Data Storage Report

Sea Ice Dynamics: The Role of Ice Rubble in Multi-Scale Deformation

Hy+_HSVA-02-UCL

HSVA ARCTECLAB – Large Ice Model Basin (LIMB)

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Status form

Document information

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Document objective

This data storage report describes the experimental program and how tests were performed. The data storage plan was updated to a data storage report after all data had been obtained. In the data storage report, the data is described so that others can use them.

Acknowledgement

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Contents

The Data Storage Plan should be submitted BEFORE the tests in the facility have started. After the tests, the plan will be finalised and becomes a Data Storage Report. The plan/report describes how the basic data and the processed data will be stored in order to make it available for those interested. Note that the user group has the first right of publication during a period of two years, but after that any European researcher should be able to use the data.

The data storage plan/report should contain a list of instruments, the proposed experiments, the sampling frequency, dimensions of the numbers in the files, and all other relevant information. It also contains a list of files, and a description of what is in the files (identify what is in each column in the table that is stored in the file, such as 'time (s)', 'pressure at location 1 (Pa)', etc., including type of column separator). It should be made clear which test corresponds with which file. Give also the data type: binary / ascii.

1. Objectives

Understanding the evolving sea ice thickness distribution and sea ice dynamics is crucial if the impacts of climate change are to be understood and adaptation strategies can be implemented. Since shear deformation and slip are controlled by friction, a better understanding of the frictional behaviour using realistic representations of broken ice between sliding ice floes is essential for understanding Arctic Ocean dynamics.

Our objectives are:

1. Perform ice tank experiments in which a saline ice block, representing a sea ice floe, flanked by ice gouge, is deformed by a pusher plate and confined by side loading, in double direct shear.
2. Investigate the effect of (i) hold time variation, (ii) sliding velocity variation and (iii) rubble angularity and size, by using round and angular rubble pieces each in two sizes.

2. Experimental Setup

2.1. General Description

The idealized experimental setup can be seen in **Fehler! Verweisquelle konnte nicht gefunden werden.**. It consists of a mobile middle block that can be pushed through a channel of open water by a pusher plate attached to the main carriage. Either side of the middle block are regions of ice rubble which are bound on their other sides by ice beams. Side load frames on both sides of the setup provide a confining force to the ice rubble regions and middle block. The length of the middle block and ice rubble regions is such that the ice rubble region is always bound on both sides by ice during sliding, and prevents ice rubble loss to the water in front or behind the middle block.

For all experiments the rubble region was one layer thick, and four different kinds of rubble were used:

1) Small round rubble (9.5 cm diameter)
2) Large round rubble (16.5 cm diameter)
3) Small diamonds (small dimension 10 cm, long dimension 17 cm)
4) Large diamonds (small dimension 18 cm, long dimension 30 cm)

Experiments were carried out in the main basin at HSVA (for dimensions see Figure 1). The main carriage, which has a maximum towing capacity of 50kN and speeds ranging from 3 mm/s to 3000mm/s, will supply the "direct" pushing force on the middle block.

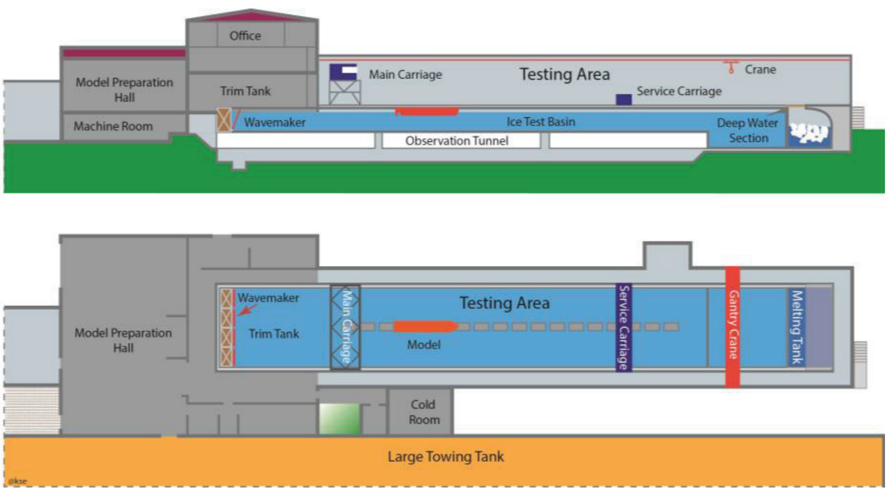

Figure 1 - Cross section (top) and plan view (bottom) of the facilities at the main basin at HSVA. (Image: www.hsva.de)

