Proposed Updates to the Siting Criteria of Heavy Earth Cover Magazines

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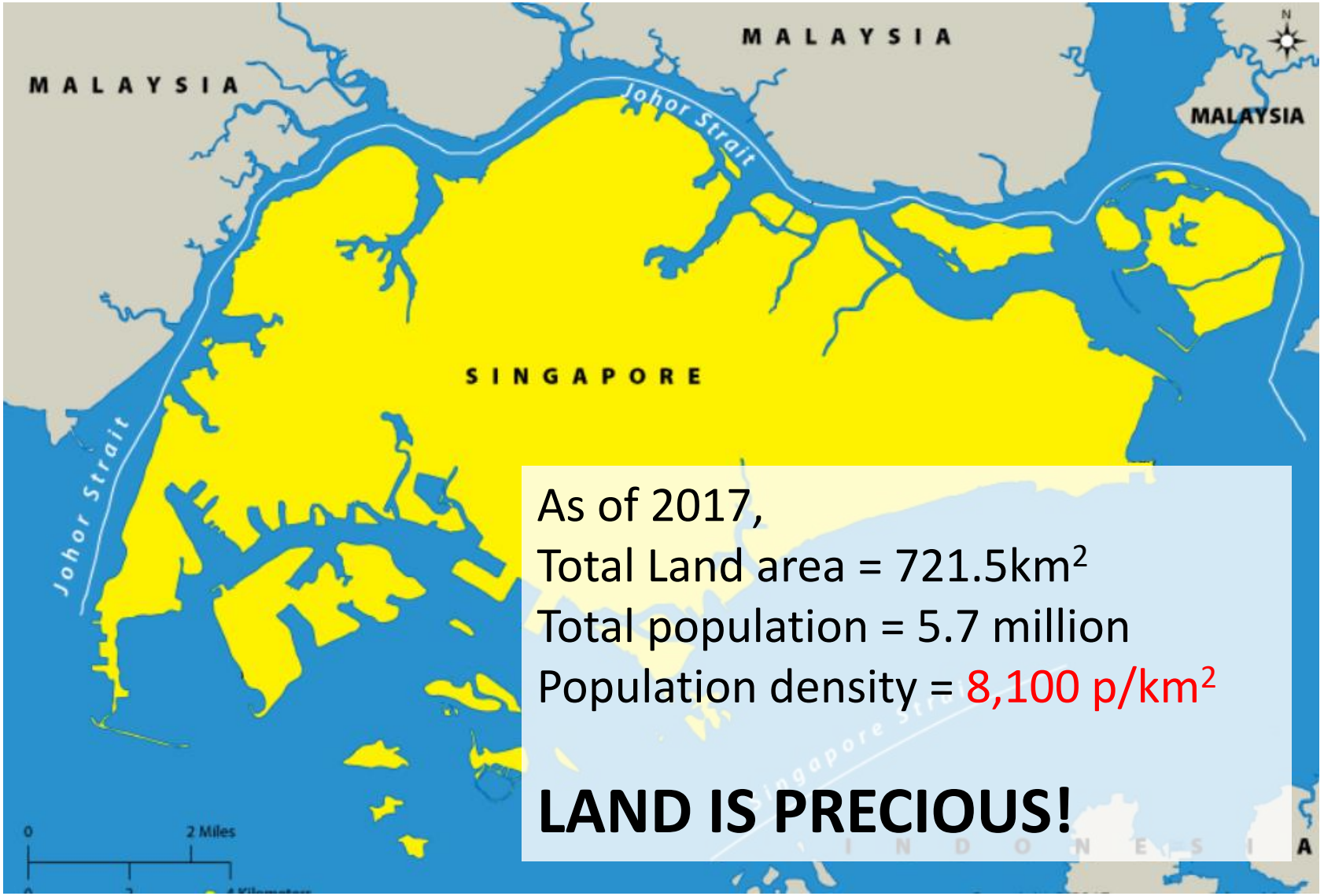
OBJECTIVES

To present on the findings in the 1/5th scale and 2/5th scale Earth-covered magazine (ECM) trials

- Eventual update of AASTP publications with the trial results

LAND FACTS IN SINGAPORE



As of 2017,
Total Land area = 721.5km^2
Total population = 5.7 million
Population density = 8,100 p/km^2

LAND IS PRECIOUS!

CURRENT AASTP GUIDELINES

Underground

Underground Ammunition Facility

Above ground

Earth Covered Magazine (ECM)

AASTP-1 *NATO Guidelines for the Storage of Military Ammunition and Explosives*
Ed B Version 1 (2015)

IBD for ECM:

