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TÜV AUSTRIA ACADEMY

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

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

by David Eager *, Chris Chapman, Yujie Qi, Karlos Ishac and Md Imam Hossain

Faculty of Engineering and Information, University of Technology Sydney, Broadway, NSW 2007, Australia

* Author to whom correspondence should be addressed.

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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

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IAS Bark

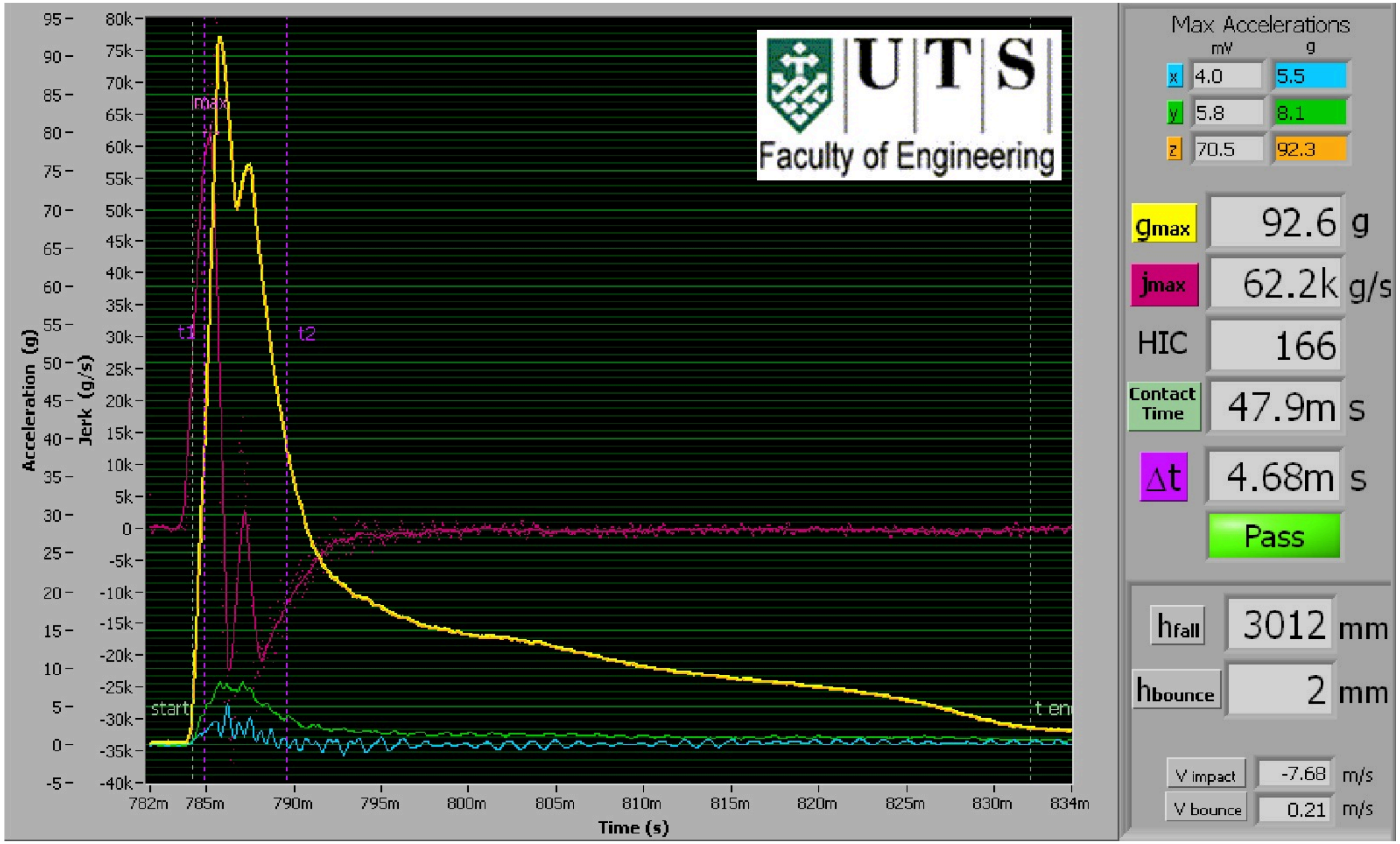
Advantages	Disadvantages	Comments
Low initial cost	Easily displaced in high traffic and near forced movement devices	Reduces ongoing maintenance if designed and installed to 400 mm minimum
Retains excellent impact attenuation properties for many years	Some barks are not suitable for disability access	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		

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	

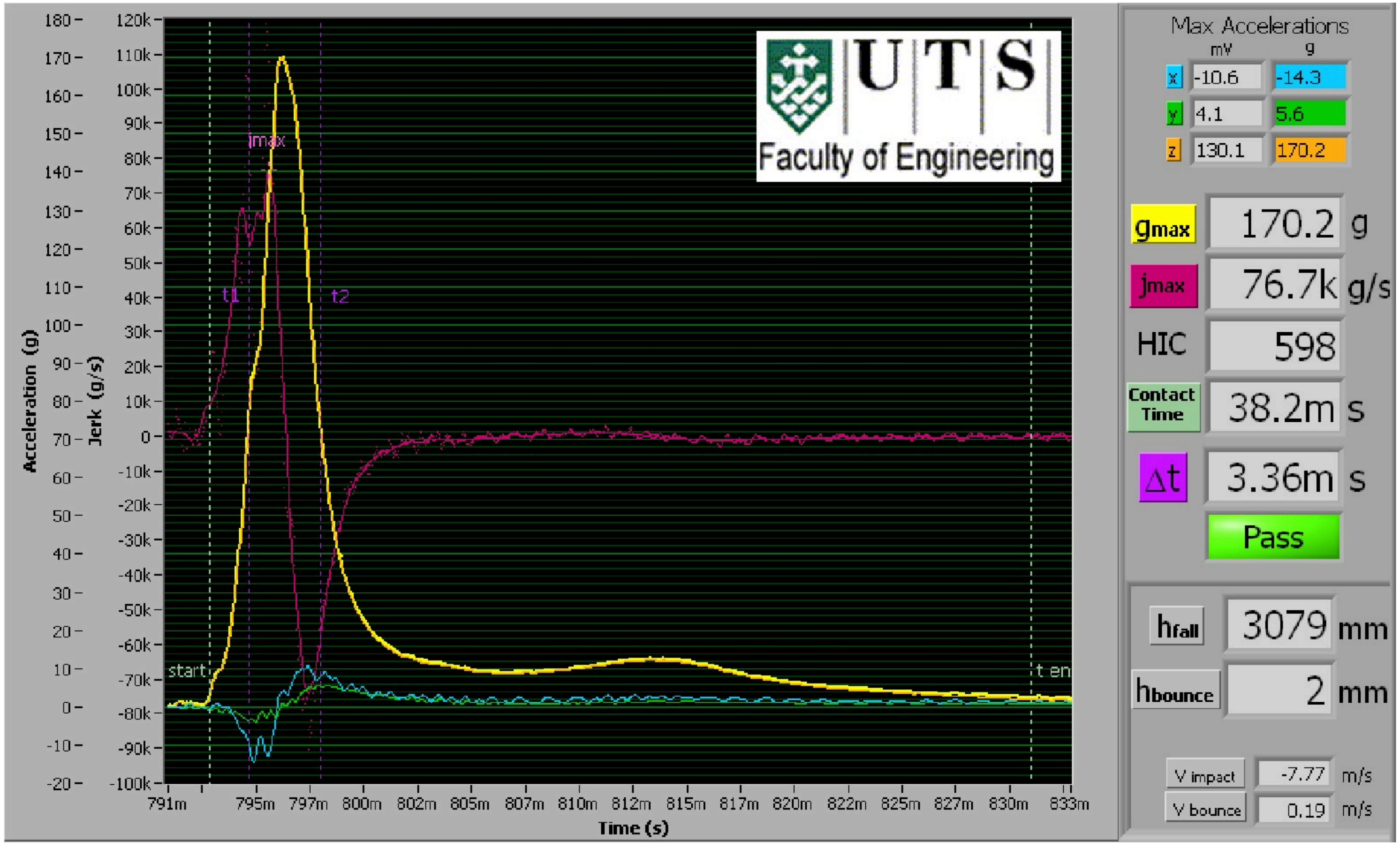
IAS behaviour during impact – dry fine sand



Sand (fine & dry): Acceleration v Time

1st drop in same location @ 3 m FHoF

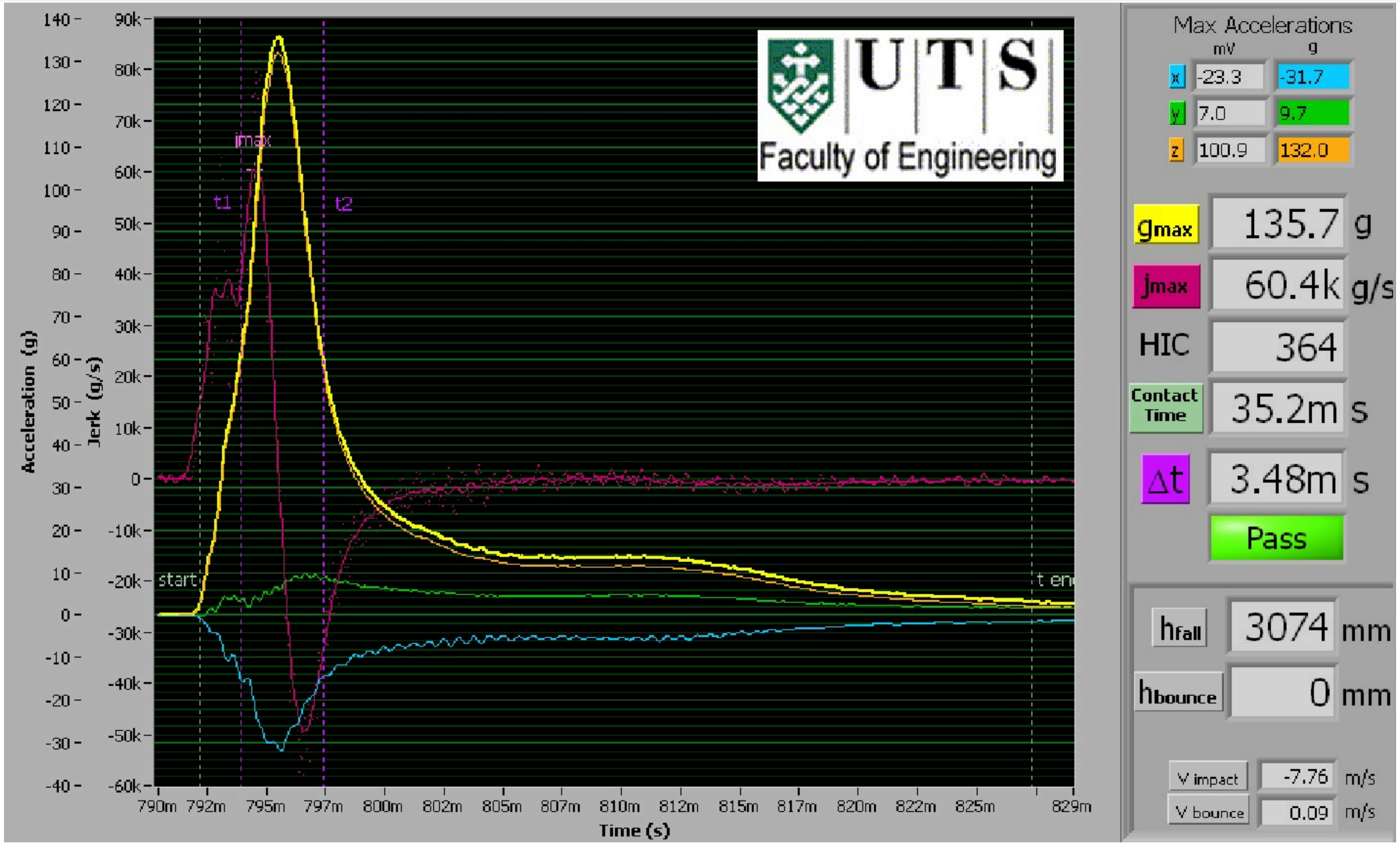
IAS behaviour during impact – dry fine sand