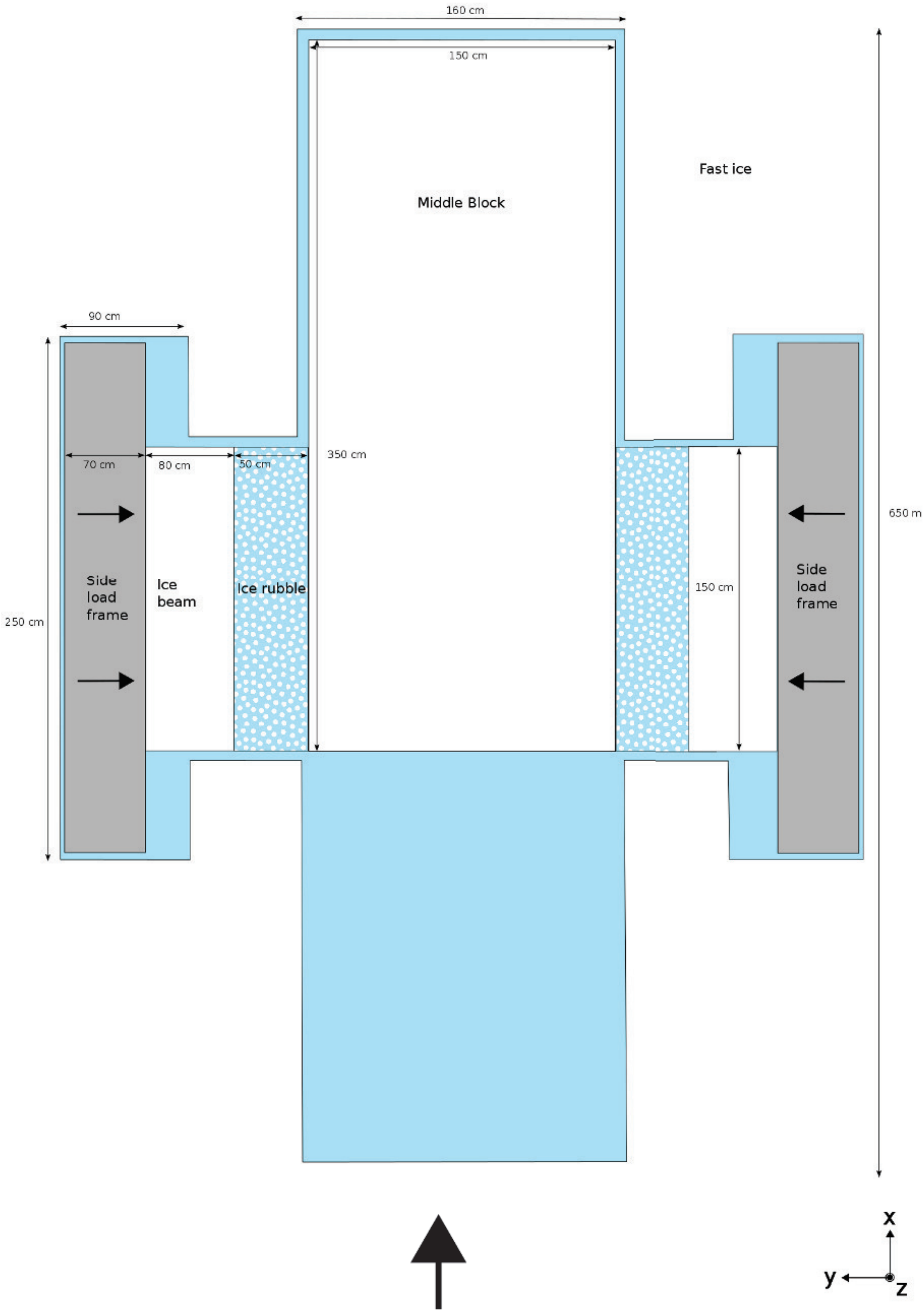

Figure 2 - The idealised experimental setup. In reality, ice growth over successive days altered the dimensions by several centimeters over the course of the time after it was first cut.

2.2. Definition of the coordinate system

The coordinate system definition can be seen in Figure 3.

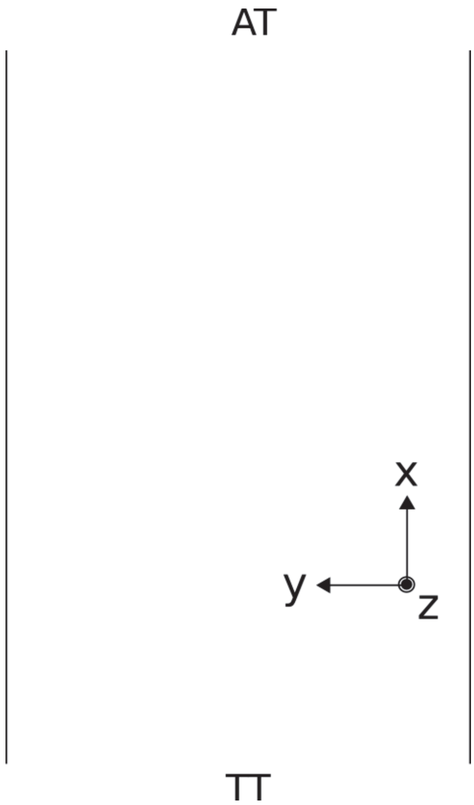

Figure 3 - Definition of the coordinate system. TT marks the location of the Trim Tank, and AT marks the location of the Melting Tank.

2.3. Relevant fixed parameters

The fast ice position is a fixed parameter throughout all experiments.

3. Instrumentation and data acquisition

3.1. Instruments

General instrumentation

- Two load cells were mounted on the pusher plate attached to the main carriage.
- Four load cells were housed in two separate side load panels (provided by HSVA).
- Four LASERs were mounted either side of the experimental area in the y direction.
- Qualisys Motion Capture System – cameras are installed on the main carriage, and markers are placed on the middle block, fast ice, and sometimes up to two pieces of rubble.
-

Instrumentation of the middle block

- Six mercury stress sensors (for calibrations see file Appendix C: Stress sensor calibrations.xlsx. See also “500 kg load cell calibration using 5kg weight - channel 13.lvm” for calibration file for the load cell used in the process.
- Nine acoustic emissions transducers connected to the Vallen AMSY-5
- Four strain gauges

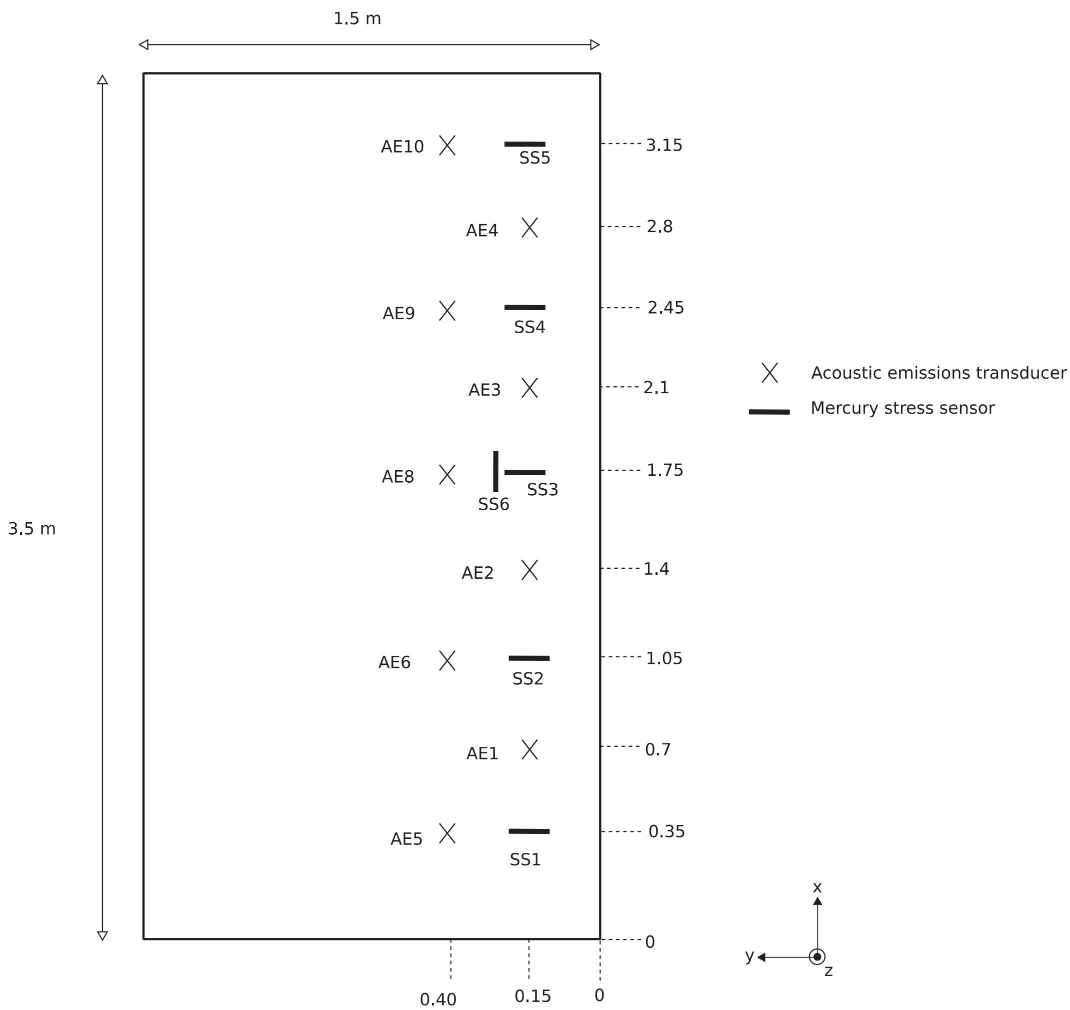

Figure 4 - Diagram showing the positions and sensor numbers of the mercury stress sensors (SS 1-6) and acoustic emissions transducers (AE 1-10).