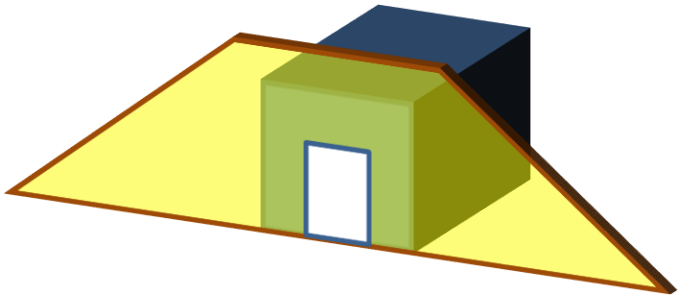
Debris IBD - 400m for all sides

Pressure IBD - K22.2 for front
- K18 for side
- K14 for rear

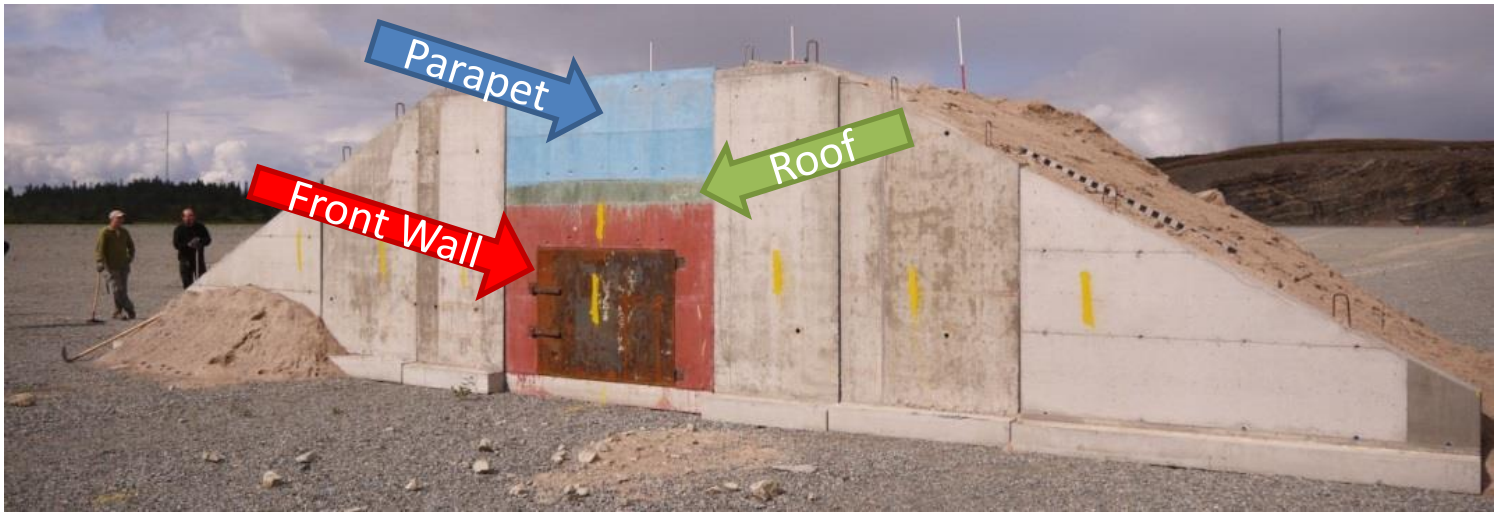
Update?

PROPOSED TEST ARTICLES

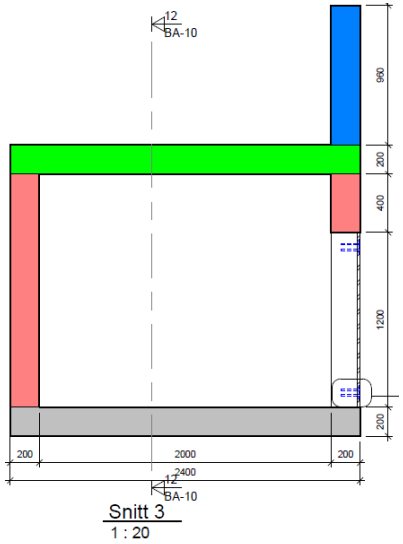
Test Series	Test Model No	Internal Dimensions			Wall Thickness (m)	Earth Cover Thickness (m)	NEQ (kg)	Loading Density (kg/m^3)
		L (m)	W (m)	H (m)				
1	1-1	1.0	1.0	0.8	0.1	0.12	2	2.5
1	1-2	1.0	1.0	0.8	0.1	0.12	8	10
1	1-3	1.0	1.0	0.8	0.1	0.24	8	10
1	1-4	1.0	1.0	0.8	0.1	0.24	16	20
2	2-1	2.0	2.0	1.6	0.2	0.48	128	20
2	2-2	2.0	2.0	1.6	0.2	0.96	128	20
3	3-1	7.0	5.0	4.0	0.5	1.2	3000	20



