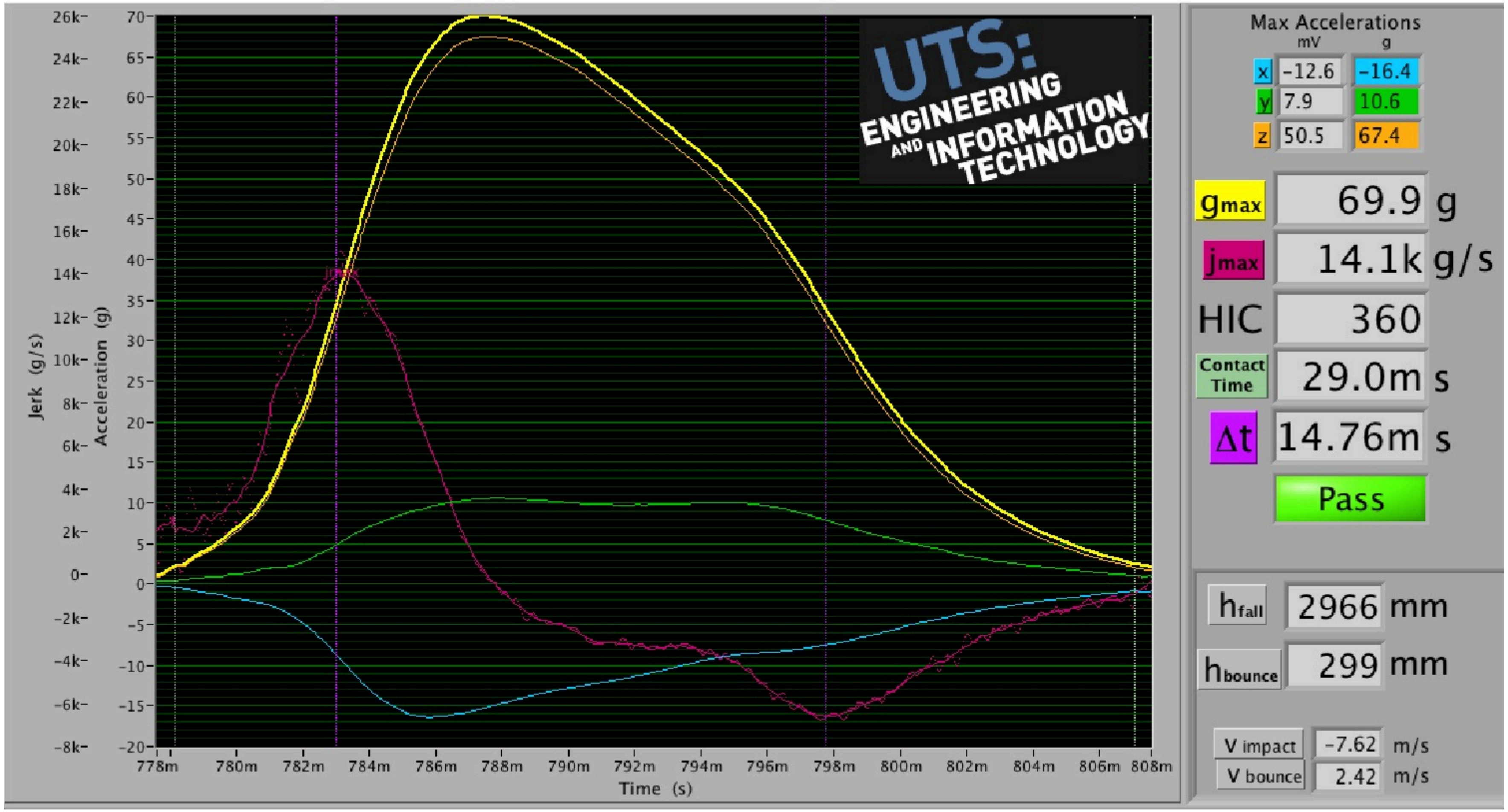
# Maintenance of bark IAS




**Bark 'unfluffed' > 12 months: Acceleration v Time**

**Low traffic – 1st drop in same location @ 3 m FHoF**

# Maintenance of bark IAS




**Bark 'unfluffed' > 12 months: Acceleration v Time**

**Low