3.2. Definition of time origin and instrument synchronization

All instruments are logged according to local time (Hamburg GMT+2). All logging systems (except for strain sensor logging) are synchronized using a 5V sync signal, which also illuminates a light bulb to synchronize cameras.

3.3. Measured parameters

Data will be collected via several methods. For each experimental run, the following data files will be collected:

1. Stress sensor logging file
2. Acoustic emissions logging file
3. One data file for containing data from Qualysis, LASERs, loads (side and direct) and carriage position.
4. Films of overall view of experiment from carriage
5. Film of the rubble region only (port side)

Measured parameters are as follows:

- Movement of middle block relative to the fast ice in x and y directions (Qualisys)
- Movement of up to two ice rubble pieces (not featured in all experiments)
- Width of experiment in y direction (LASERs)
- Force required to push middle block

- Side load force applied
- Stress in the middle block (mercury stress sensors)
- Acoustic emissions in the middle block

4. Experimental procedure and test program

4.1. Test plan

Two types of experiment were performed: 1) steady sliding tests where the middle block was pushed at four different sliding speeds, and 2) hold time tests which employed a slide-hold-slide procedure, where the hold times varied from 1 – 10,000 seconds (see

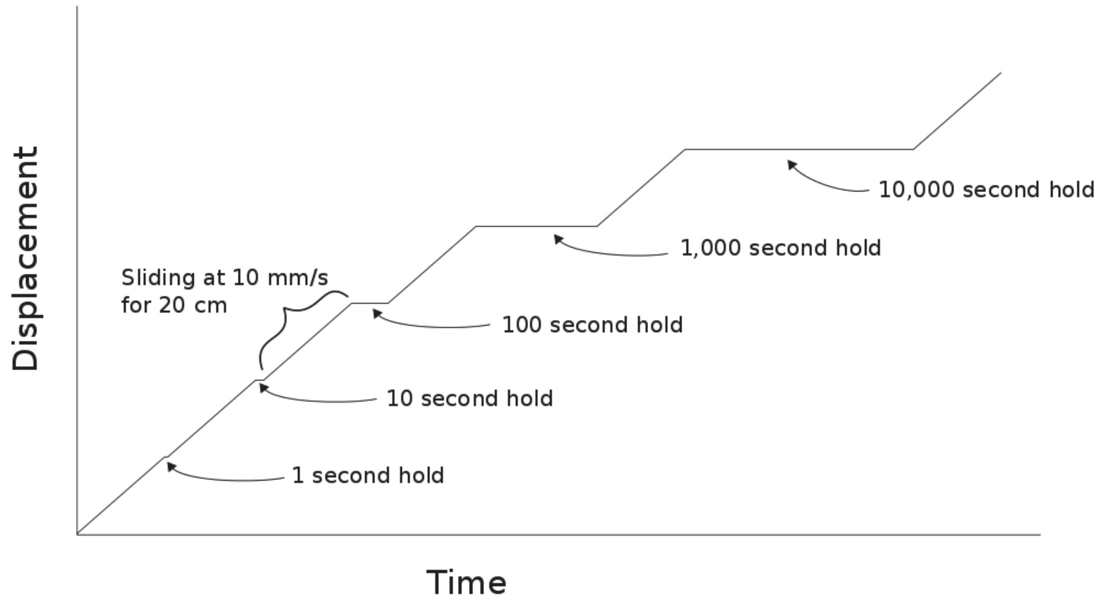

Figure 5).

The initial test plan can be seen in Table 1, however actual experiment test numbers and descriptions can be seen in Appendix B “Experiment Details.xlsx”.

Rubble type	Test number	Description	
Small round rubble (10cm diameter)		Steady sliding over 2m at:	3 mm/s
	1		10 mm/s
			30 mm/s
	2		100 mm/s
	3	Hold time experiment: one run which has a slide-hold-slide nature. Hold times will increase from 1s, 10s, 100s, 1000s, 10,000s	
Large round rubble (17cm diameter)		Steady sliding over 2m at:	3 mm/s
	4		10 mm/s
			30 mm/s
	5		100 mm/s
	6	Hold time experiment: one run which has a slide-hold-slide nature. Hold times will increase from 1s, 10s, 100s, 1000s, 10,000s	

Small angular rubble (short axis 10cm, long axis 17cm)		Steady sliding over 2m at:	3 mm/s
	7		10 mm/s
			30 mm/s
	8		100 mm/s
	9	Hold time experiment: one run which has a slide-hold-slide nature. Hold times will increase from 1s, 10s, 100s, 1000s, 10,000s	
Large angular rubble (short axis 17cm, long axis 30cm)		Steady sliding over 2m at:	3 mm/s
	10		10 mm/s
			30 mm/s
	11		100 mm/s
	12	Hold time experiment: one run which has a slide-hold-slide nature. Hold times will increase from 1s, 10s, 100s, 1000s, 10,000s	

Table 1 - The initial experimental plan.

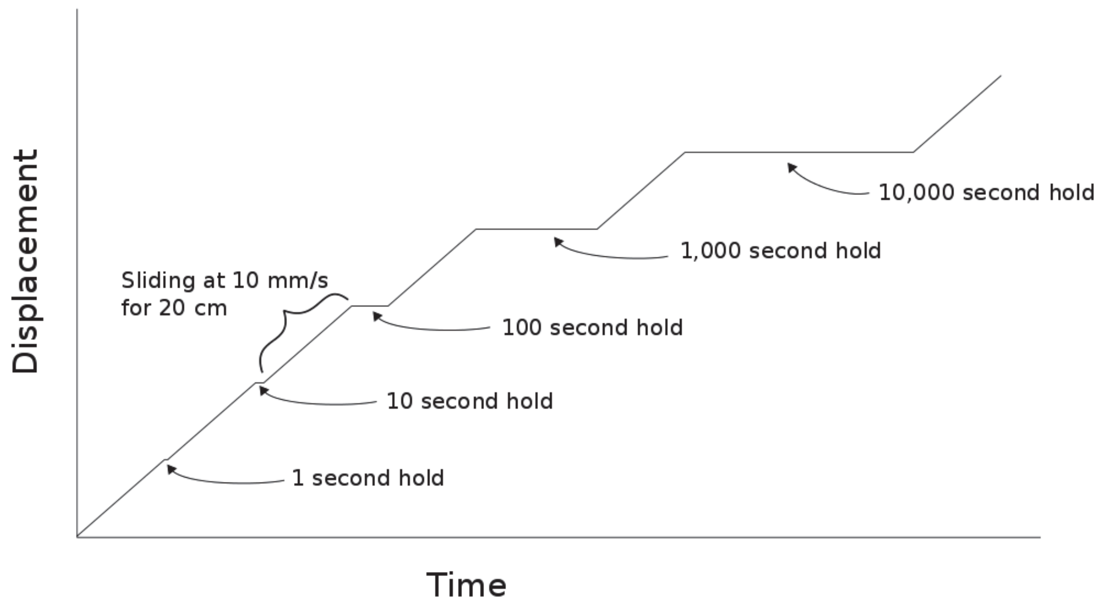

Figure 5 - Schematic of a typical hold time experiment.