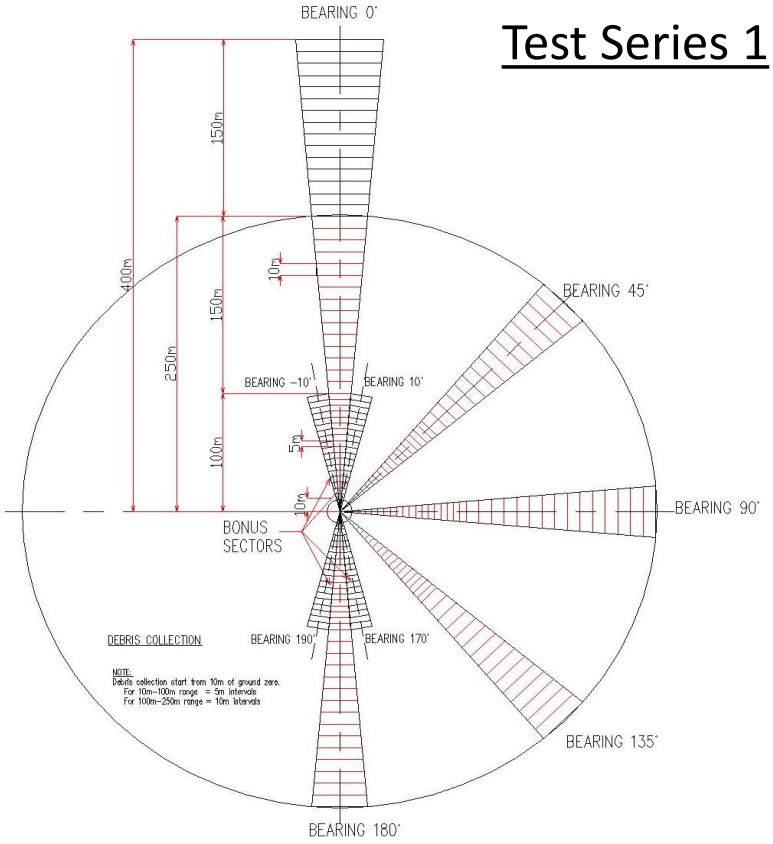
TEST SETUP



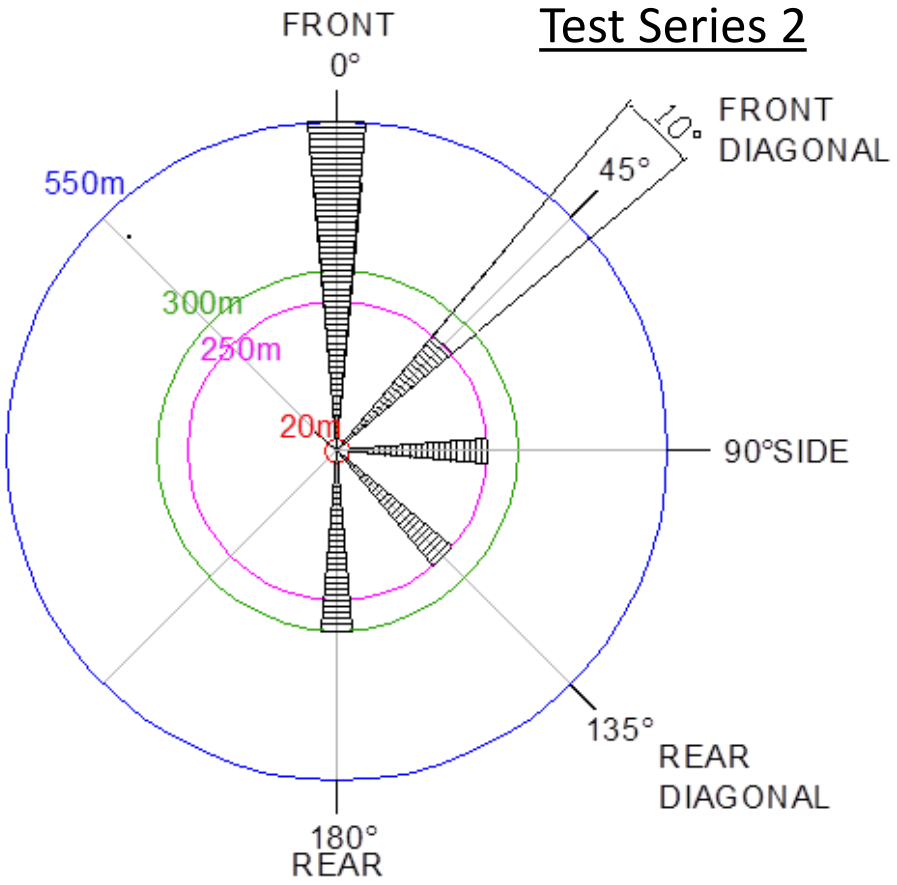
- Debris dyed for identification
- Only concrete debris analysed
- Smallest debris considered = 0.9g for Test Series 1
  = 8g for Test Series 2