Sand (fine & dry): Acceleration v Time

2nd drop in same location @ 3 m FHoF

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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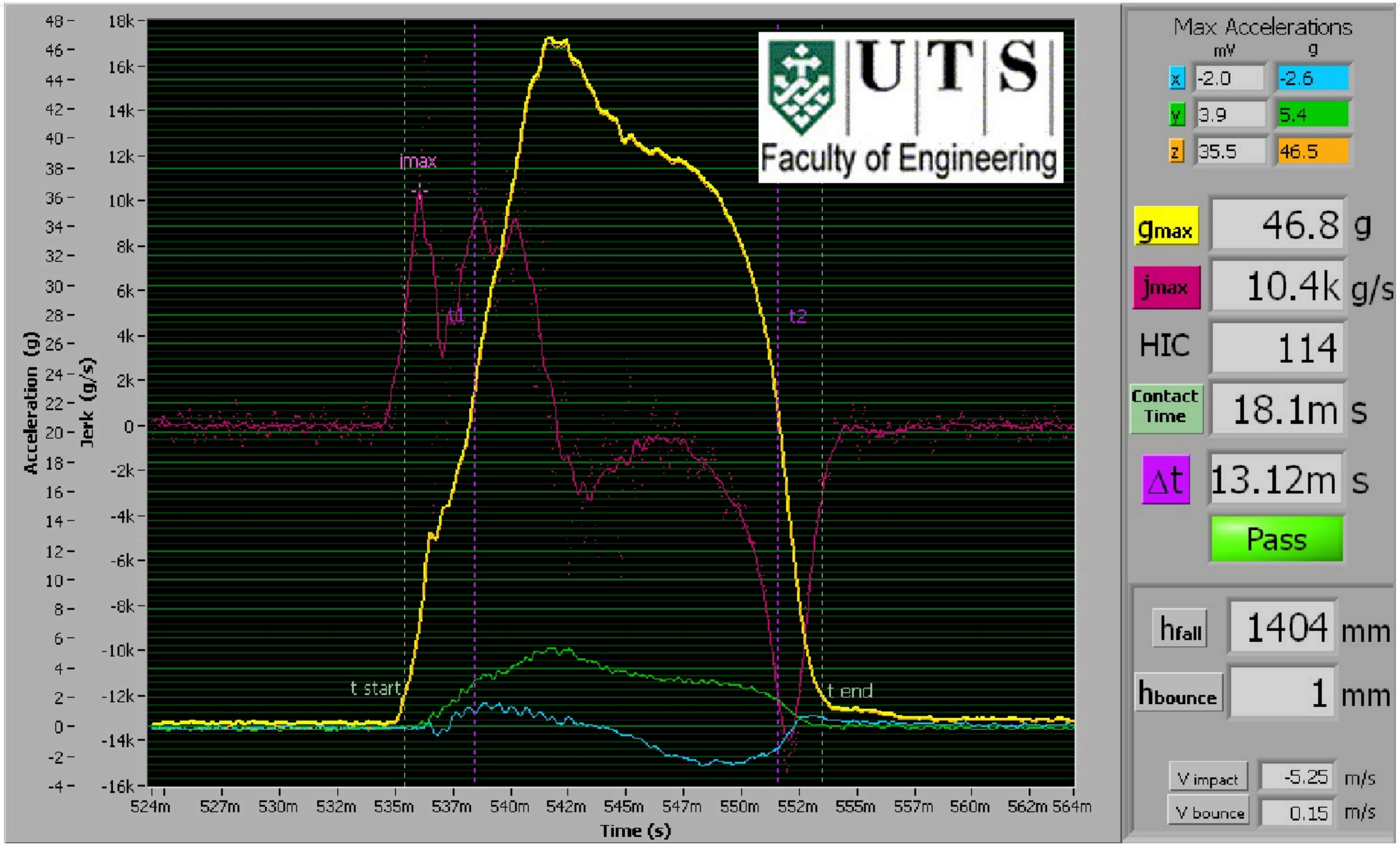
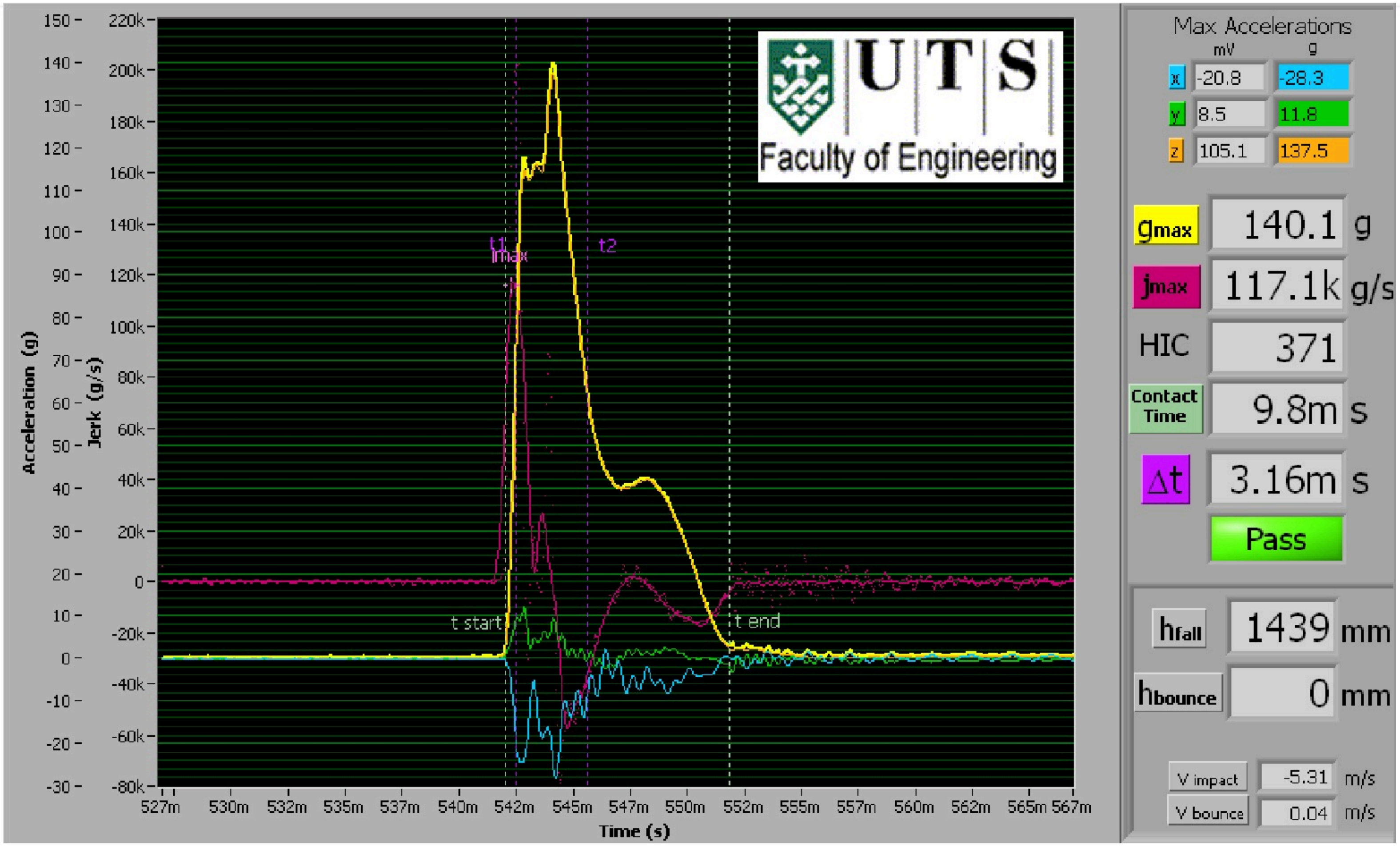
IAS behaviour during impact – wet fine sand



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

IAS behaviour during impact – wet fine sand

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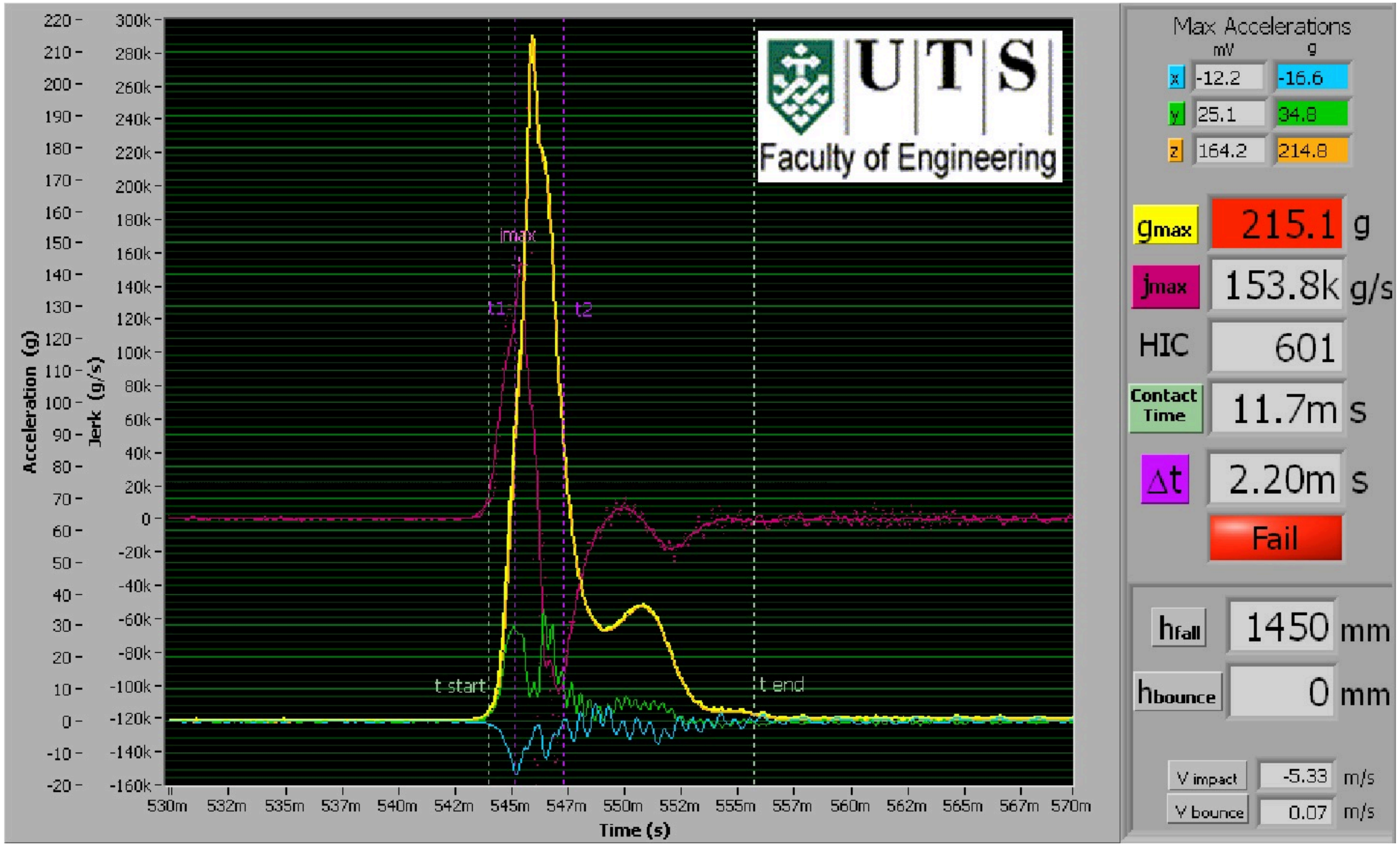
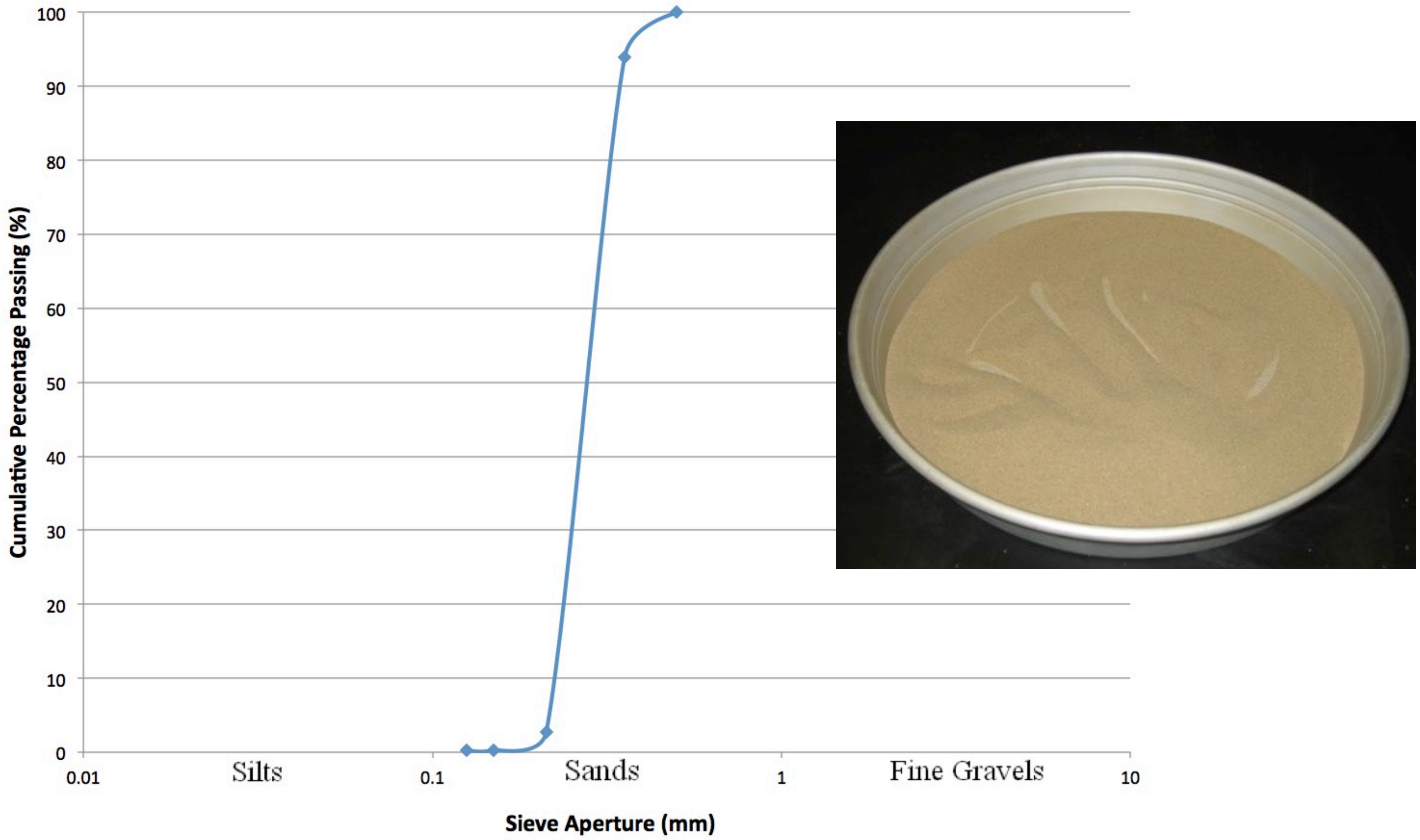