4.2. Preparation of ice rubble

Large round rubble

This rubble was produced by coring the level ice with a 16.5cm core auger. The resulting cores were then cut on a band saw to a depth of 9cm.

Small round rubble

This was created by coring with a 9.5cm diameter core auger and cutting the resulting cores to a depth of 7cm each.

Large angular rubble

A grid was marked on the level ice such that diamonds with shortest dimension 17cm and longest dimension 30cm were produced when the ice was cut. Level ice thickness was 20cm, so these blocks were cut in half to create diamonds 10cm deep

Small angular rubble

Over a weekend, the “open water” region in front of the middle block was left to freeze. The ice that formed was 9cm thick, and this was excavated and cut on the band saw to create diamonds with a short dimension of 10cm and a longest dimension of 17cm. The depth was kept the same at 9cm.

5. Data post-processing

No filtering or post-processing had been performed.

6. Organization of data files

File names take the form “test_x” where the test number changes. Descriptions for each test number can be seen below and in “Experiment details.xlsx”.

Date	Rubble type	Test number	File name	Test Description
11/05/17 (Thurs)	N/A	ice-ice_1	ice-ice_1	Middle block and ice beam sliding in contact. Moved ~40cm at 0.01 m/s
	N/A	ice-ice_2	ice-ice_2	Same as above but sliding at 0.03 m/s.
	N/A	ice-ice_3	ice-ice_3	Same as above but sliding at 0.003 m/s
	N/A	ice-ice_4	ice-ice_4	Same as above, sliding at 0.1 m/s
12/05/17 (Fri)	Small round (10cm diameter, 7cm depth)	1	test_1	Steady sliding with small rubble. 0.003 m/s
		2	test_2	Same as above but sliding at 0.01 m/s
		3	test_3	Same as above but sliding at 0.3 m/s
15/05/17 (Mon)	Large round (17cm diameter, 9cm depth)	4	test_4	Sliding at 3mm/s, 10mm/s then 30mm/s for ~40cm each. Large round rubble.
		5	test_5	Sliding at 100mm/s for 1m. Large round rubble.
16/05/17 (Tues)	Large round (17cm diameter)	6a	test_6a	Hold for 1s, 10s and 100s, sliding for 20cm at 10mm/s in between. Test stops during 1000s hold.
		6a1	test_6a1	Holding for 100s and 1000s. Sliding for 20cm at 10mm/s in between.
		6b	test_6b	Continuation of test 6a1. Sliding for 20cm at 0.003 after the 10,000s (2.7 hr) hold.

		6b1	test_6b1	Same as above - sliding at 3mm/s for ~20cm
17/05/17 (Wed)	Small angular (diamonds, short axis 10cm, long axis 17cm, depth 9cm)	7	test_7	Steady sliding at 3mm/s then 10mm/s (40cm each)
		7a	test_7a	Steady sliding at 10 and 30mm/s (40cm each)
		8	test_8	Steady sliding: 100mm/s for 1m
		9a	test_9a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.
		9b	test_9b	Final slide (at 3mm/s for 20cm) after 10,000s hold
18/05/17 (Thurs)	Large angular (long axis 30cm, short axis 18cm, depth 10cm)	10	test_10	Steady sliding at 3, 10 and 30mm/s for 40cm
		12a	test_12a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.
		12b	test_12b	Sliding at 3mm/s for 20cm after hold of 2hr 42 mins
19/05/2017 (Fri)	Small round (10cm diameter)	13a	test_12a	Hold times 1, 10, 100, 1000s. Sliding at 30mm/s in between.
		13b	test_12b	Sliding at 3mm/s for 20cm after hold of 1hr 42 mins

22/05/2017 (Mon)	Open water - no rubble, no side load	Test 14	test_14	Steady sliding at 3, 10 and 30 mm/s, sliding ~40cm for each.
		Test 15	test_15	Steady sliding at 100mm/s for ~1m
		Test 16	test_16	Repeat of test 14

Mercury Pressure Sensor files

Each file contains a header as follows:

X_Value Channel 1 Channel 2 Channel 3 Channel 4 Channel 13 Channel 14 Channel 15 Channel 16 Channel 17 Channel 18 Channel 19 Comment

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Column 1 (X_Value)	shows the time since the start of logging.
Columns 2-5 (Channel1 – Channel 4)	show displacement transducers via NI 6224 card.
Columns 6-11 (Channel 13 – Channel 18)	show mercury stress sensors SS1 – SS6 respectively on NI 6143 card.
Column 12 (Channel 19)	shows the synchronization signal shared between logging equipment.

Acoustic Emissions Sensors

Each file contains a header (seen below) which gives the structure of the output from the Vallen AMSY-5. Each row below the header corresponds to an individual hit i.e. a signal on an individual channel which exceeded the given threshold:

Id HHMMSS MSEC CHAN A E D DSET TRAI FCOG FMXA R THR PA0 PA1 CHIT DAY
[hhmmss] [ms.μs] [dB] [eu] [μs] [kHz] [kHz] [μs] [dB] [mV] [mV]

Column 1 (Id) is	an unused label
Column 2 (HHMMSS) is	Time in hh:mm:ss
Column 3 (MSEC) is	ms.us (3 digits of milliseconds, followed by four digits of microseconds)
Column 4 (CHAN) is	the channel the hit was recorded on (1-10)
Column 5 (A) is	the amplitude of the hit (in dB)
Column 6 (E) is	a measure of the energy in the hit
Column 7 (D) is	the duration of the hit in microseconds
Column 8 (DSET) is	an index in the data set
Column 9 (TRAI) is	an index of the transients being recorded
Column 10 (FCOG) is	the frequency centre of gravity of the recorded transient
Column 11 (FMXA) is	the peak frequency of the recorded transient
Column 12 (R) is	the risetime of the signal in microseconds
Column 13 (THR) is	the threshold amplitude required for a hit to be recognised
Column 14 (PA0) is	a parametric input (i.e. an additional signal, to be used here for a time synchronisation signal shared between logging equipment)
Column 15 (PA1) is	a second parametric input, unused here
Column 16 (CHIT) is	a count of the number of hits in the hit-cascade
Column 17 (DAY) is	the day of the month of the experiment

HSVA logging file

Explanations of the parameter abbreviations used in the HSVA logging file header are shown in Table 2 and their positions can be seen in Figure 6.