DATA COLLECTION



Test Series 1

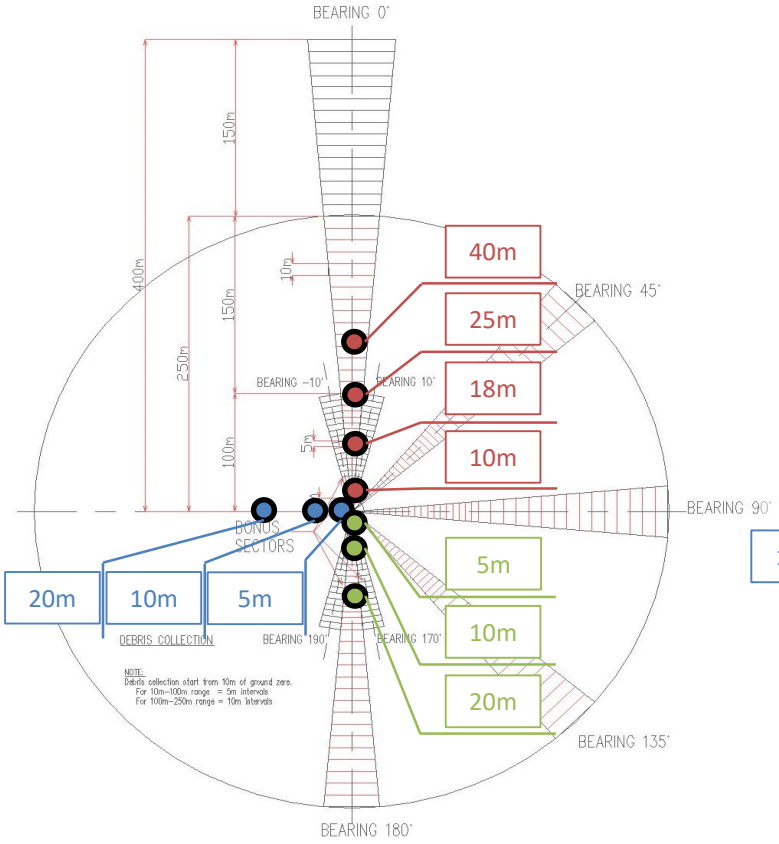


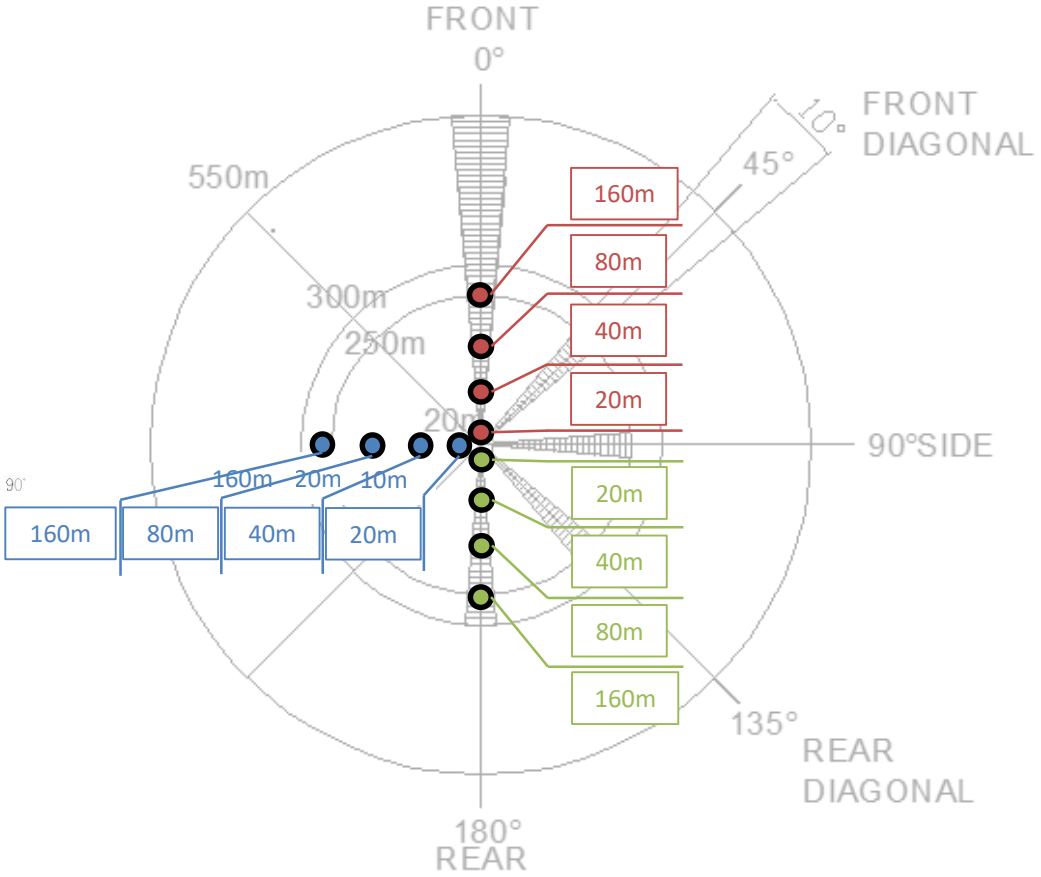
Test Series 2

Debris Collection Plan

- 10° sectors
- 5 or 10m intervals

DATA COLLECTION



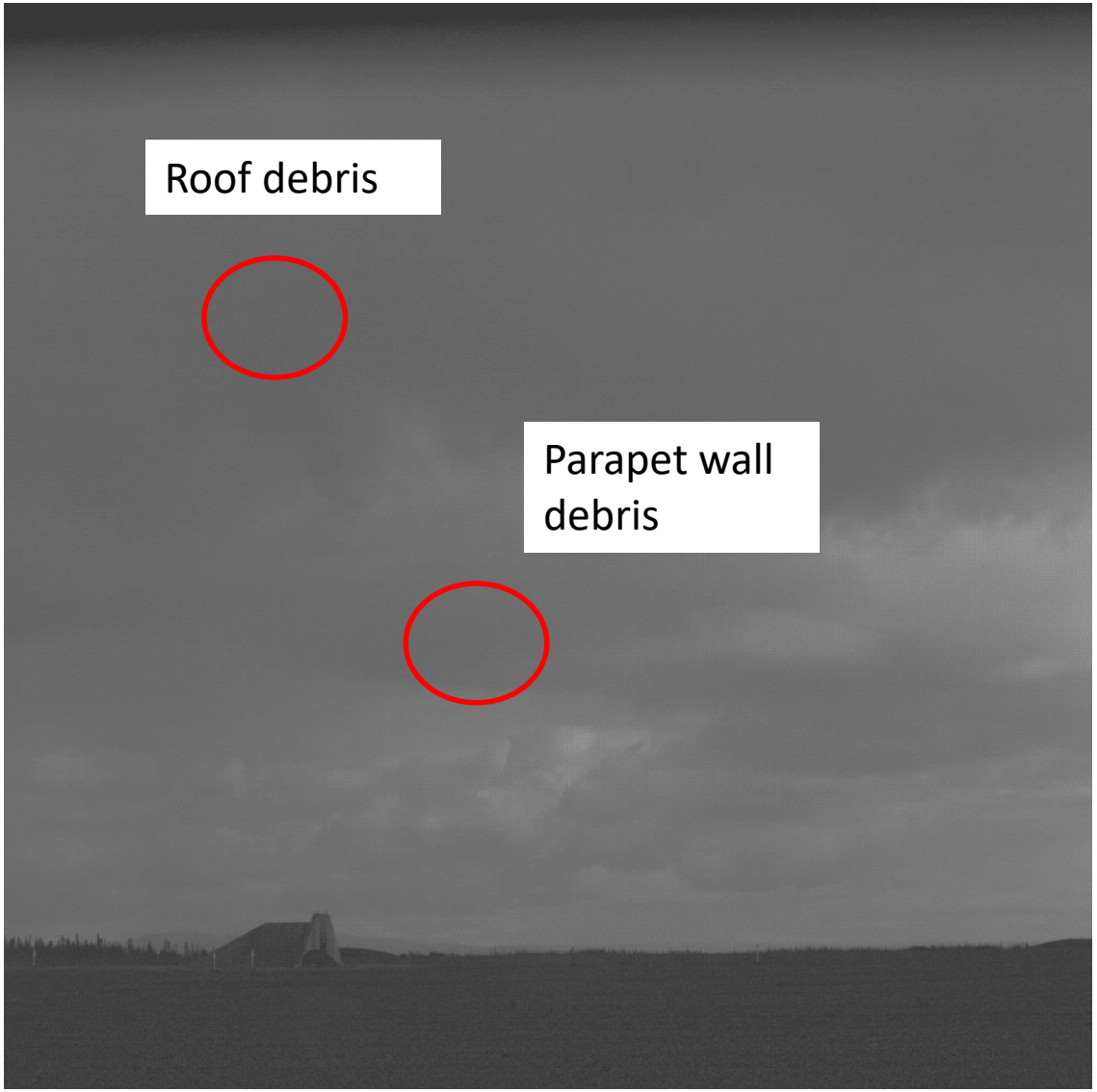


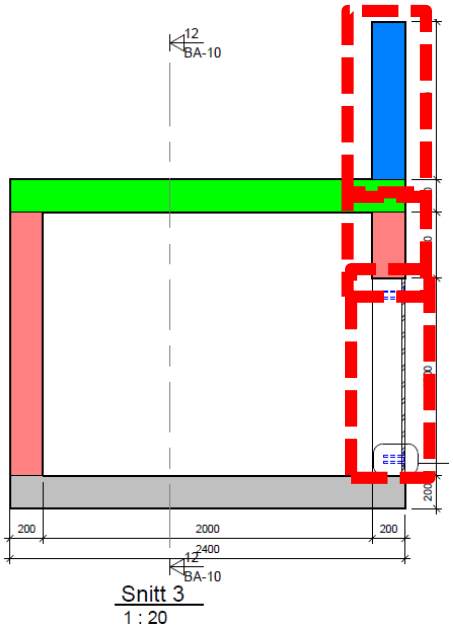
Debris Collection Plan