Sand (fine & wet): Acceleration v Time

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

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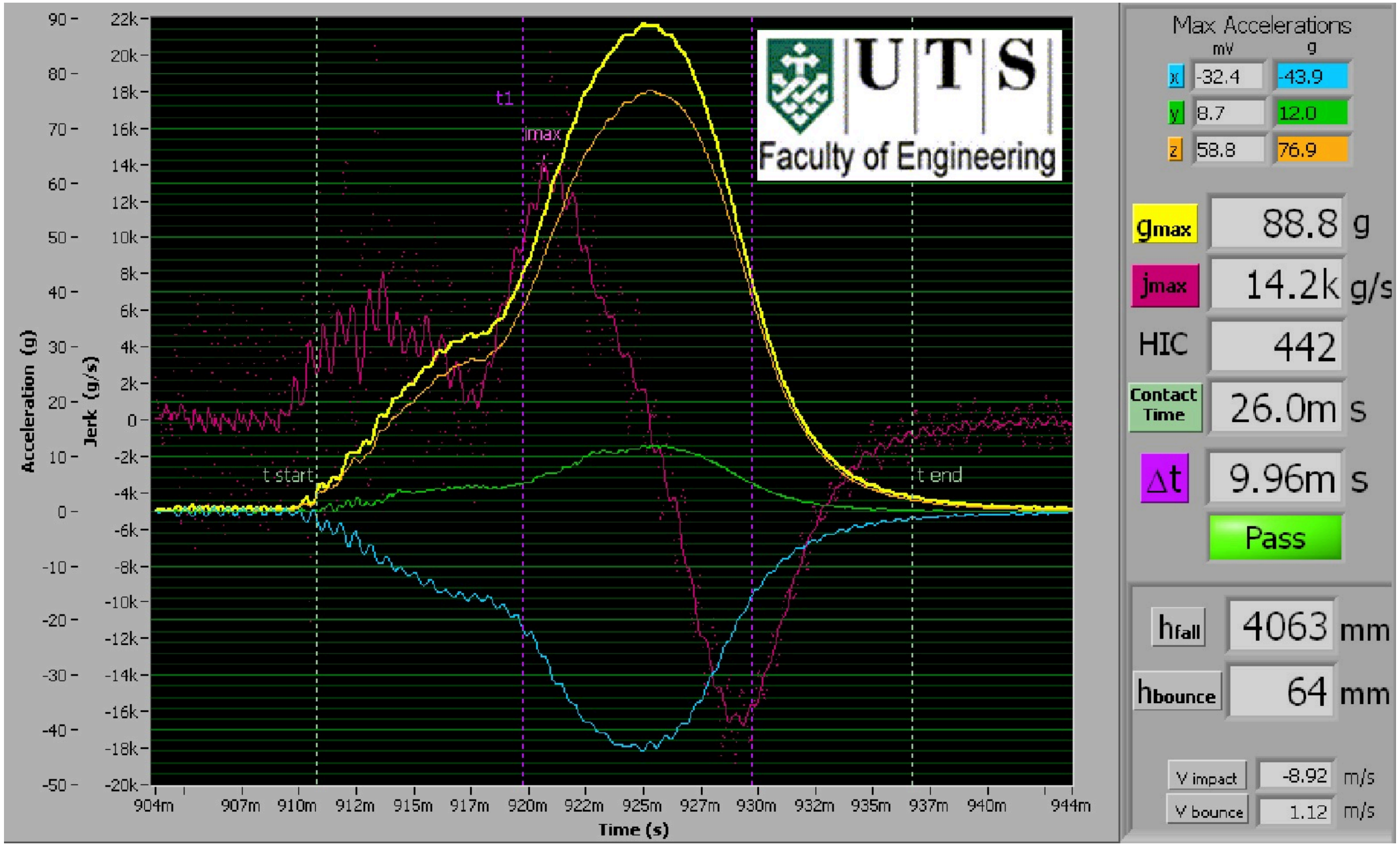

Bark (WA dry): Acceleration v Time

1st drop in same location @ 4 m FHoF

IAS behaviour during impact – dry bark

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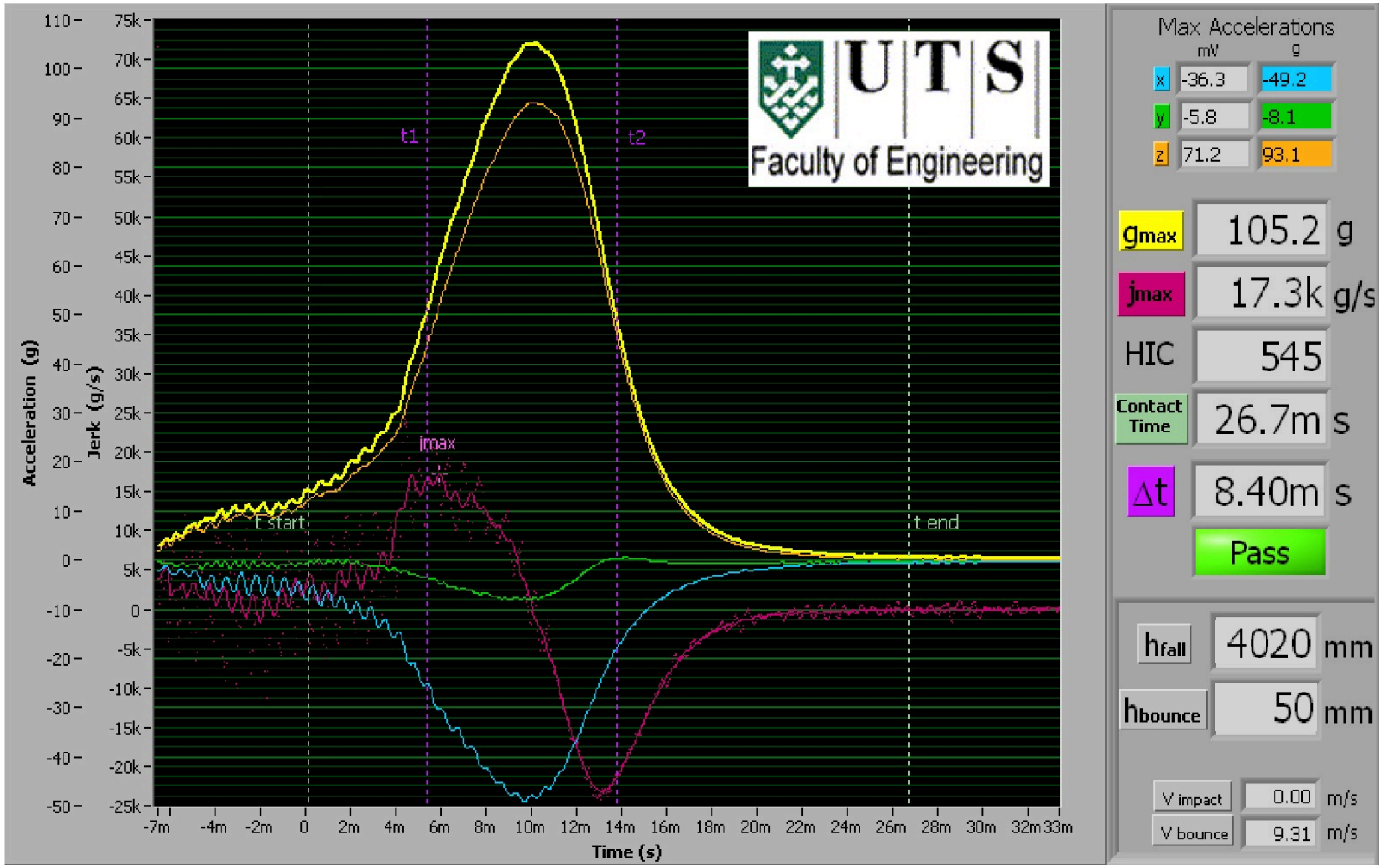
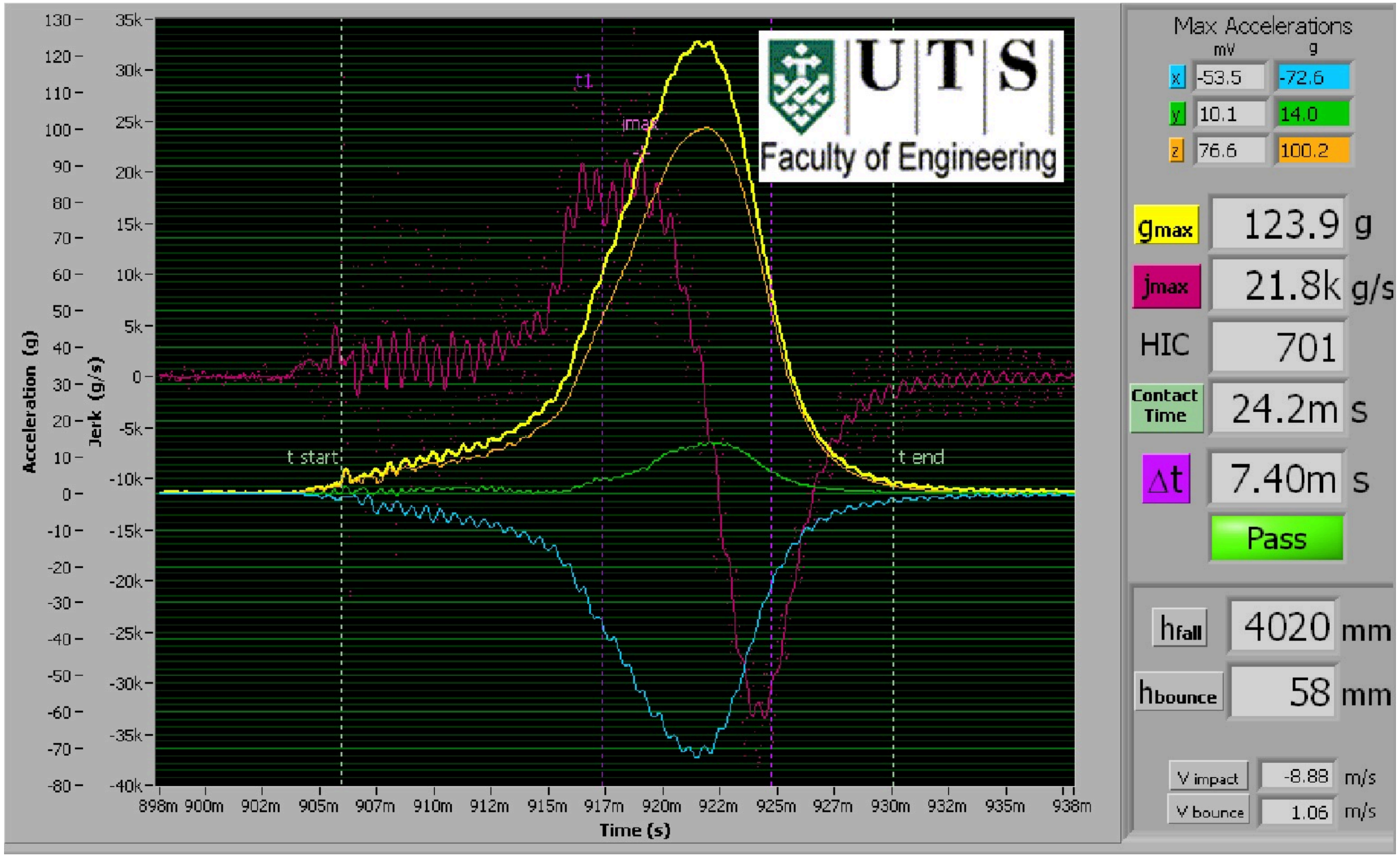