Parameter	Parameter abbreviation	Unit
Main carriage position	s_x	m
Main carriage velocity	v_x	m/s
Sync signal	Sync	V
Rubble 1 position (x)	RU1_X	mm
Rubble 1 position (y)	RU1_Y	mm
Rubble 1 yaw	RU1_YAW	deg
Rubble 2 position (x)	RU2_X	mm
Rubble 2 position (y)	RU2_Y	mm
Rubble 2 yaw	RU2_YAW	deg
Fixed ice position (x)	FI_X	mm
Fixed ice position (y)	FI_Y	mm
Middle block position (x)	MB_X	mm
Middle block position (y)	MB_Y	mm
Middle block yaw	MB_YAW	deg
Pushing force (port side)	FP_1	N
Pushing force (starboard side)	FP_2	N
Side pressure	P_1	bar
Side force 1 (starboard side)	F_1	N
Side force 2 (starboard side)	F_2	N
Side force 3 (port side)	F_3	N
Side force 4 (port side)	F_4	N
Side panel extension 1	d_1	mm
Side panel extension 2	d_2	mm
Side panel extension 3	d_3	mm
Side panel extension 4	d_4	mm

Table 2 - HSVA logging file parameters with their abbreviations and units.

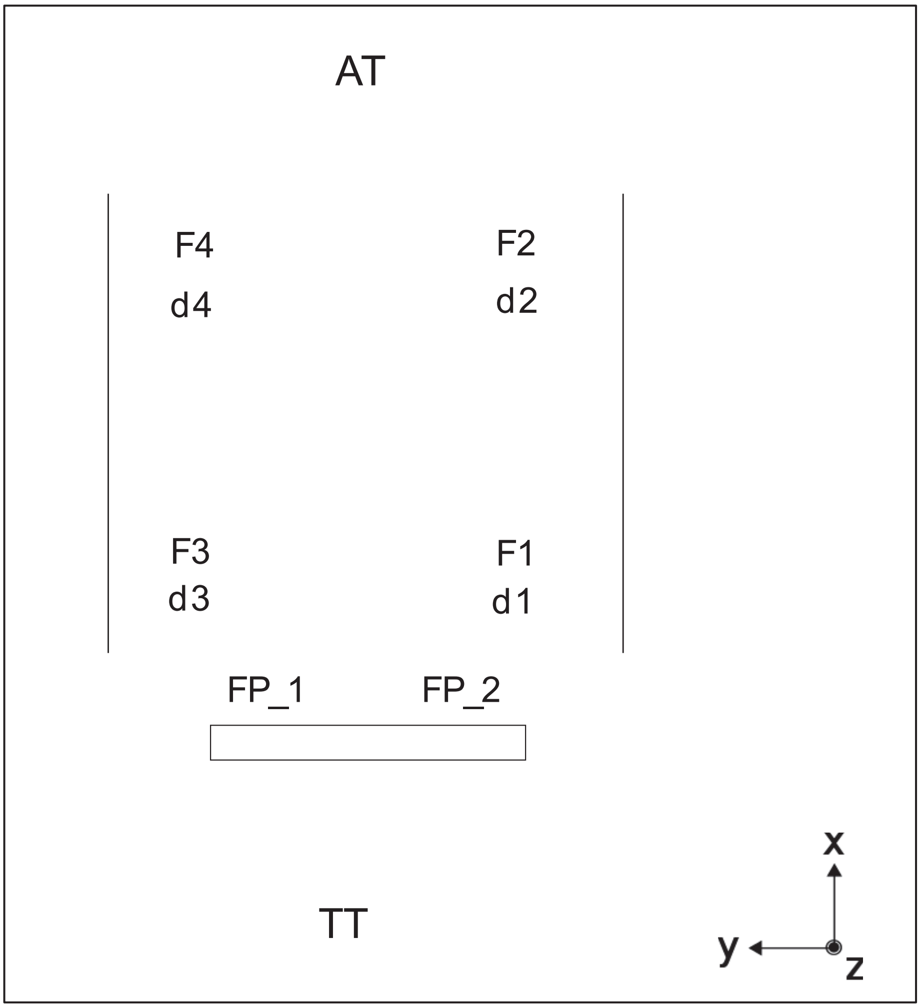


Figure 6 - Rough positions of load cells and LASER sensors in the setup.

7. Remarks

No remarks.

8. Appendices

8.1. Appendix A: Day log

See separate pdf document.

8.2. Appendix B: Experiment details.xlsx

See separate Excel document.

8.3. Appendix C: Stress sensor calibrations.xlsx

See separate Excel document.

UCL Project at HSVA – 1st – 24th May 2017

Day Log

1. Tuesday 2nd May

Unloading van

PC and logging set up

Check all logging

Meeting with Kalle, Philipp, Steve, Roland and Mario

Started making foam housings for Vallen preamps

Safety presentation with Kalle

2. Wednesday 3rd May

Mercury stress sensor calibration and testing (see file "Stress sensor calibrations.xlsx")

500kg load cell calibration (see file "500 kg load cell calibration using 5kg weight - channel 13.lvm")

Vallen training for Sally and Mark

Preparation of Mark's experiment

Tour of HSVA – workshops, large ice flume, cavitation tank

Ordered BNC in-line connectors

Ice making:

> -17°C @ 5pm on 2nd May
>
> Waves started @ 12pm on 3rd May (with open water)
>
> Waves stopped @ 4pm on 3rd (first pancakes formed)

Comments/queries:

Enquire about maximum hold time possible. Can side loading plates be locked overnight and pump removed?

What is the maximum range on the LASER?

Things to do before Monday:

> Testing out stress sensors in sample ice (and possibly acoustic sensors)
>
> Moving logging to in situ position on bridge

Make Mark's frames

3. Thursday 4th May

Set up consolidation experiment frame (1/4)

Completed diagram of experimental setup in the LIMB, including frame positions (emailed out by Kalle)

Data storage plan produced

Middle block sensor arrangement mapped

Cable management (cables connected and numbered appropriately)

Took ice thickness measurements at 14.40 (ice ~37mm thick)

Made an experiment checklist

4. Friday 5th May

Set up logging in the carriage.

Tested surface profiling kit.

Continued assembling consolidation experiment frames.

5. Monday 8th May

Ice sheet thickness ~15cm

Meeting with Kalle, Steve and Roland

Prepared RTDs (Mark, Ellie, Sammie)

Marked out Mark's experiment on the ice with spray paint. Hole cored and RTDs left to freeze in.

Small diameter (9.5cm) cores augered (~50 cores). These will be cut into cylinders 7cm in length.

6. Tuesday 9th May

Made small rubble using 10cm auger. Cut cores to make rubble pieces 7cm deep.

Marked out setup area

Cut the setup. Removed ice from area in front of middle block, ice rubble region and side load frame regions.

7. Wednesday 10th

Finished cutting out middle block – it now moves freely.

Plastic shims made to reinforce the far edges of the ice rubble region and ice beam. These are in situ.

Decided to see whether Qualisys cameras work at -10°C. If not, a constant temperature of -5°C will be maintained throughout instead.

Marks experiment – blocks cut and arranged.

8. Thursday 11th

Freed up moving ice parts which had re-frozen in.

Side loading frames installed.

Cables to instruments on middle block were set up (stress sensors and AE sensors).