- 10° sectors
- 5 or 10m intervals

Pressure gauge

STRUCTURAL RESPONSE





STRUCTURAL RESPONSE

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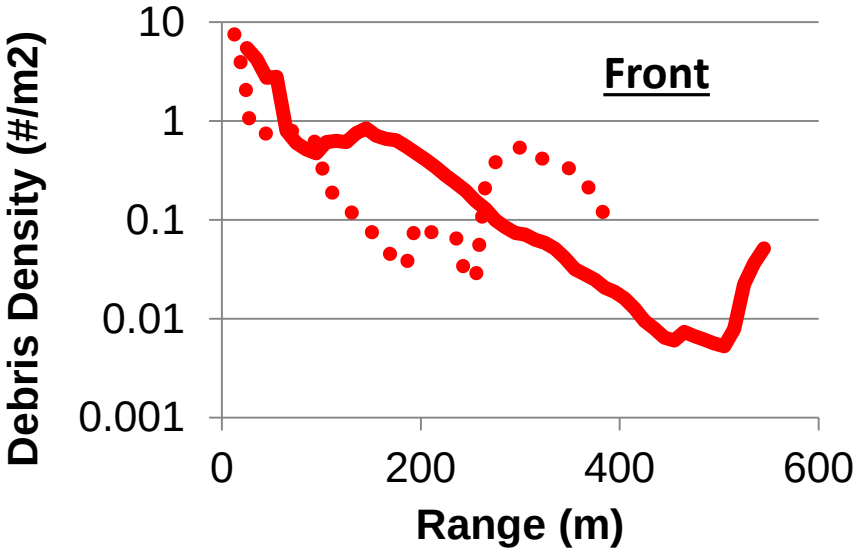
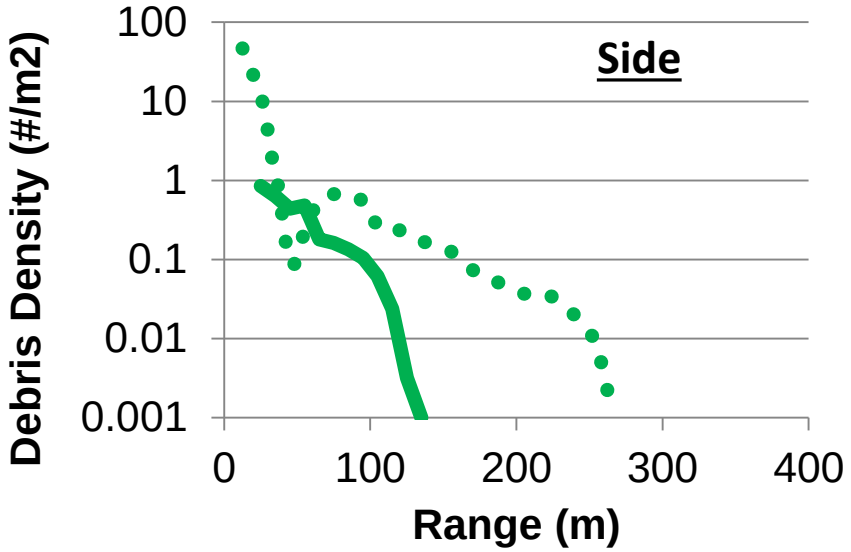
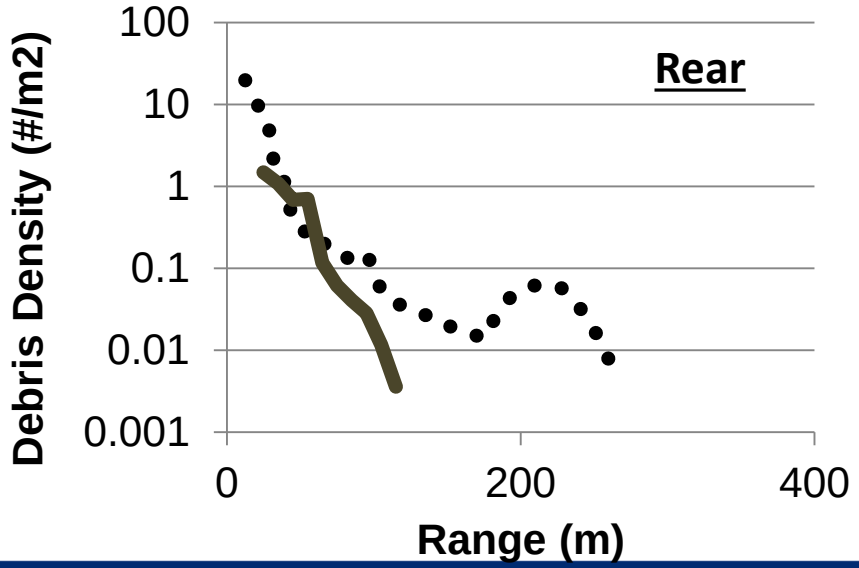
	1/5th Scale	2/5th Scale
Front view		
Side view		