traffic – 4th drop in same location @ 3 m FHoF**

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# Maintenance of bark IAS

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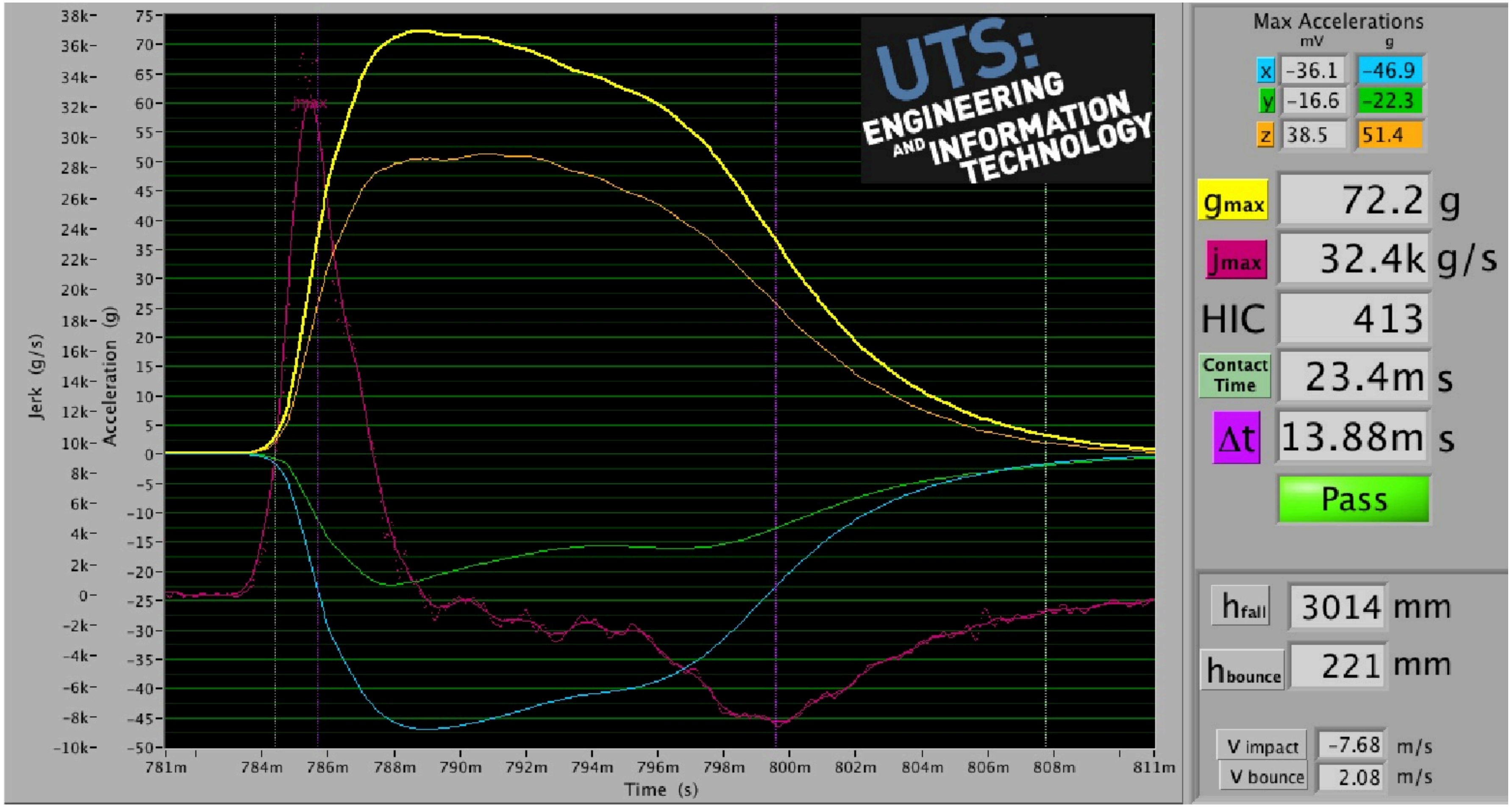
**Bark only topped up & ‘unfluffed’ (compacted)**