Ice-ice tests run (see table below).

Date	Test number	File name	Test Description	Comments
11/05/17	ice-ice_1	ice-ice_1	Middle block and ice beam sliding in contact. Moved ~40cm at 0.01 m/s	Wooden spacer frames (made to fill ice rubble gap) raft upwards at side load pressures over ~1kN
	ice-ice_2	ice-ice_2	Same as above but sliding at 0.03 m/s. Side load ~0.8kN	Buoyancy of middle frame altered.
	ice-ice_3	ice-ice_3 (apart from Vallen which is ice-ice_3a)	Same as above but sliding at 0.003 m/s	Qualisys reflector on middle block pushed up knocked as it came into contact with fast ice.
	ice-ice_4	ice-ice_4	Same as above but sliding at 0.1 m/s	No stick slip observed

9. Friday 12th

Prepared experiment area – freed up moving parts of the ice which had re-frozen in.

All large diameter (16.5cm) cylinders have been cored. These now need cutting in half so that their length is 9cm (half have already been cut).

Date	Test number	File name	Test Description	Comments	
12/05/17 (Fri)	1	test_1	Steady sliding with small rubble. 0.003 m/s	Rubble pushed downwards on port side, pushed upwards on starboard side. 2min 30secs between total side load being applied and carriage pushing MB. Rubble was freed up immediately before test started. A few pieces of rubble rotated nearest the sliding edges.	No Qualisys on rubble. Green markers on rubble on starboard side.
	2	test_2	Same as above but sliding at 0.01 m/s	No obvious rubble rotation occurred. Rubble was not freed up in between experiments. Rubble on port side was slightly submerged after side load applied. Rubble on starboard side only started to be pushed upwards towards the end (weights had been added to the SL panel here).	
	3	test_3	Same as above but sliding at 0.3 m/s	Started to apply side load, but rubble started to capsize (mostly on port side, but some on the starbord side). Decided not to continue with test, so no data available.	

Test 3 wasn't run because the rubble started to capsize. A suggested solution to this is to use rubble cylinders with a shorter length, such that lateral melting doesn't result in a ratio of depth:width that causes capsizing.

10. Monday 15th

Frozen "open water" region in front of block was cleared of ice. This thinner ice (9cm) was set aside for the purpose of generating small angular ice rubble (long axis 17cm, short axis 10cm).

Fresh ice, which grew over the weekend, was cut and setup was cleared.

Main carriage was moved back into place.

Cables and load plate reattached, side load panels put back into place.

Steady sliding tests run with large round rubble (16.5cm diameter):

Date	Rubble type	Test number	File name	Test Description	Comments	
15/05/17 (Mon)	Large round (17cm diameter)	4	test_4	Sliding at 3mm/s, 10mm/s then 30mm/s for ~40cm each. Large round rubble.	AE and stress sensor logging started before side load applied. Sync signal now going to Vallen too. Rubble stayed in plane during 3mm/s. Started to submerge at 10mm/s. Many blocks (~5 each side) submerged @ 30mm/s.	Stick slip observed but rubble rotation was not. Mush tended to form in -ve x direction, consolidation of rubble pieces tended to occur in +ve x direction (similar behaviour observed during small rubble sliding tests)
		5	test_5	Sliding at 100mm/s for 1m. Large round rubble.	Vallen started logging before side load applied.	

11. Tuesday 16th

Ran hold time experiment with large round rubble.

Date	Rubble type	Test number	File name	Test Description	Comments
		6a	test_6a (test_6aa on Vallen)	Hold for 1s, 10s and 100s, sliding for 20cm at 10mm/s in between. Test stops during 1000s hold.	Rubble pushed out of plane on both sides by the 1000s hold. Decided to stop, release side load, rearrange rubble and continue with test 6a1.
		6a1	test_6a1	Holding for 100s and 1000s. Sliding for 20cm at 10mm/s in between.	Some rubble moved out of plane, but in-plane rubble was still supporting the side load.
16/05/17 (Tues)	Large round (17cm diameter)	6b	test_6b	Continuation of test 6a1. Sliding for 20cm at 0.003 after the 10,000s (2.7 hr) hold.	A lower sliding speed (3 instead of 10mm/s was chosen so that force on the load cell could be more closely monitored to avoid breaking it (max capacity 10kN). This pushing force was not adequate, and test was stopped. NO USEFUL DATA.
		6b1	test_6b1	Same as above - sliding at 3mm/s for ~20cm	Frozen water behind pusher and in front of block were cleared. Contacts between middle block and level ice were sawed (but no ice was broken in the rubble region). Stick slip observed. Max load required to move block ~7.5kN.

Continued making small angular rubble (diamonds, long axis 17cm, short axis 10cm, height 8cm)

12. Wednesday 17th

Date	Rubble type	Test number	File name	Test Description	Comments
17/05/17 (Wed)	Small angular (diamonds, short axis 10cm, long axis 17cm)	7	test_7	Steady sliding at 3mm/s then 10mm/s (40cm each)	3mm/s ran OK. At transition to 10mm/s the direct load plate started creaking and experiment was stopped. This was because the middle block was sliding in contact with the fast ice. This was freed up before starting the next test. The middle edge of the middle block in contact with the pusher plate was flattened to improve the contact (previously most of the load was being transferred through only 1 of 2 load cells)
		7a	test_7a	Steady sliding at 10 and 30mm/s (40cm each)	Ran well. Some minor lifting or rubble out of water on port side but rubble stayed in plane elsewhere.
		8	test_8	Steady sliding: 100mm/s for 1m	Some stick slip towards the end of the run as force chains collapsed.
		9a	test_9a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.	
		9b	test_9b	Final slide (at 3mm/s for 20cm) after 10,000s hold	Briefly stopped direct force at beginning, as load plate started creaking. Continued straight afterwards. Max load 7.7kN, ~2kN afterwards

Produced large angular rubble (diamonds, long axis 30cm, short axis 18cm, height 10cm).

13. Thursday 18th

Date	Rubble type	Test number	File name	Test Description	Comments
18/05/17 (Thurs)	Large angular (long axis 30cm, short axis 18cm, depth 10cm)	10	test_10	Steady sliding at 3, 10 and 30mm/s for 40cm	Stopped before 300mm/s slide was complete as load plate broke (but load cells still in tact). Seemed to be some ice-ice contact between the middle block and fast ice which may be the cause for the high loads. Stick slip observed, (worth noting that load plate was flexing).
		12a	test_11a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.	Stick slip observed. Rubble movement minimal.
		12b	test_11b	Sliding at 3mm/s for 20cm after hold of 2hr 42 mins	Could not move block. Force required must be in excess of 12kN

14. Friday 19th

Date	Rubble type	Test number	File name	Test Description	Comments
19/05/2017 (Fri)	Small round (10cm diameter)	13a	test_12a	Hold times 1, 10, 100, 1000s. Sliding at 30mm/s in between.	After 1000s hold, pushed at 3mm/s to control load more effectively (pusher plate started to creak). More rubble movement and rotation than angular rubble. Stick slip not observed. From observation, only some chains of rubble support the load, and this changed as rubble moved and rotated. Large loads encountered at one stage (pusher plate creaking), likely due to the ice block bashing against the side of the ice channel instead of forces resulting from the rubble. Rubble gradually lifted out of water on both sides (more pronounced on port side). Vallen may not have worked
		13b	test_12b	Sliding at 3mm/s for 20cm after hold of 1hr 42 mins	No Vallen data