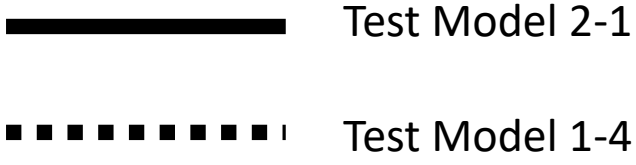
DEBRIS DATA ANALYSIS

Comparison between 1/5th and 2/5th scale tests









GRAVITY ISSUE FOR SMALL SCALE TESTS

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2/5th scale test

Assume gravitational acceleration = g

Theory of replica scaling

1/5th scale test

gravitational acceleration = 2g ✖

Therefore,

Lesser resistance from earth cover for 1/5th scale test

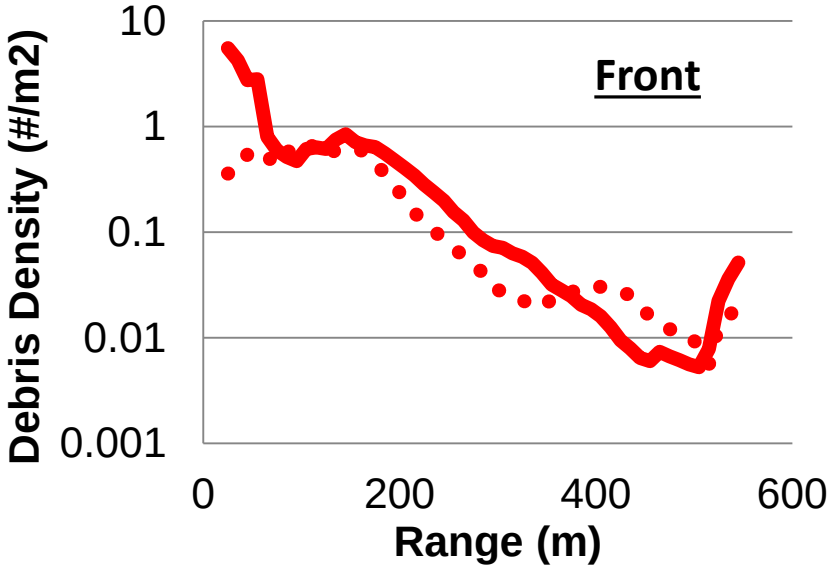
- more debris ejected

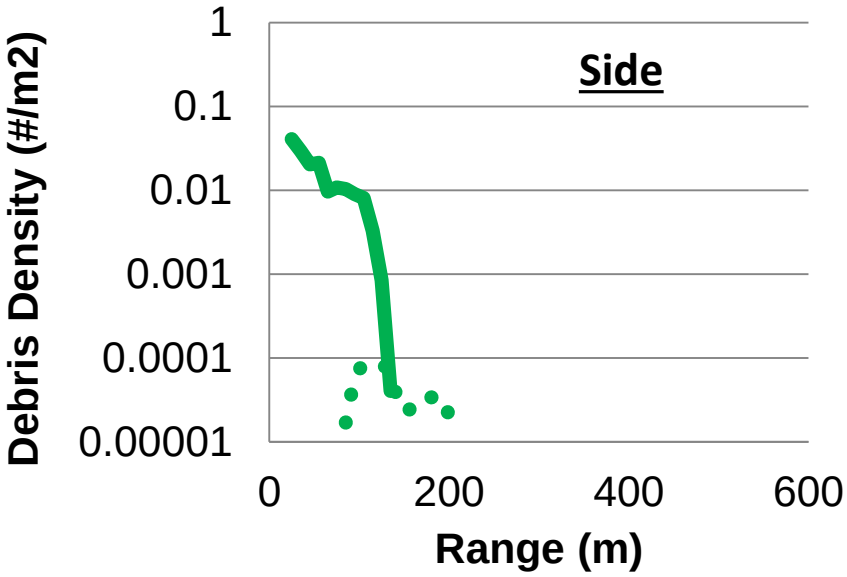
Lower gravitational pull

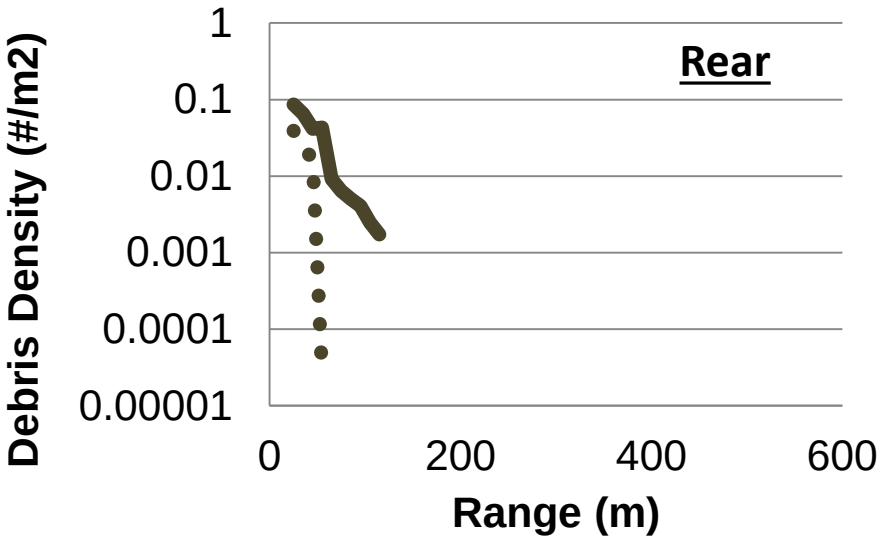
- Debris travel further