**> 12 months high travel area**

# Maintenance of bark IAS




**Bark ‘unfluffed’ > 12 months: Acceleration v Time**

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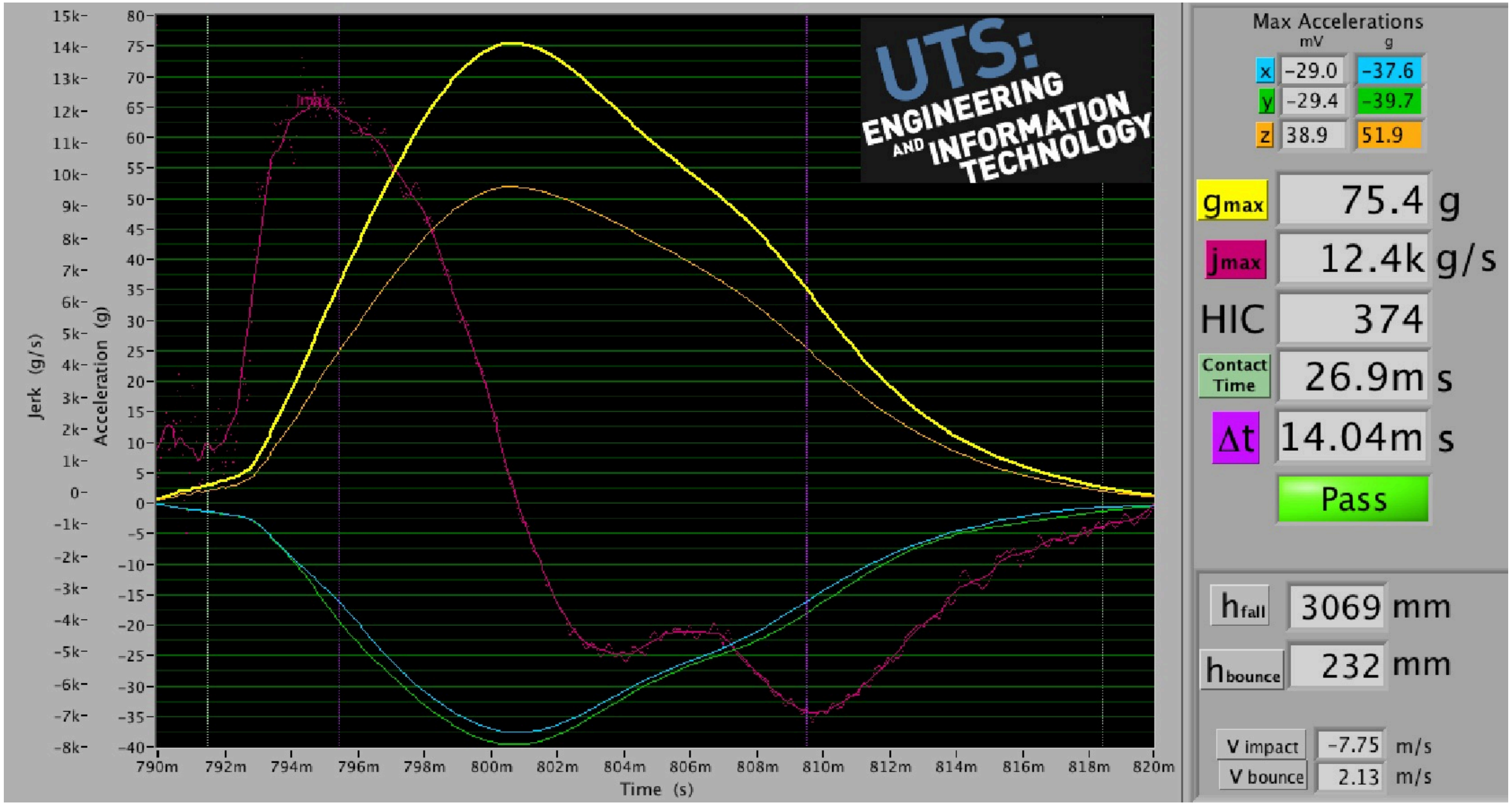
# Maintenance of bark IAS




**Bark 'unfluffed' > 12 months: Acceleration v Time**

**High traffic – 4th drop in same location @ 3 m FHoF**

# Summary

- ✔ **Bark – the following is recommended:**
  - Provided bark is correctly installed to depth of 400 mm there is no need for in-situ testing (if tested in laboratory)
  - Requires little maintenance apart from topping up to maintain 400 mm depth
- ✔ **Sand – in addition to a low HIC the sand shall have the following properties:**
  - Particles well rounded
  - Particles all the same size
  - No fines
  - Low degradation
  - No solubles

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Proudly promoting the value of play and supporting all Australians to play every day

# Natural and loose-fill impact attenuating surfaces for use in children's playgrounds

**Previously presented in Vienna 22 October 2013 at: 'International Conference Playground fall impacts: are the Standards providing adequate safety?'**


**Prof. Ing. Dr. David Eager**

**University of Technology Sydney, Australia**