Monday 22nd

Date	Rubble type	Test number	File name	Test Description	Comments
22/05/2017 (Mon)	Open water - no rubble, no side load	Test 14	test_14	Steady sliding at 3, 10 and 30 mm/s, sliding ~40cm for each.	Some noticeable ice-ice contact between middle block and channel edge
		Test 15	test_15	Steady sliding at 100mm/s for ~1m	Middle block travelled smoothly
		Test 16	test_16	Repeat of test 14	Less ice-ice contact

15. Tuesday 23rd

Thin sections

Using acoustic emissions to measure wave speed in ice

Removing thermistor strings

Date	Rubble type	Test number	File name	Test Description	Comments	
11/05/17 (Thurs)	N/A	ice-ice_1	ice-ice_1	Middle block and ice beam sliding in contact. Moved ~40cm at 0.01 m/s	Wooden spacer frames (made to fill ice rubble gap) raft upwards at side load pressures over ~1kN	
	N/A	ice-ice_2	ice-ice_2	Same as above but sliding at 0.03 m/s.	Buoyancy of middle frame altered.	
	N/A	ice-ice_3	ice-ice_3	Same as above but sliding at 0.003 m/s	Qualisys reflector on middle block pushed up knocked as it came into contact with fast ice.	
	N/A	ice-ice_4	ice-ice_4	Same as above, sliding at 0.1 m/s	No stick slip observed	
12/05/17 (Fri)	Small round (10cm diameter, 7cm depth)	1	test_1	Steady sliding with small rubble. 0.003 m/s	Rubble pushed downwards on port side, pushed upwards on starboard side. 2min 30secs between total side load being applied and carriage pushing MB. Rubble was freed up immediately before test started. A few pieces of rubble rotated nearest the sliding edges.	No Qualisys on rubble. Green markers on rubble on starboard side.
		2	test_2	Same as above but sliding at 0.01 m/s	No obvious rubble rotation occurred. Rubble was not freed up in between experiments. Rubble on port side was slightly submerged after side load applied. Rubble on starboard side only started to be pushed upwards towards the end (weights had been added to the SL panel here).	
		3	test_3	Same as above but sliding at 0.3 m/s	Started to apply side load, but rubble started to capsize (mostly on port side, but some on the starbord side). Decided not to continue with test. NO USEFUL DATA.	
15/05/17 (Mon)	Large round (17cm diameter, 9cm depth)	4	test_4	Sliding at 3mm/s, 10mm/s then 30mm/s for ~40cm each. Large round rubble.	AE and stress sensor logging started before side load applied. Sync signal now going to Vallen too. Rubble stayed in plane during 3mm/s. Started to submerge at 10mm/s. Many blocks (~5 each side) submerged @ 30mm/s.	Stick slip observed but rubble rotation was not. Mush tended to form in -ve x direction, consolidation of rubble pieces tended to occur in +ve x direction (similar behaviour observed during small rubble sliding tests)
		5	test_5	Sliding at 100mm/s for 1m. Large round rubble.	Vallen started logging before side load applied.	

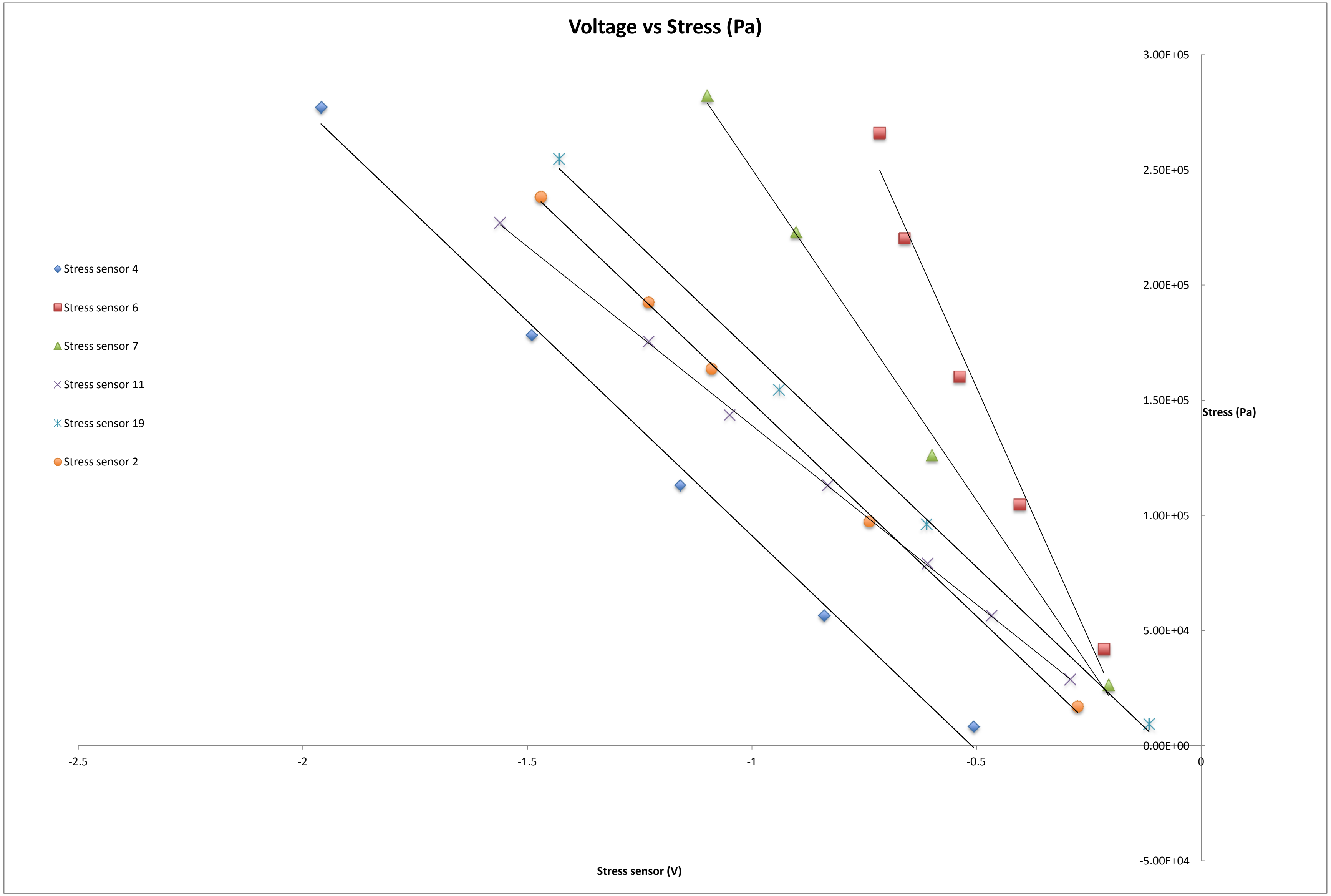
16/05/17 (Tues)	Large round (17cm diameter)	6a	test_6a	Hold for 1s, 10s and 100s, sliding for 20cm at 10mm/s in between. Test stops during 1000s hold.	Rubble pushed out of plane on both sides by the 1000s hold. Decided to stop, release side load, rearrange rubble and continue with test 6a1.
		6a1	test_6a1	Holding for 100s and 1000s. Sliding for 20cm at 10mm/s in between.	Some rubble moved out of plane, but in-plane rubble was still supporting the side load.
		6b	test_6b	Continuation of test 6a1. Sliding for 20cm at 0.003 after the 10,000s (2.7 hr) hold.	A lower sliding speed (3 instead of 10mm/s was chosen so that force on the load cell could be more closely monitored to avoid breaking it (max capacity 10kN). This pushing force was not adequate, and test was stopped.
		6b1	test_6b1	Same as above - sliding at 3mm/s for ~20cm	Frozen water behind pusher and in front of block were cleared. Contacts between middle block and level ice were sawed (but no ice was broken in the rubble region). Stick slip observed. Max load required to move block ~7.5kN.
17/05/17 (Wed)	Small angular (diamonds, short axis 10cm, long axis 17cm, depth 9cm)	7	test_7	Steady sliding at 3mm/s then 10mm/s (40cm each)	3mm/s ran OK. At transition to 10mm/s the direct load plate started creaking and experiment was stopped. This was because the middle block was sliding in contact with the fast ice. This was freed up before starting the next test. The middle edge of the middle block in contact with the pusher plate was flattened to improve the contact (previously most of the load was being transferred through only 1 of 2 load cells)
		7a	test_7a	Steady sliding at 10 and 30mm/s (40cm each)	Ran well. Some minor lifting or rubble out of water on port side but rubble stayed in plane elsewhere.
		8	test_8	Steady sliding: 100mm/s for 1m	Some stick slip towards the end of the run as force chains collapsed.
		9a	test_9a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.	
		9b	test_9b	Final slide (at 3mm/s for 20cm) after 10,000s hold	Briefly stopped direct force at beginning, as load plate started creaking. Continued straight afterwards. Max load 7.7kN, ~2kN afterwards