Bark (WA dry): Acceleration v Time

2nd drop in same location @ 4 m FHoF

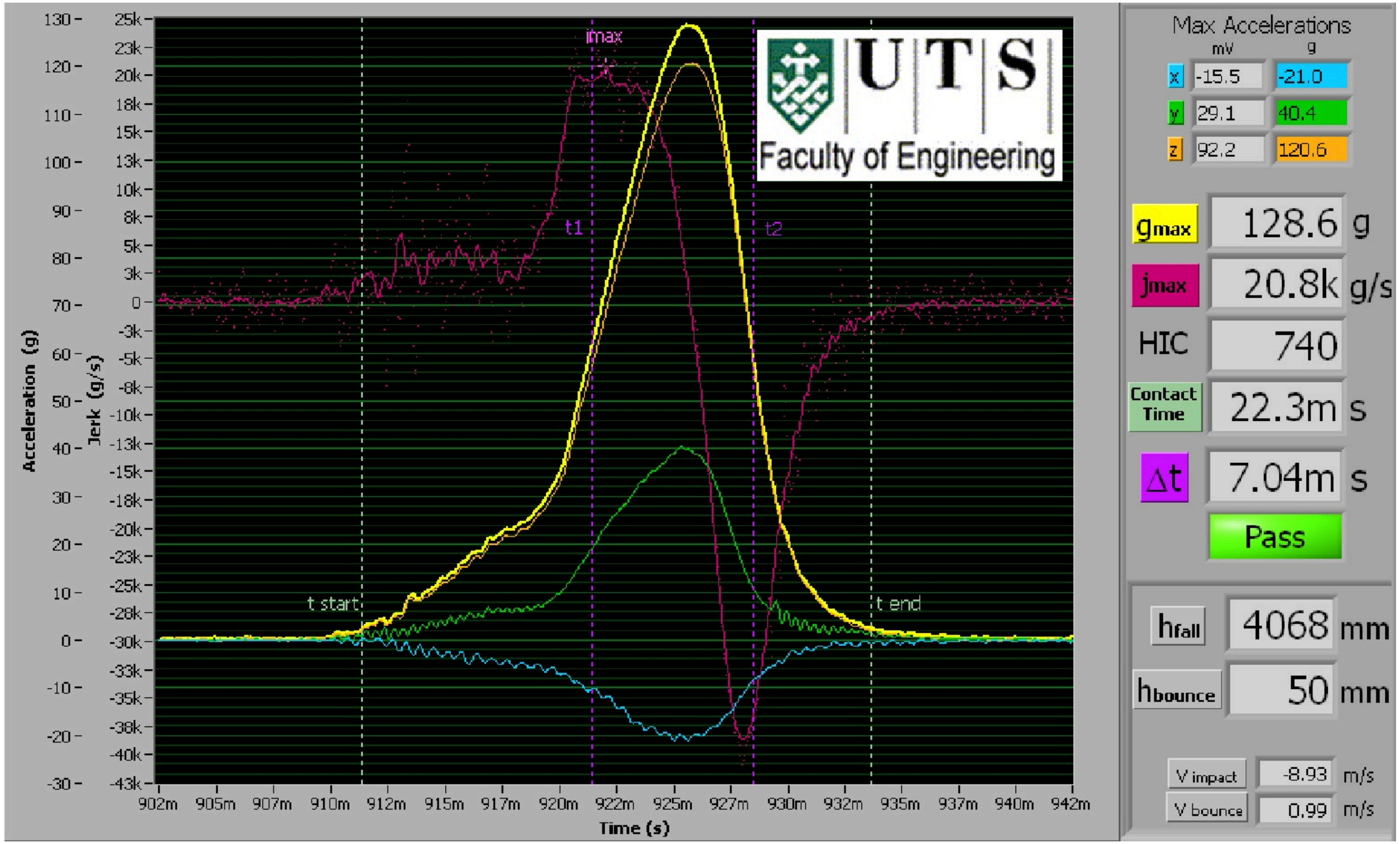
IAS behaviour during impact – dry bark



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

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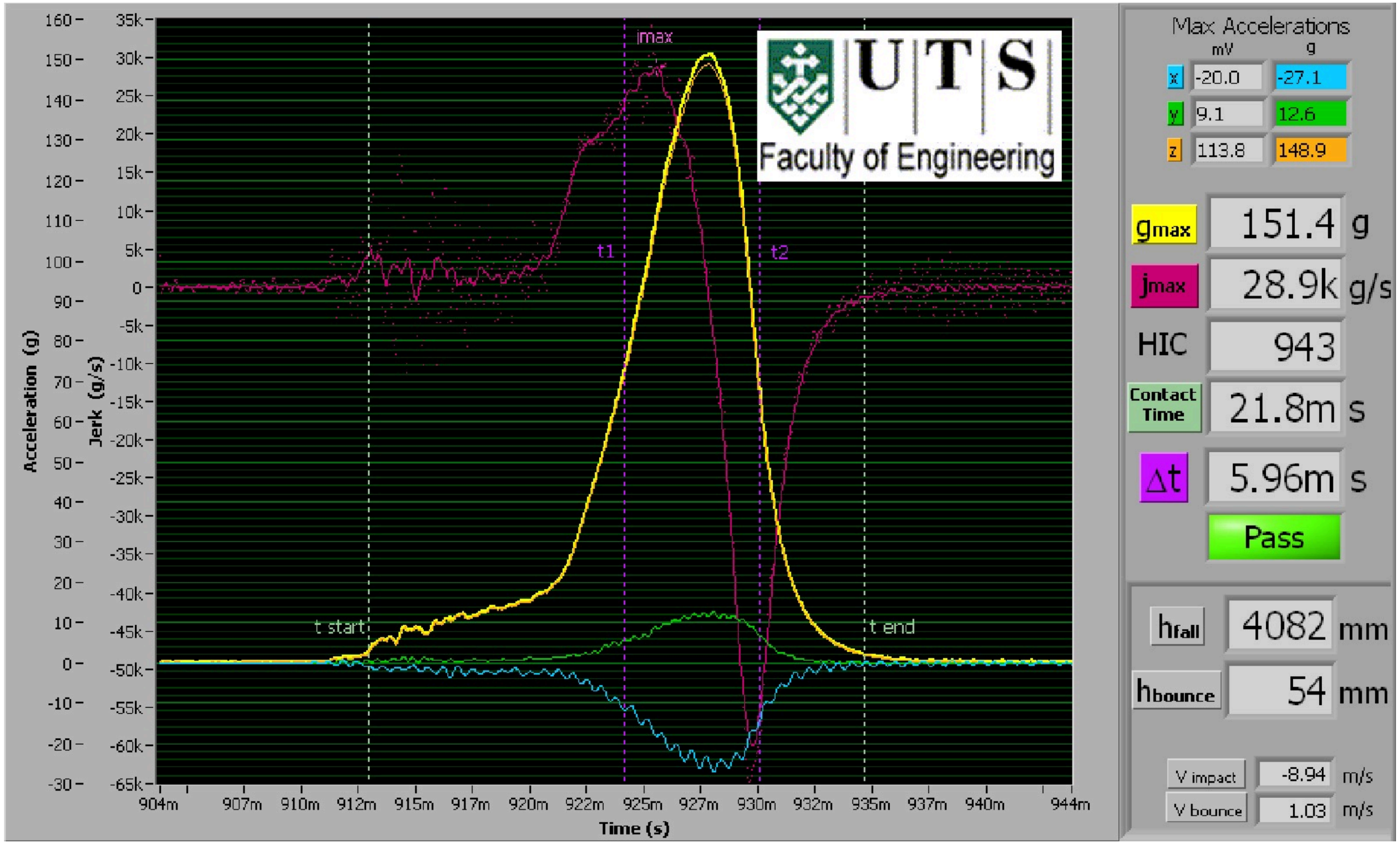
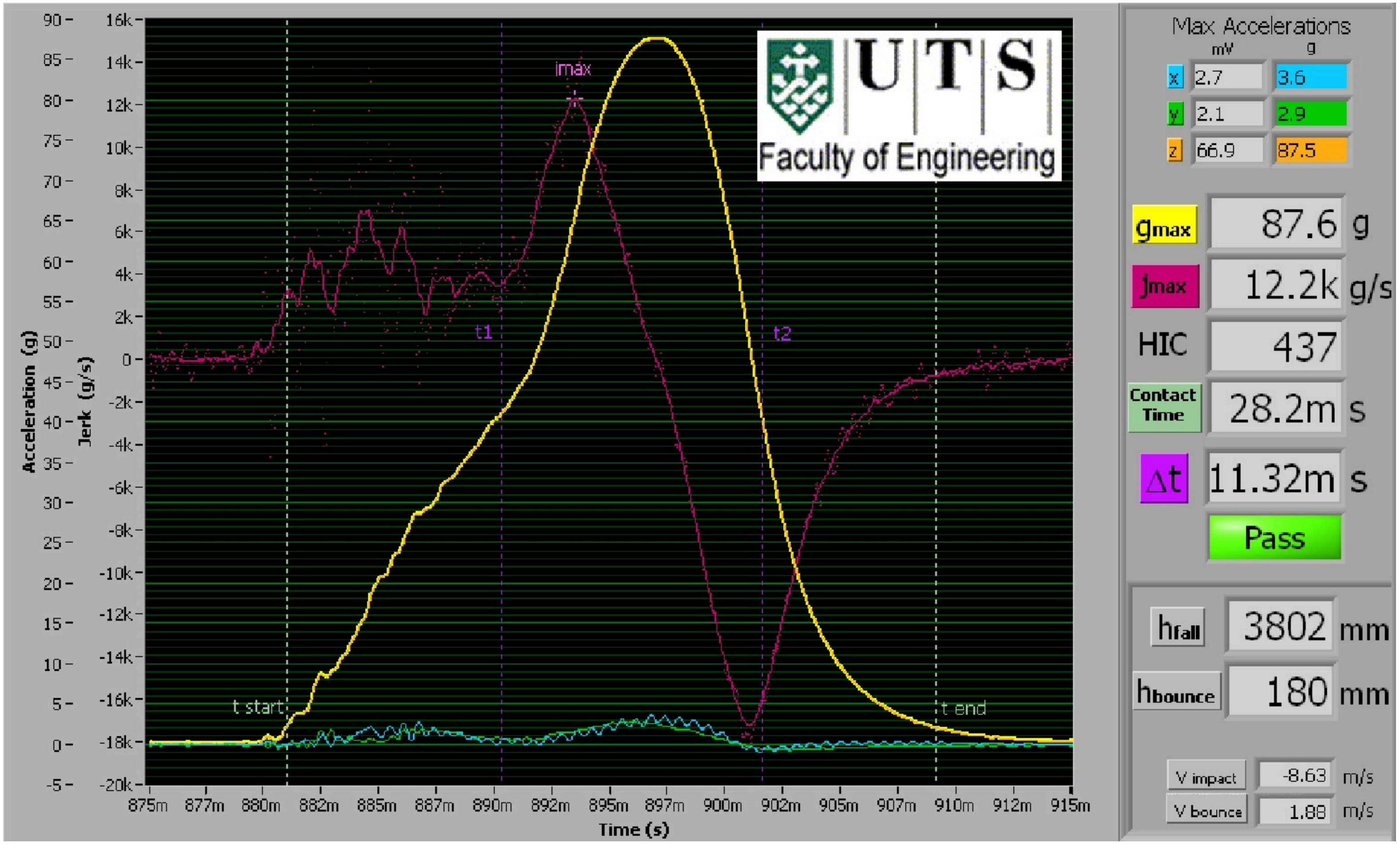


Bark (WA dry): Acceleration v Time

5th drop in same location @ 4 m FHoF

IAS behaviour during impact – wet bark



Bark (WA wet): Acceleration v Time

1st drop in same location @ 3.8 m FHoF

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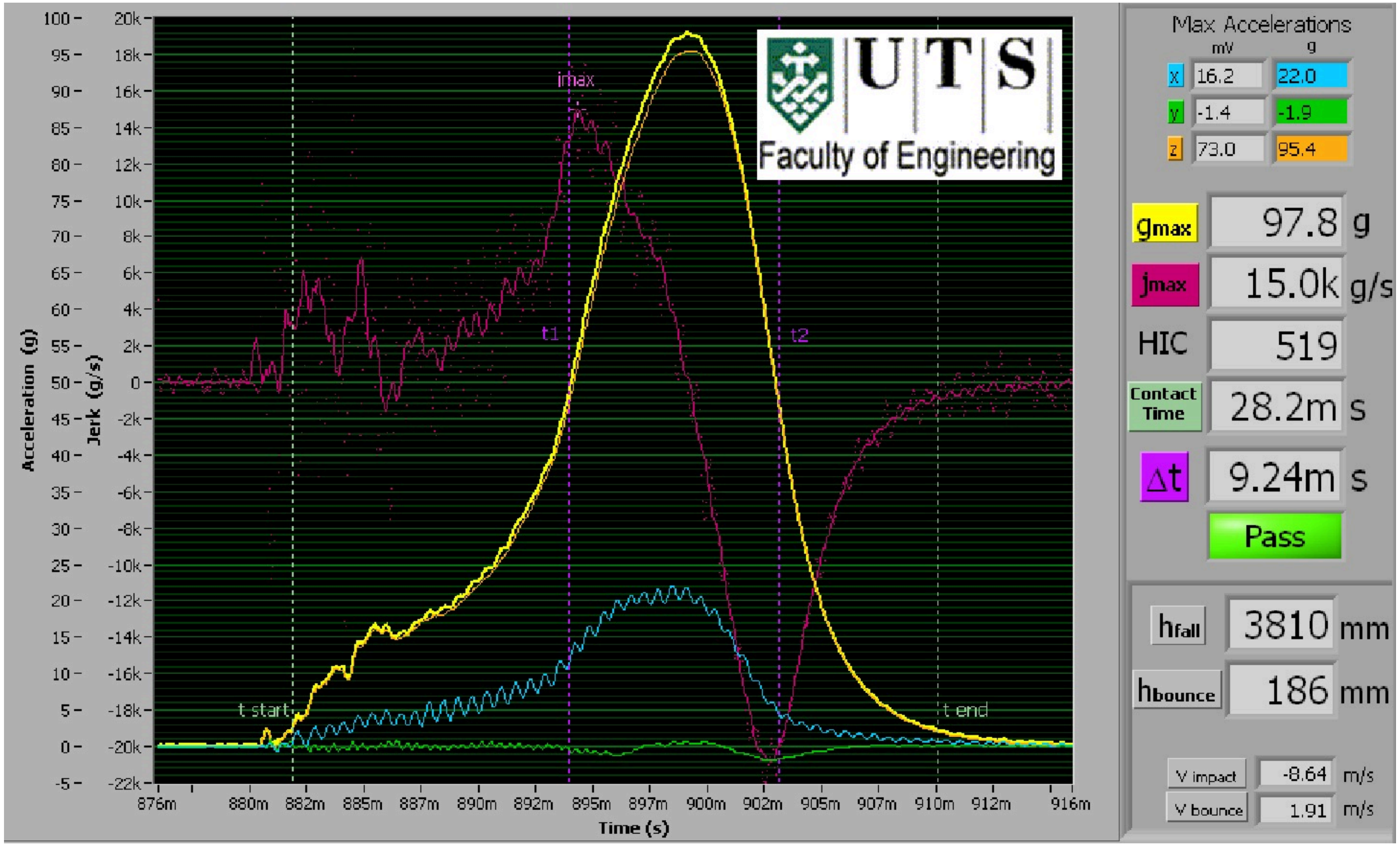
IAS behaviour during impact – wet bark