DEBRIS DATA ANALYSIS

Effects of Earth Cover Thickness





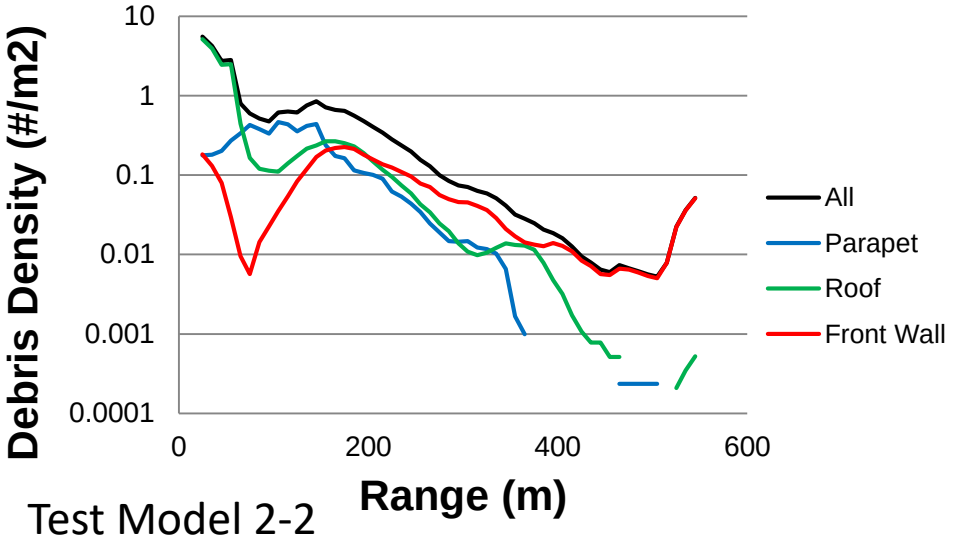


Test Model 2-1
(0.48m earth cover)

Test Model 2-2
(0.96m earth cover)

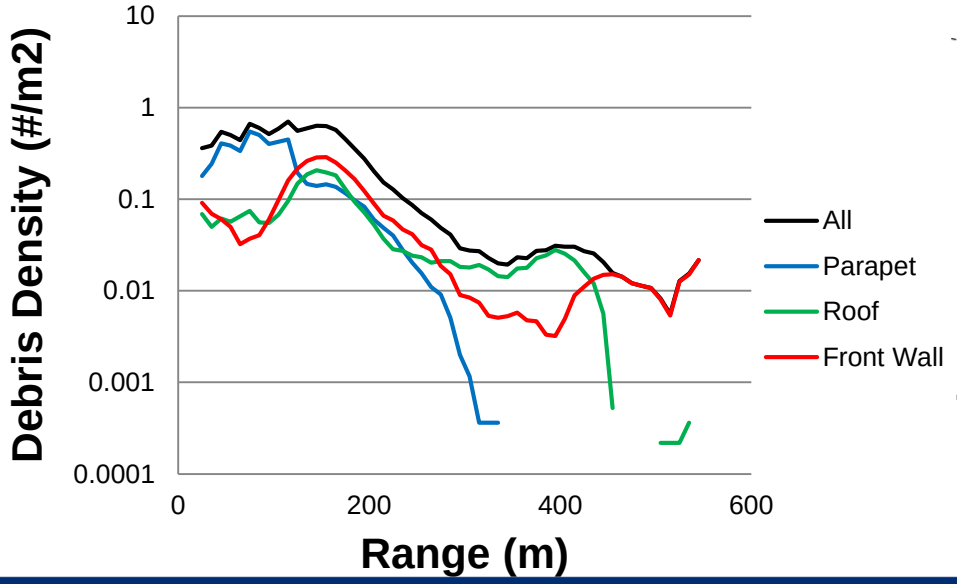
DEBRIS DATA ANALYSIS

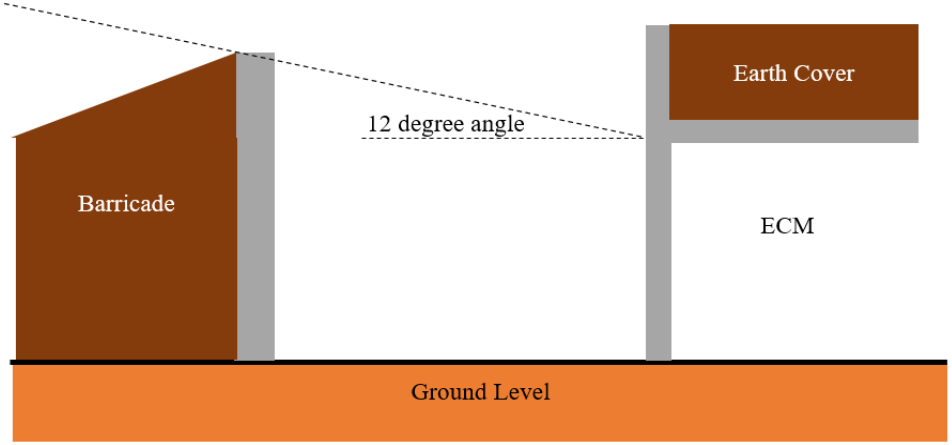
Test Model 2-1



Test Model No	Launch Angles (°)			
	Door	Front Wall (Red)	Retaining Wall (Blue)	Roof (Green)
2-1	6	12	58	89
2-2	8	12	63	86

Test Model 2-2





BLAST PRESSURE ANALYSIS

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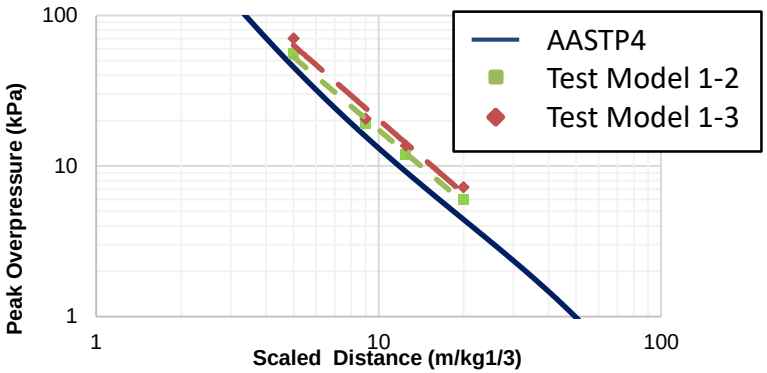
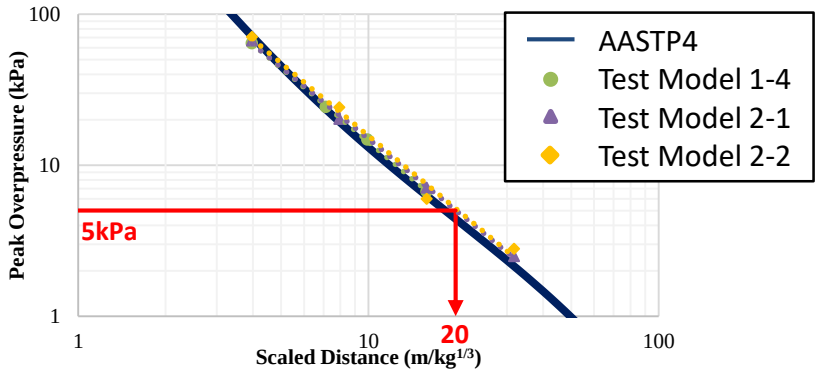
LD = 10kg/m³