18/05/17 (Thurs)	Large angular (long axis 30cm, short axis 18cm, depth 10cm)	10	test_10	Steady sliding at 3, 10 and 30mm/s for 40cm	Stopped before 300mm/s slide was complete as load plate broke (but load cells still in tact). Seemed to be some ice-ice contact between the middle block and fast ice which may be the cause for the high loads. Stick slip observed, (worth noting that load plate was flexing).
		12a	test_12a	Hold times 1, 10, 100, 1000s. Sliding at 10mm/s in between.	Stick slip observed. Rubble movement minimal.
		12b	test_12b	Sliding at 3mm/s for 20cm after hold of 2hr 42 mins	Could not move block. Force required must be in excess of 12kN
19/05/2017 (Fri)	Small round (10cm diameter)	13a	test_13a	Hold times 1, 10, 100, 1000s. Sliding at 30mm/s in between.	After 1000s hold, pushed at 3mm/s to control load more effectively (pusher plate started to creak). More rubble movement and rotation than angular rubble. Stick slip not observed. From observation, only some chains of rubble support the load, and this changed as rubble moved and rotated. Large loads encountered at one stage (pusher plate creaking), likely due to the ice block bashing against the side of the ice channel instead of forces resulting from the rubble. Rubble gradually lifted out of water on both sides (more pronounced on port side). Vallen seemed not to work properly.
		13b	test_13b	Sliding at 3mm/s for 20cm after hold of 1hr 42 mins	No Vallen data
22/05/2017 (Mon)	Open water - no rubble, no side load	Test 14	test_14	Steady sliding at 3, 10 and 30 mm/s, sliding ~40cm for each.	Some noticeable ice-ice contact between middle block and channel edge
		Test 15	test_15	Steady sliding at 100mm/s for ~1m	Middle block travelled smoothly
		Test 16	test_16	Repeat of test 14	Less ice-ice contact

Stress sensor no.	HSVA '17 no.	Fylde channel no.	6143 channel	Stress sensor (V)	Load cell (V)	Load cell (N)	Stress (Pa)	Change of 1V on stress sensors corresponds to change in stress of __ Pa	
				-0.507	0.015	37.5	8.49E+03		
				-0.84	0.1	250	5.66E+04		
4	1	2	14	-1.16	0.2	500	1.13E+05	-1.85E+05	185 kPa
				-1.49	0.315	787.5	1.78E+05		
				-1.96	0.49	1225	2.77E+05		
				-0.216	0.074	185	4.19E+04		
				-0.404	0.185	462.5	1.05E+05		
6	2	3	15	-0.538	0.283	707.5	1.60E+05	-4.48E+05	448 kPa
				-0.66	0.389	972.5	2.20E+05		
				-0.716	0.47	1175	2.66E+05		
				-0.206	0.047	117.5	2.66E+04		
				-0.6	0.223	557.5	1.26E+05		
7	6	4	16	-0.902	0.394	985	2.23E+05	-2.86E+05	2.86 kPa
				-1.1	0.499	1247.5	2.82E+05		
17		NOT WORKING							
				-0.292	0.051	127.5	2.89E+04		
				-0.467	0.1	250	5.66E+04		
				-0.61	0.14	350	7.92E+04		
11	3	5	17	-0.831	0.2	500	1.13E+05	-1.56E+05	1.56 kPa
				-1.05	0.254	635	1.44E+05		
				-1.23	0.31	775	1.75E+05		
				-1.56	0.401	1002.5	2.27E+05		
				-0.116	0.0165	41.25	9.34E+03		
				-0.612	0.17	425	9.62E+04		
19	5	6	18	-0.94	0.273	682.5	1.54E+05	-1.87E+05	1.87 kPa
				-1.43	0.45	1125	2.55E+05		
				-0.275	0.03	75	1.70E+04		
				-0.739	0.172	430	9.73E+04		
2	4	6	18	-1.09	0.289	722.5	1.64E+05	-1.85E+05	1.85 kPa
				-1.23	0.34	850	1.92E+05		
				-1.47	0.421	1052.5	2.38E+05		

For these calibrations, 500kg load cell used and on channel 13 (6143) and channel 1 (Fylde)
On Fylde, switch set to 1V for stress sensors, 100mV for load cell
Diameter of the stress sensors is 75mm, so radius is 37.5mm
1V change on the stress sensor corresponds to change in stress of: 185kPa

See load cell calibration file "500 kg load cell calibration using 5kg weight - channel 13.lvm"
1mV = 2.5N



Voltage vs Stress (Pa)
Stress sensor 4
Stress sensor 6
Stress sensor 7
Stress sensor 11
Stress sensor 19
Stress sensor 2
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
-5.00E+04
Stress (Pa)
-2.5
-2
-1.5
-1
-0.5
0
Stress sensor (V)