Bark (WA wet): Acceleration v Time

2nd drop in same location @ 3.8 m FHoF

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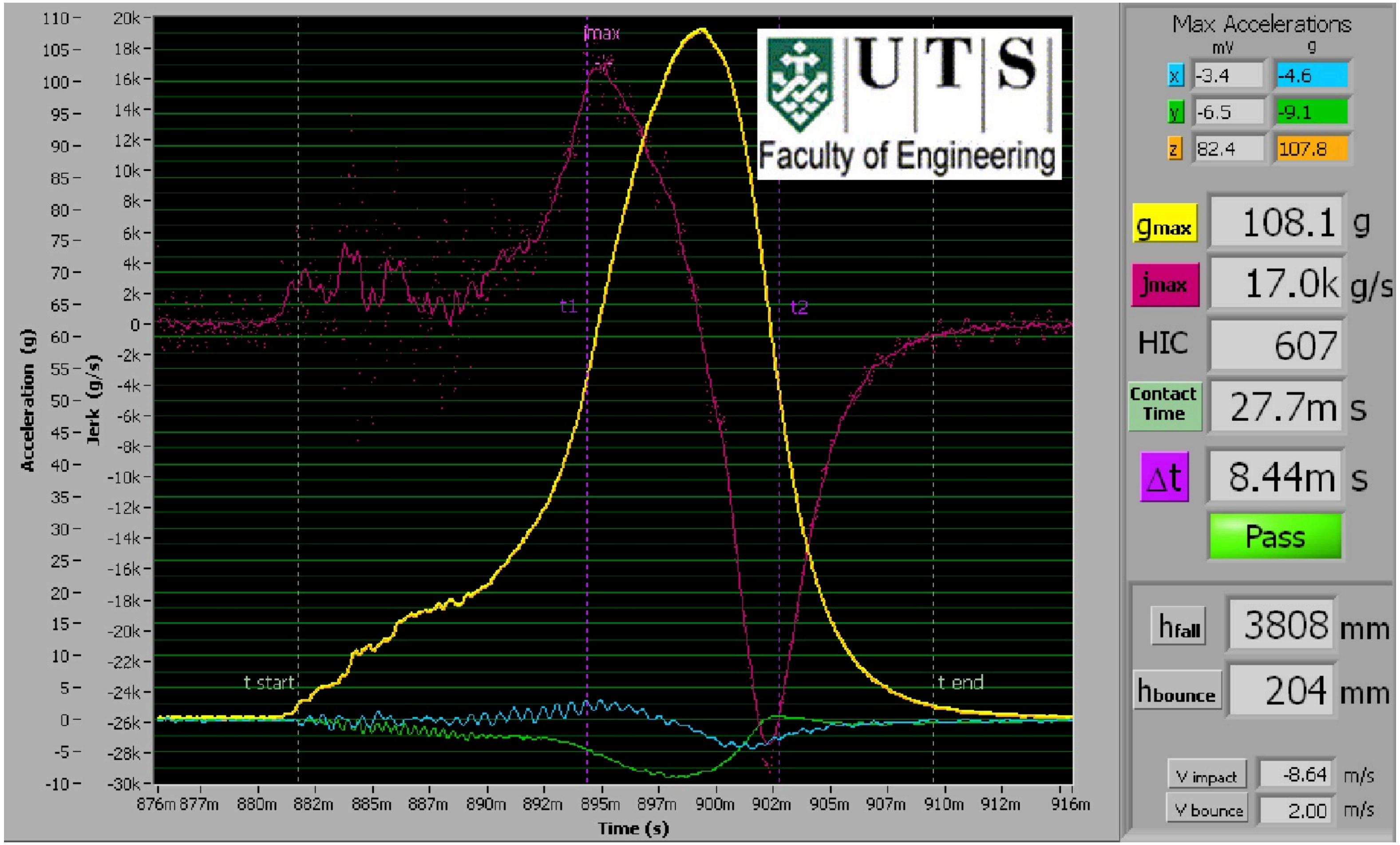
IAS behaviour during impact – wet bark

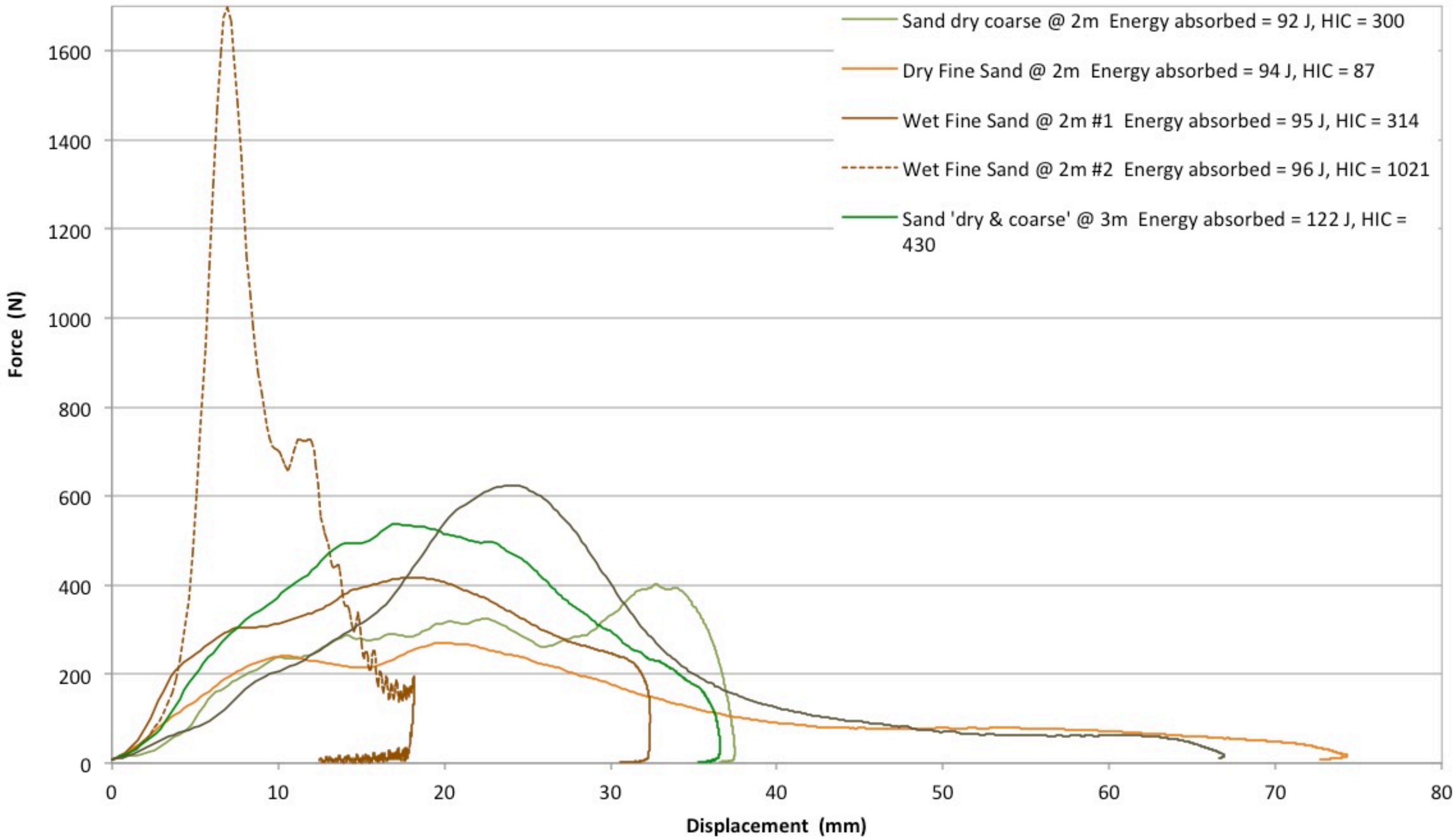
TÜV AUSTRIA ACADEMY



Bark (WA wet): Acceleration v Time

3rd drop in same location @ 3.8 m FHoF

Properties of loose-fill surfaces



Force v Displacement hysteresis curves

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

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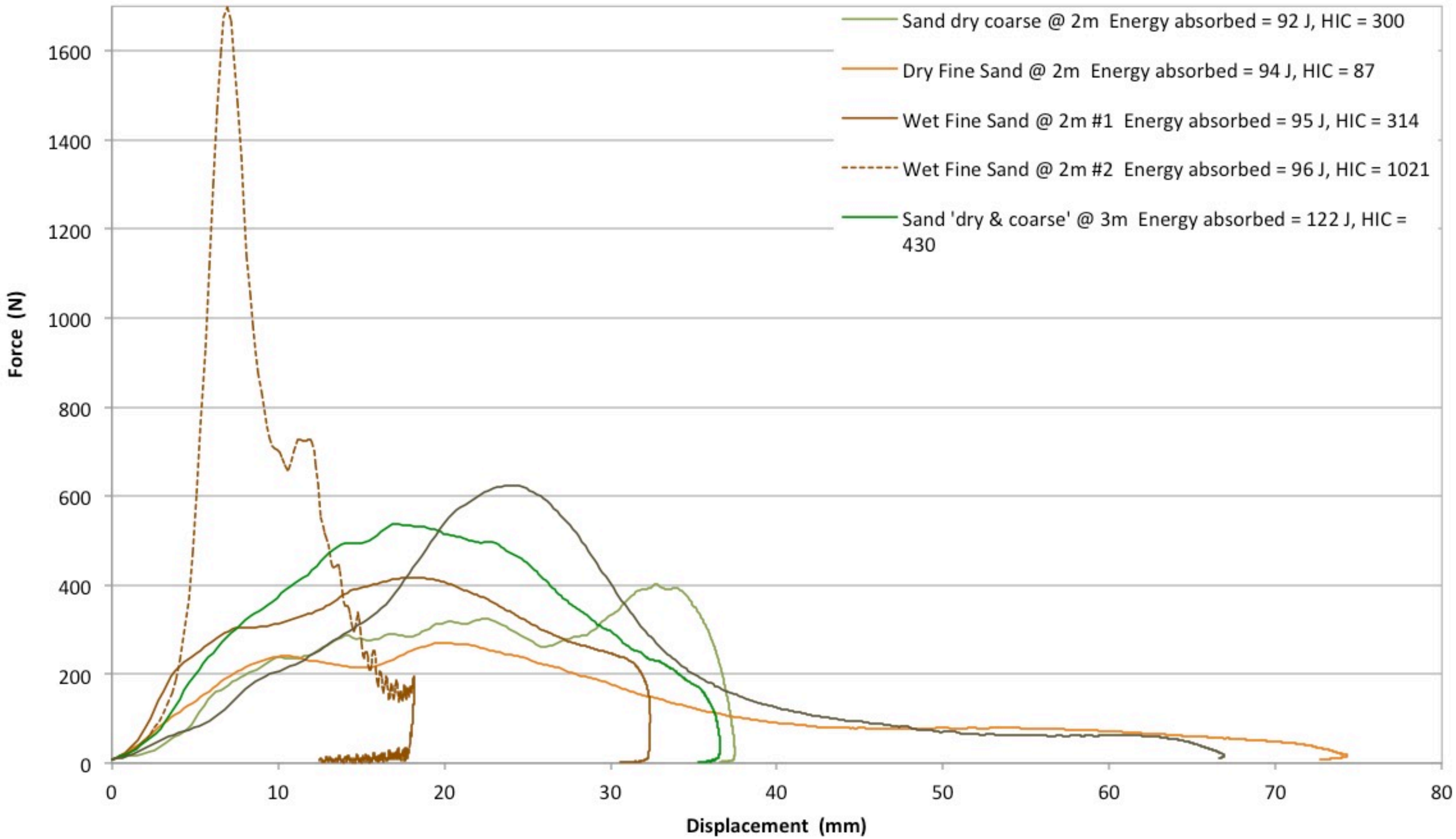
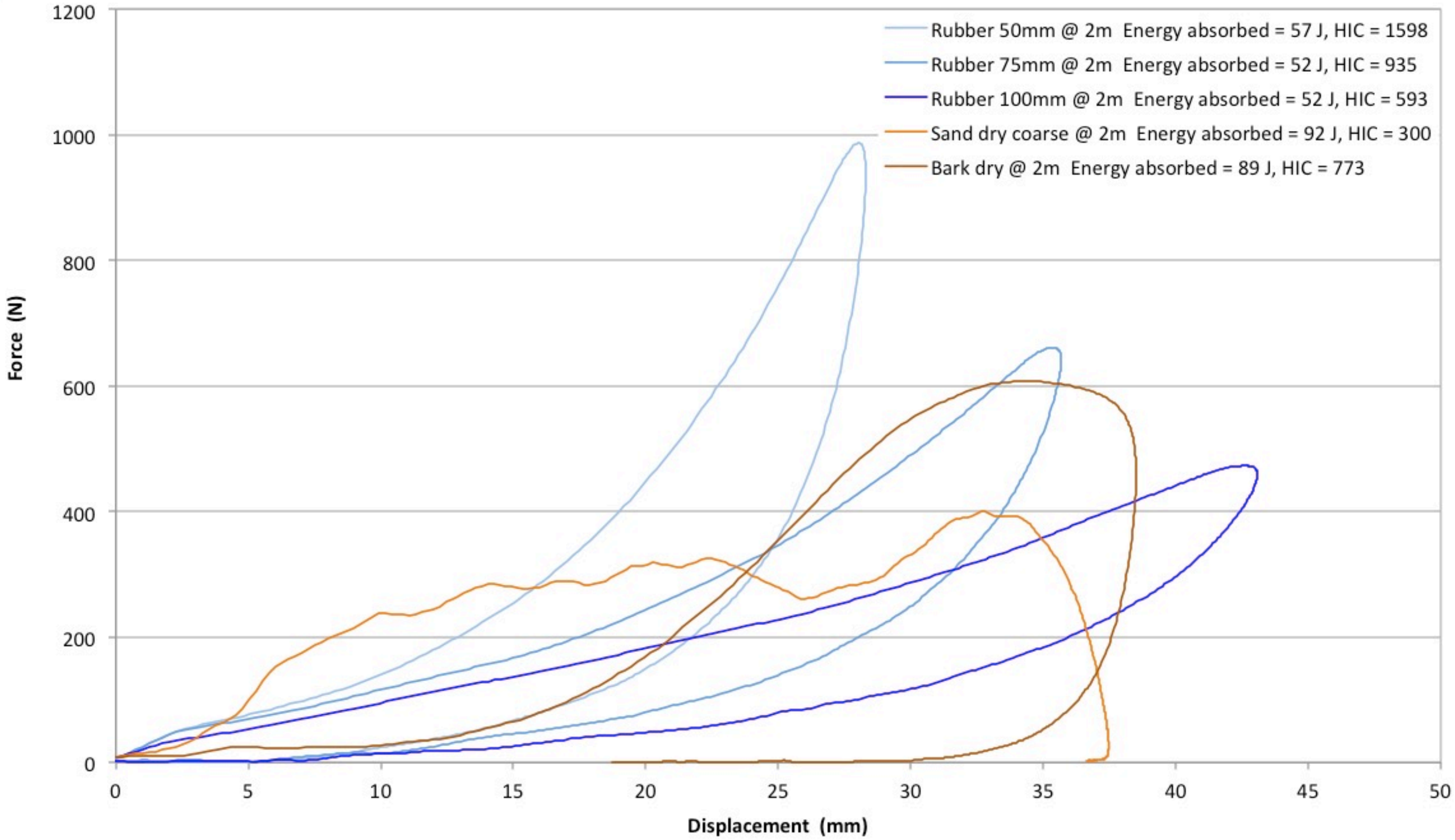
Properties of loose-fill surfaces