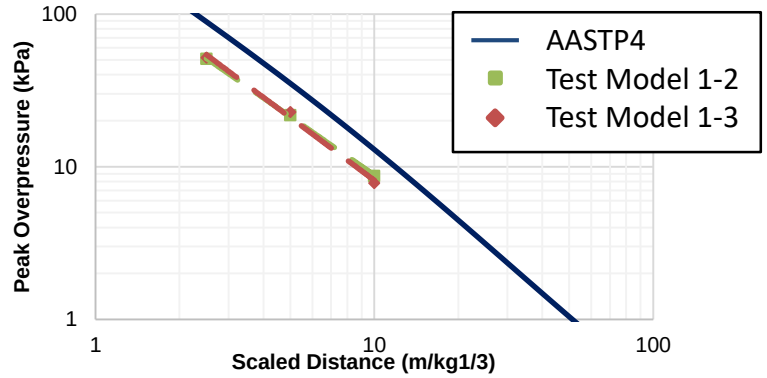
LD = 20kg/m³

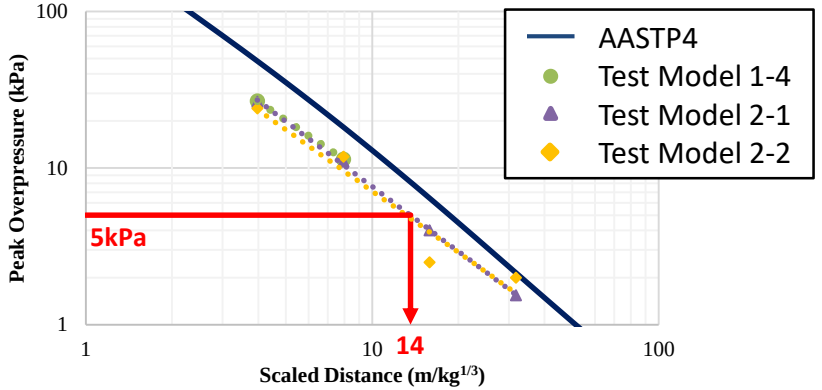
FRONT



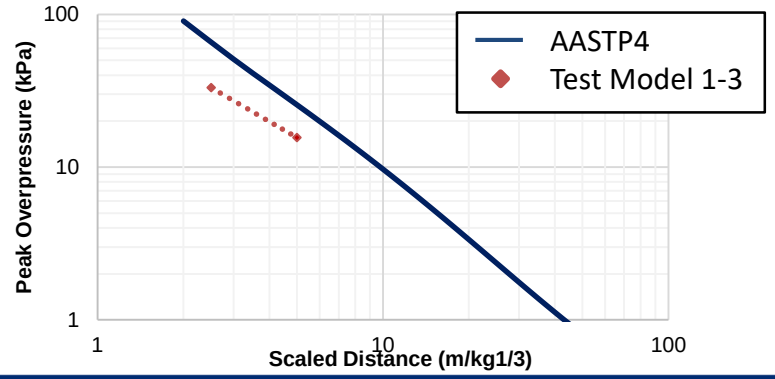


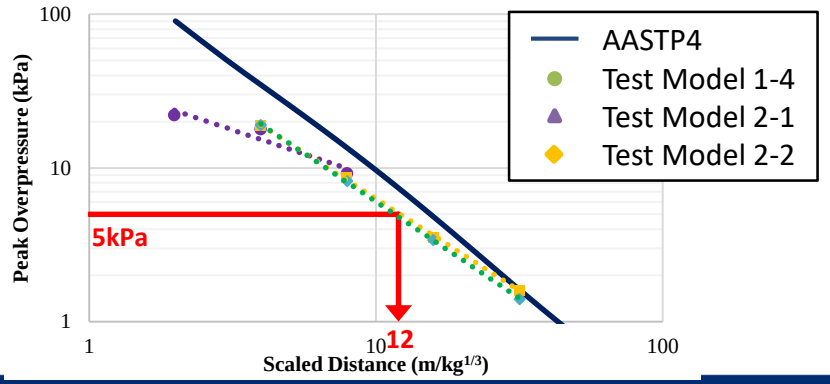
SIDE





REAR





BLAST PRESSURE ANALYSIS

	Quantity Distance ($m/kg^{1/3}$)			
	IBD based on AASTP-4	IBD based on AASTP-1	Average IBD based on LD = $10kg/m^3$	Average IBD based on LD = $20kg/m^3$
Front	18.4	22.2	22.6	20
Side	18.8	18	14.9	14
Rear	15.5	14	-	12

Upper bound: LD = $20kg/m^3$

SUMMARY

1. Debris
   - IBD can potentially be reduced to 200m at the side and rear based on the 2/5th scale test results.
   - It was observed that IBD in AASTP1 may be underestimated for the front (>400m), but can be mitigated with barricade at the front. (based on 12° launch angle for the front wall debris)
   - To be validated in Test Series 3. (Full Scale Test)

2. Blast Pressure
   - AASTP4 underestimates IBD at the front and overestimates IBD at the side and rear for loading density of 20kg/m^3
   - Recommended IBD as below:

	Quantity Distance (m/kg$^{1/3}$)		
	IBD based on AASTP-4	IBD based on AASTP-1	Average IBD based on LD = 20kg/m^3
Front	18.4	22.2	20
Side	18.8	18	14
Rear	15.5	14	12

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Thank you for your attention

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