Force v Displacement hysteresis curves

rubber & bark @ 1 m FHoF

Properties of loose-fill surfaces



Force v Displacement hysteresis curves

rubber & bark @ 2 m FHoF

Properties of loose-fill surfaces

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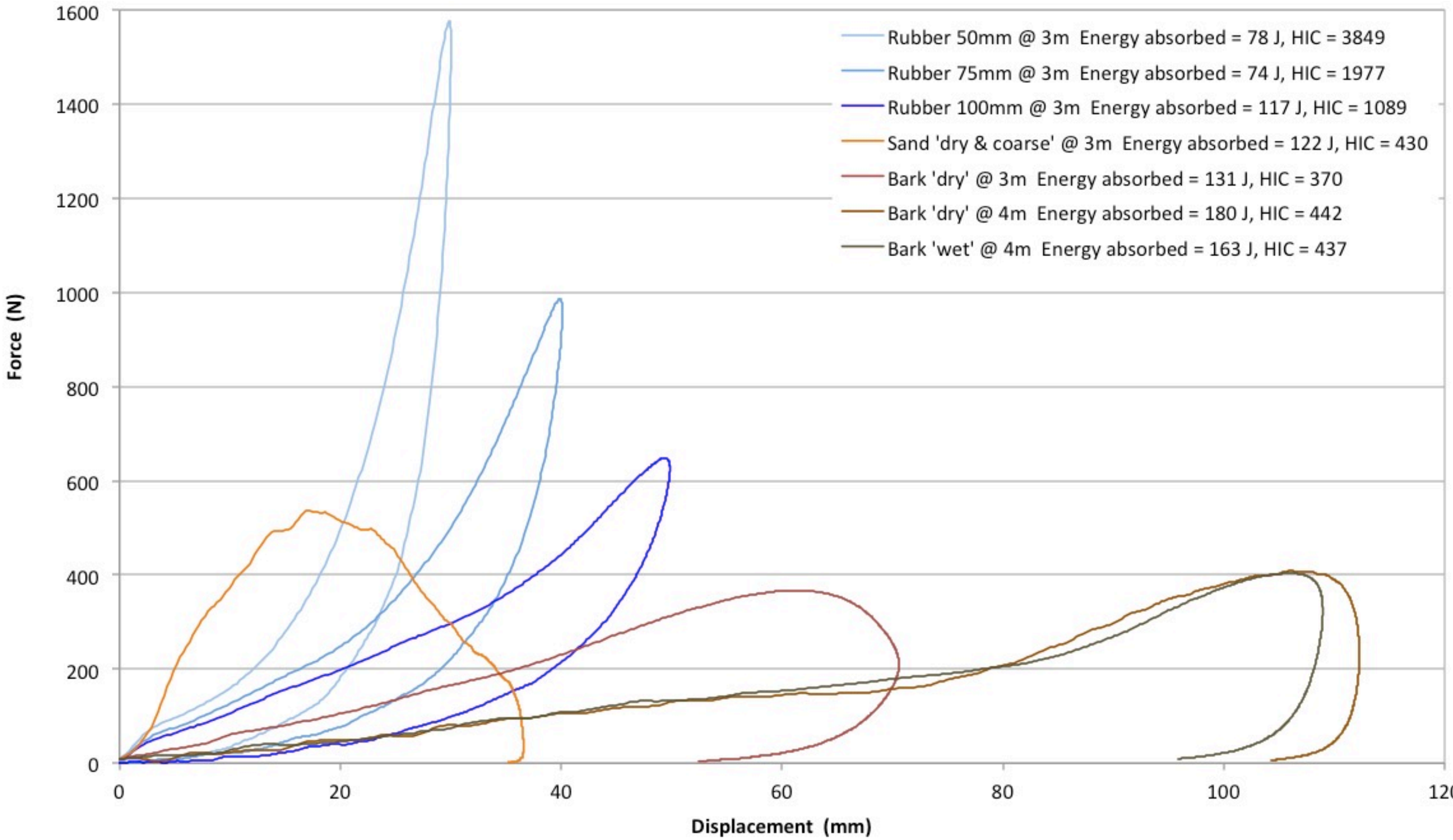

Force v Displacement hysteresis curves

rubber & bark @ 3 m & 4 m FHoF

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)

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 !!!

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Natural and loose-fill surfaces

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

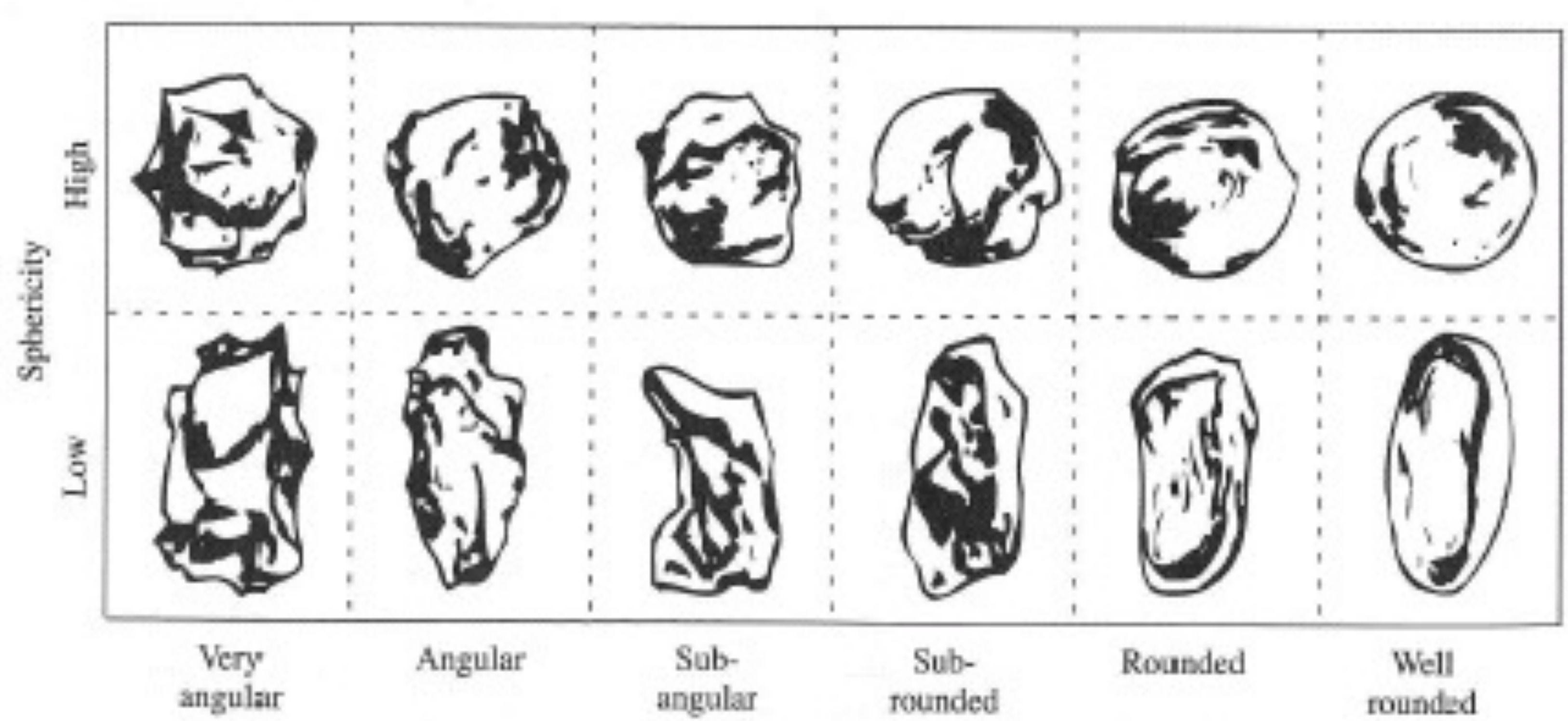






Properties of loose-fill surfaces – Sand

- ✔ **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

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Properties of loose-fill surfaces – Sand

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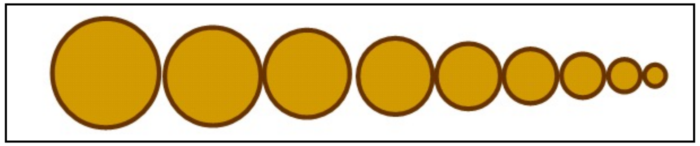
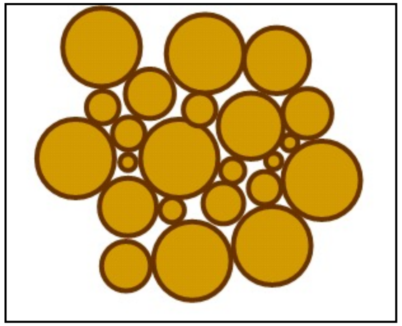
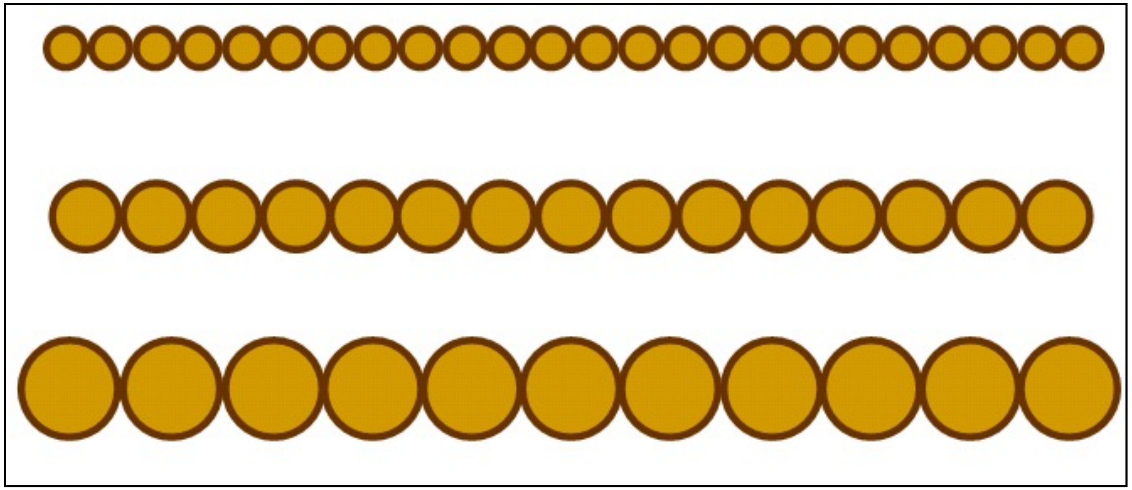
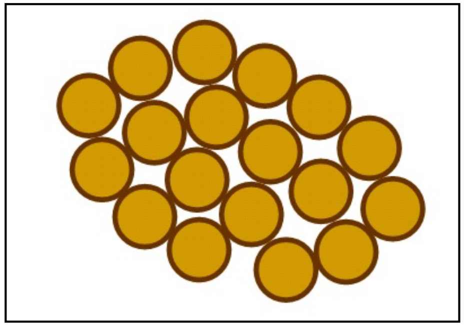
X **Well graded sand is undesirable as a playground IAS**





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





Properties of loose-fill surfaces – Sand

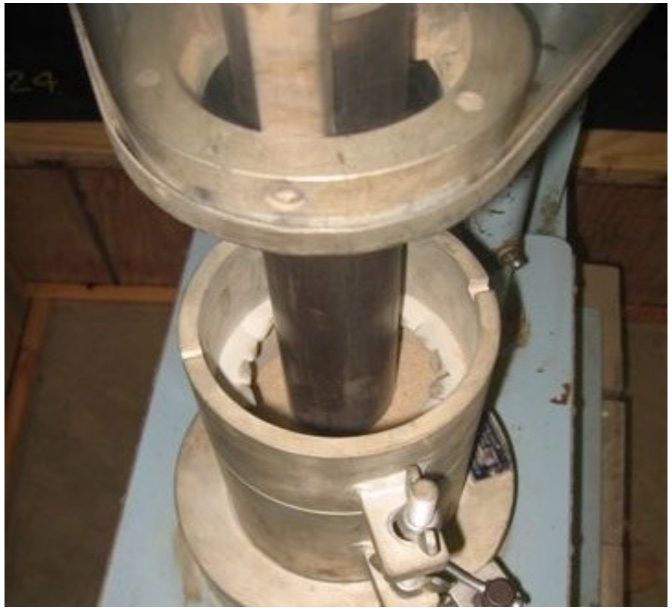
✔ No fines

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

Properties of loose-fill surfaces – Sand

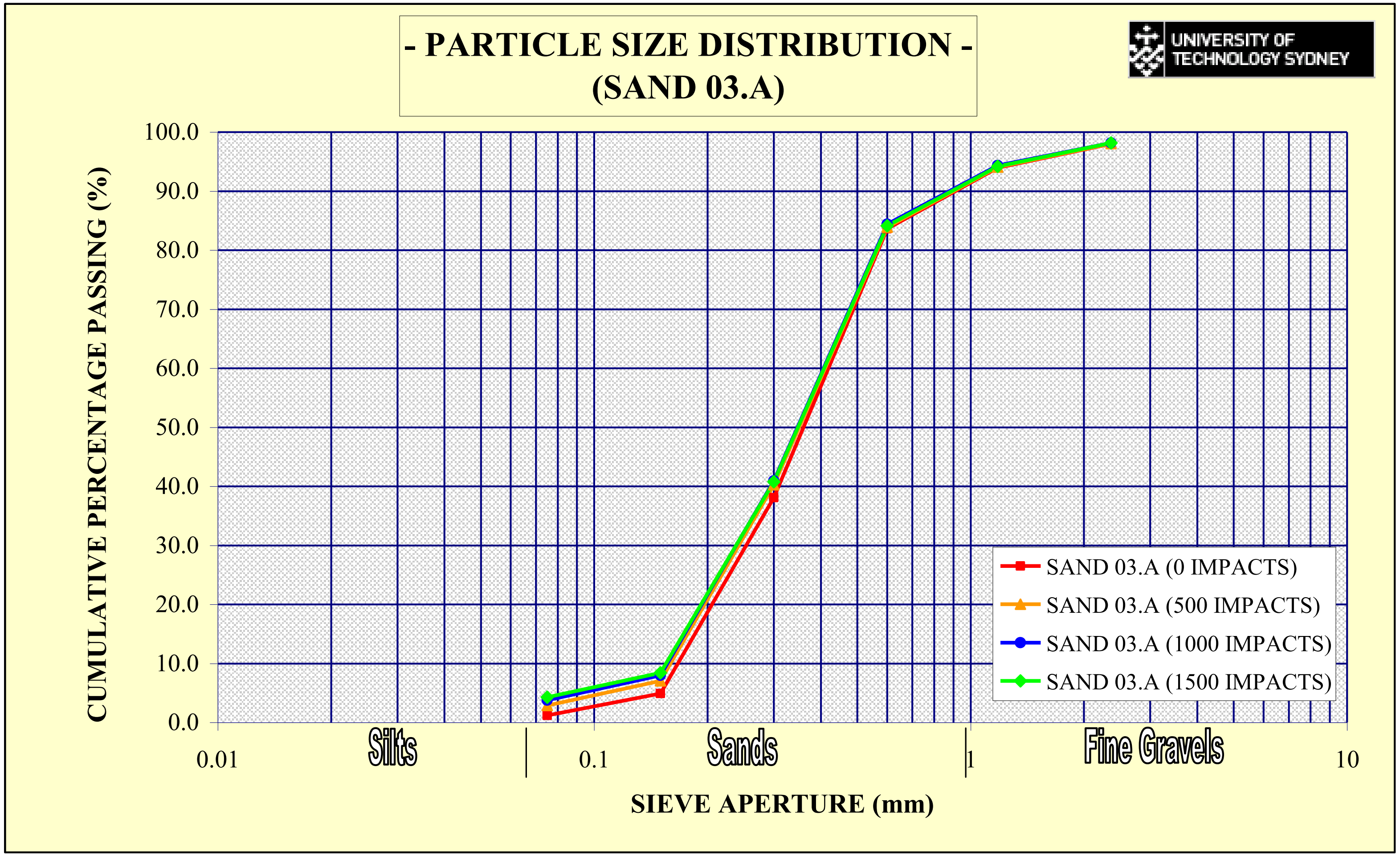
✓ **Low degradation**

- 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



Properties of loose-fill surfaces – Sand

✔ **Low degradation – good example**



Properties of loose-fill surfaces – Sand

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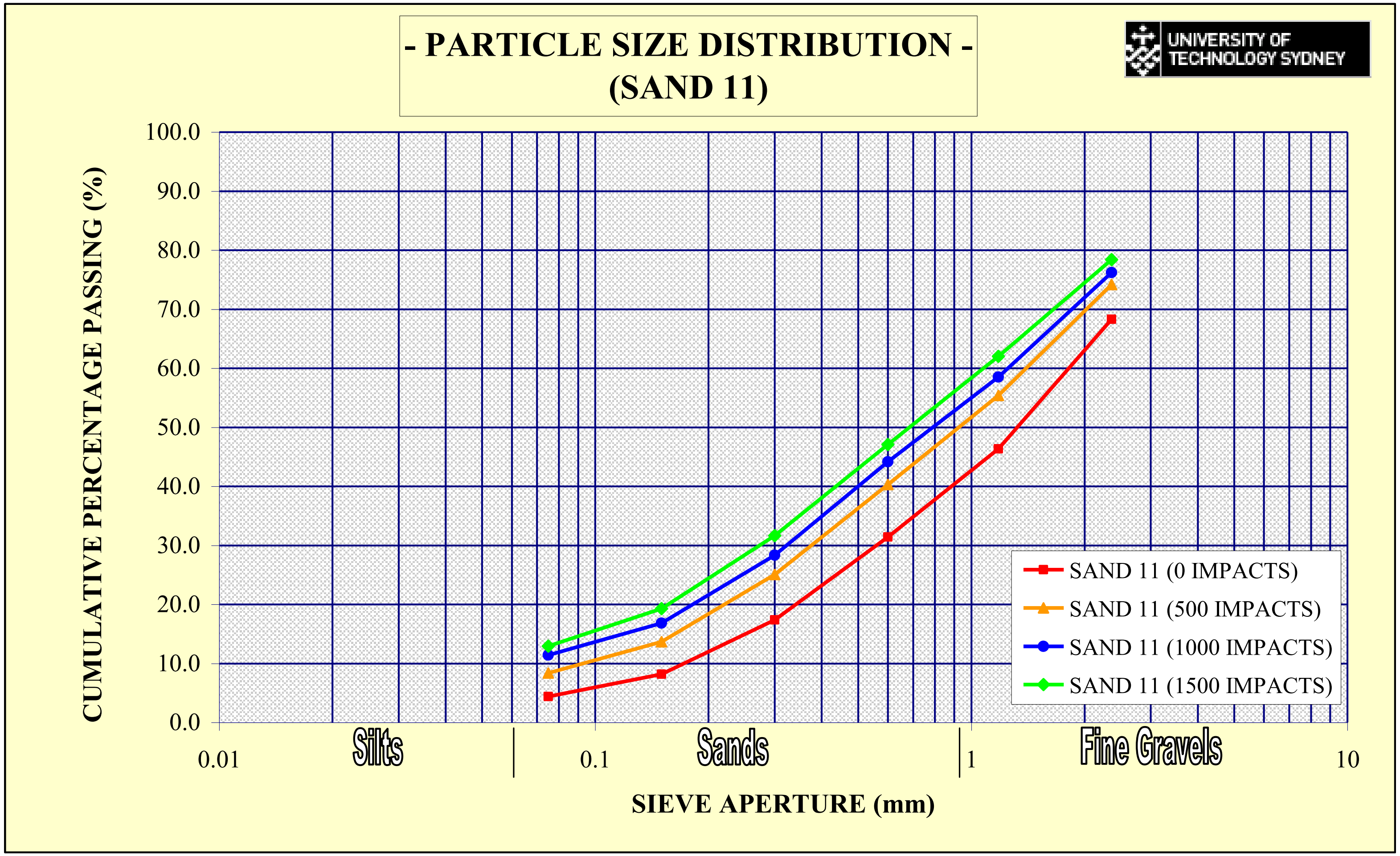
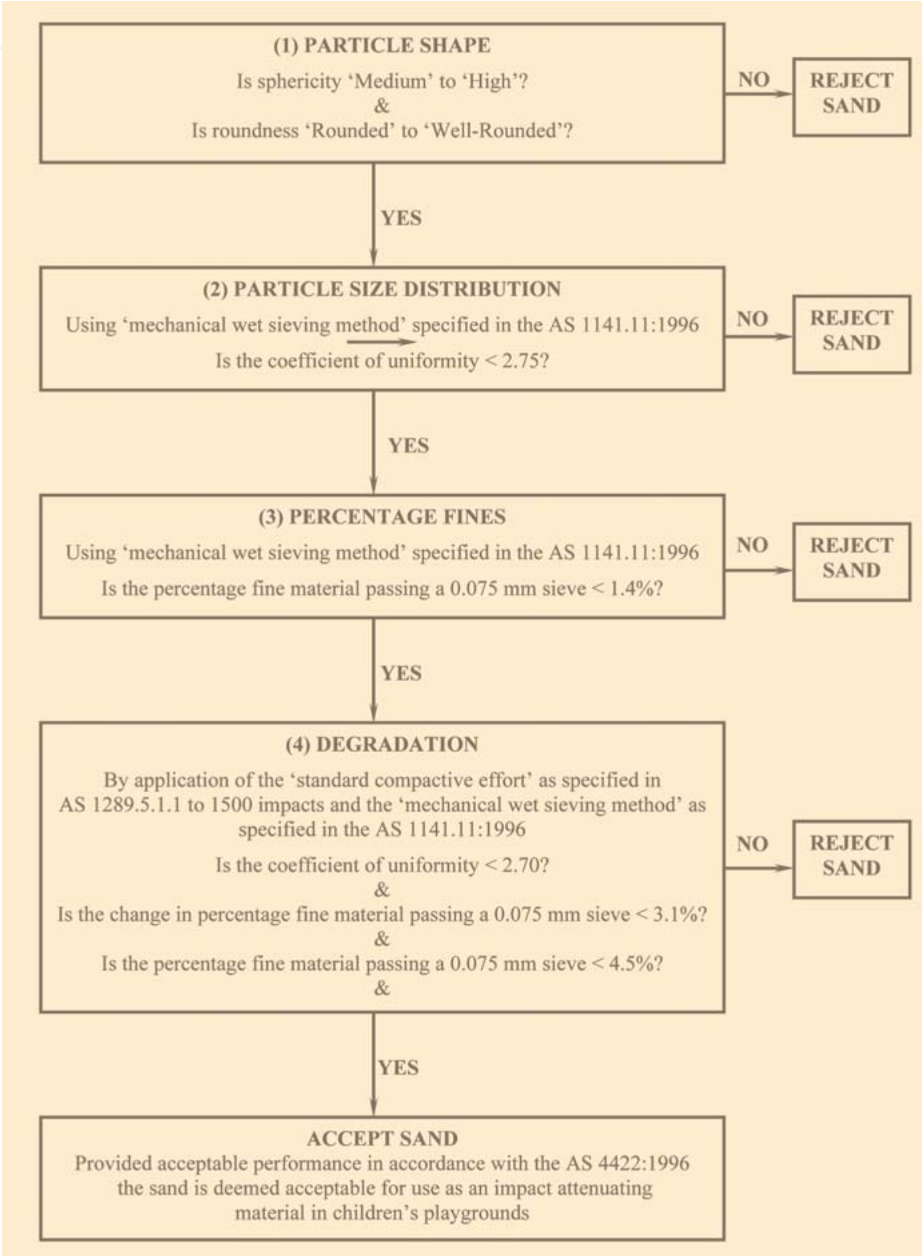
✔ Low degradation – poor example



Properties of loose-fill surfaces – Sand

- ✔ **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



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Maintenance of sand IAS

In-situ sieving using portable vibrating sieve

Maintenance of sand IAS

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In-situ sieving using portable vibrating sieve

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Maintenance of sand IAS

In-situ sieving using portable vibrating sieve

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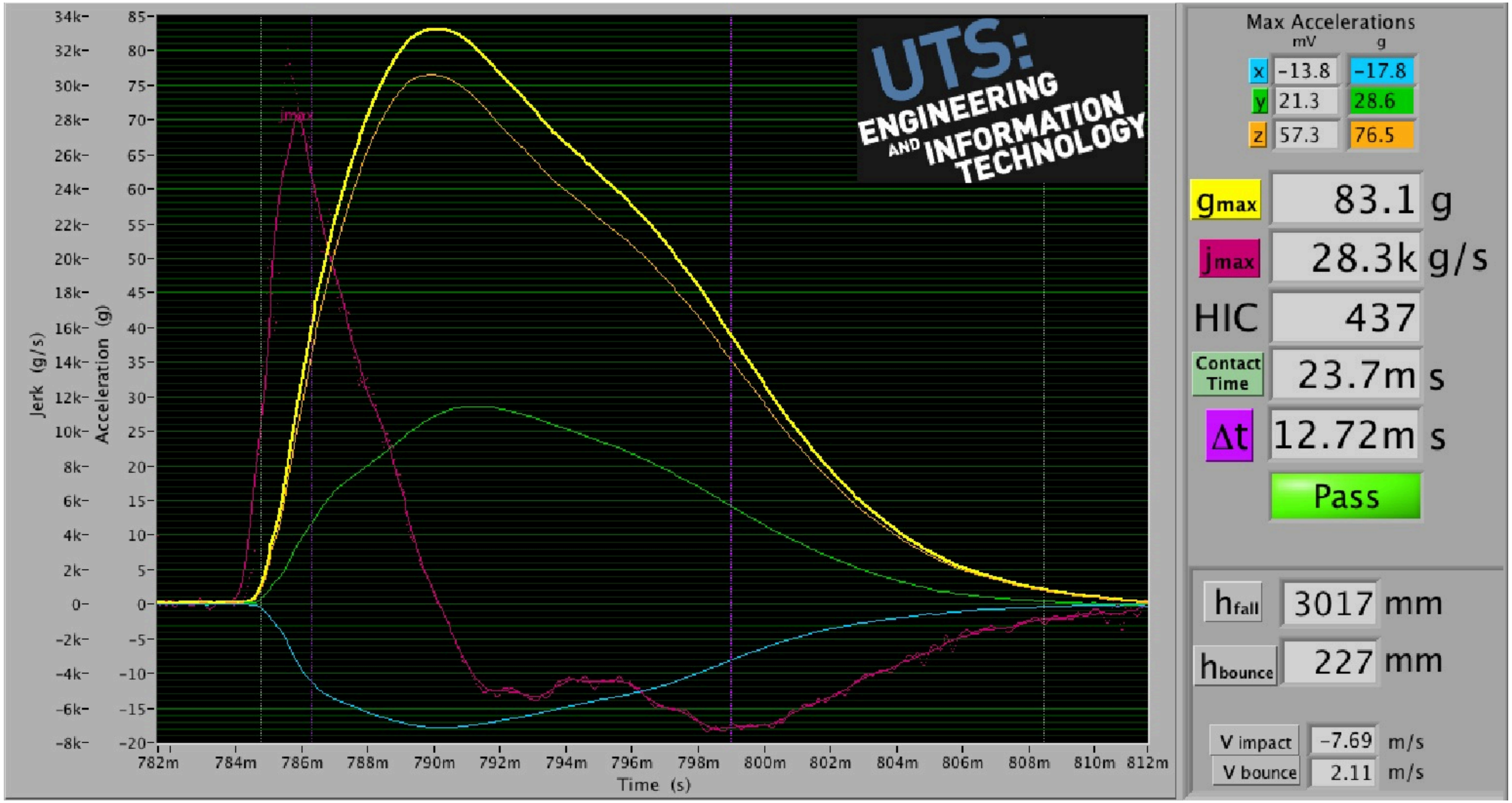
Maintenance of bark IAS

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

> 12 months low travel area

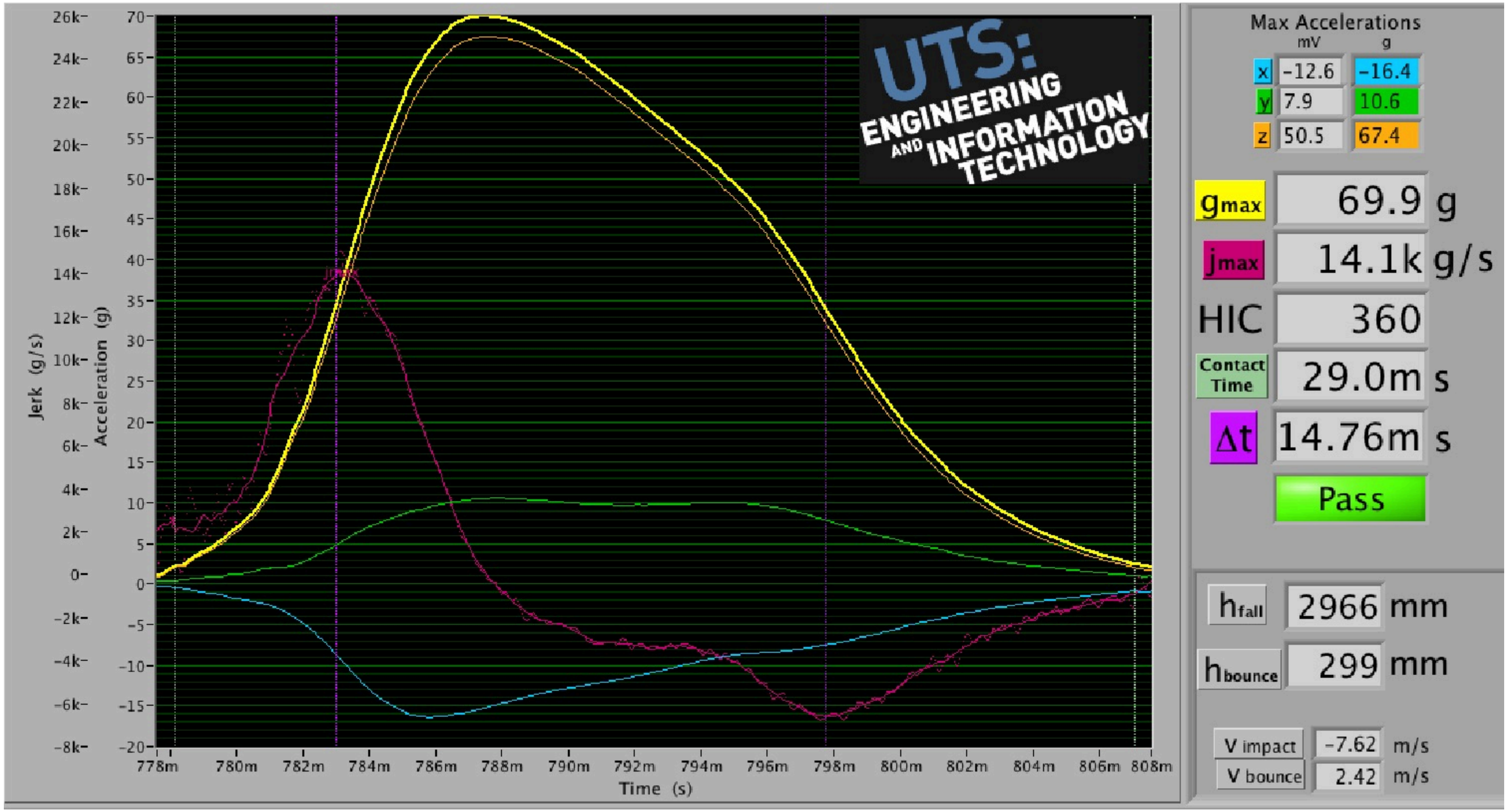
Maintenance of bark IAS



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

Bark only topped up & 'unfluffed' (compacted)

> 12 months high travel area

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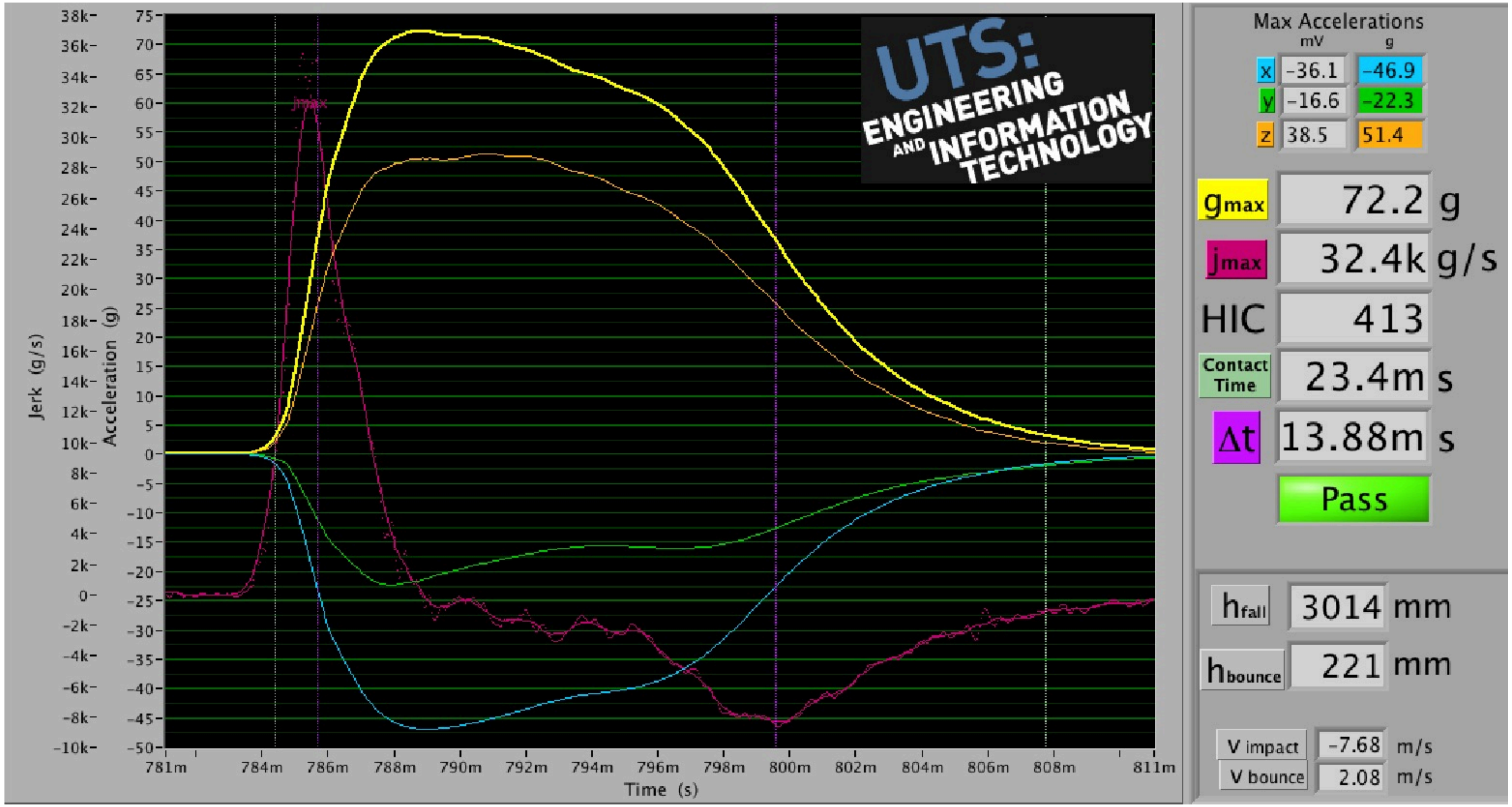
Maintenance of bark IAS



Bark 'unfluffed' > 12 months: Acceleration v Time

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

Maintenance of bark IAS

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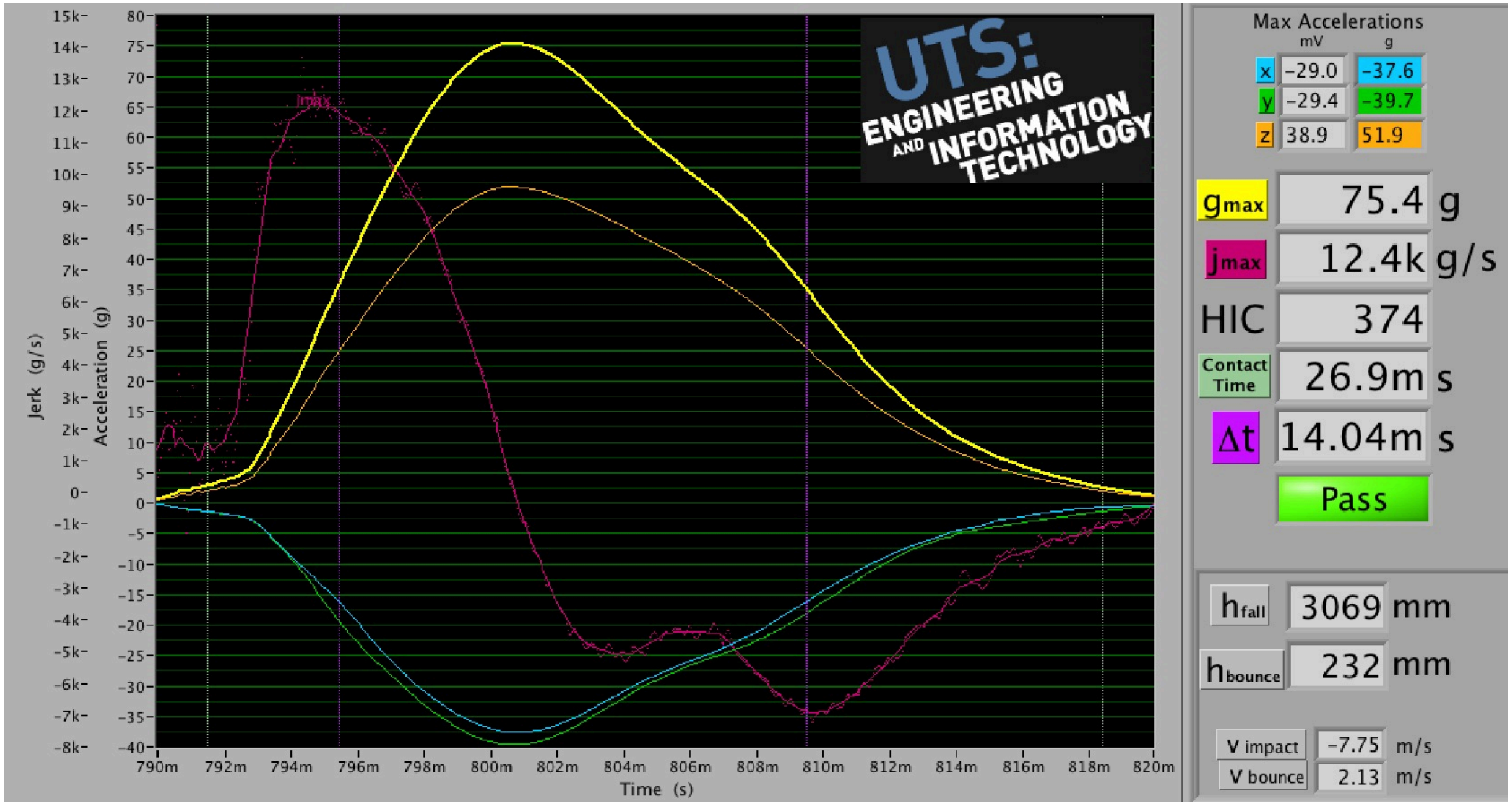

Bark ‘unfluffed’ > 12 months: Acceleration v Time

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

Summary

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✔ **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

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

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Prof. Ing. Dr. David Eager

University of Technology Sydney, Australia

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