Assessment of Existing Container Terminal Quay for Increased Gantry Crane Loads

PIANC

The World Association for Waterborne Transport Infrastructure

Presentation by

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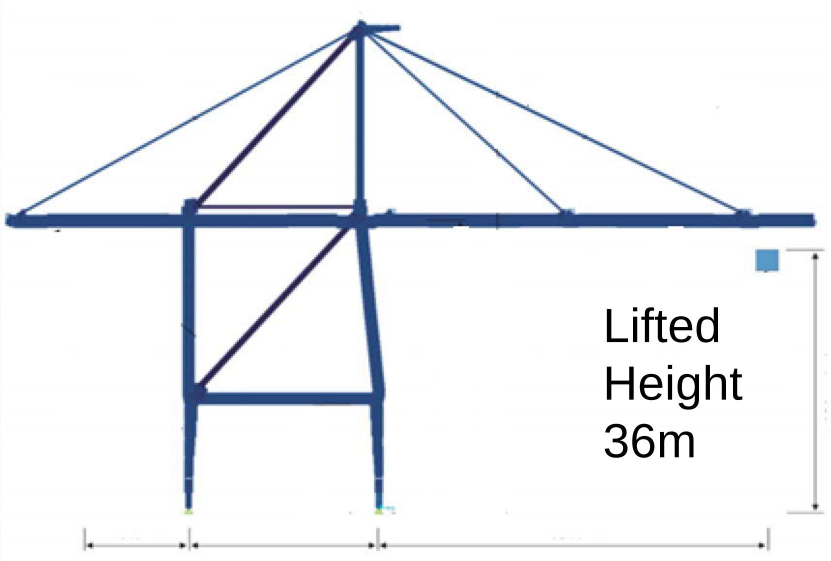
at the occasion of

AGA 2021 / 26 & 27 May 2021

1.1 Introduction

2.0 Project Background

The Cranes



Backreach 25m

Gauge 30.5m

Outreach 50m

Outreach 50m*+5m*

2.0 Project Background

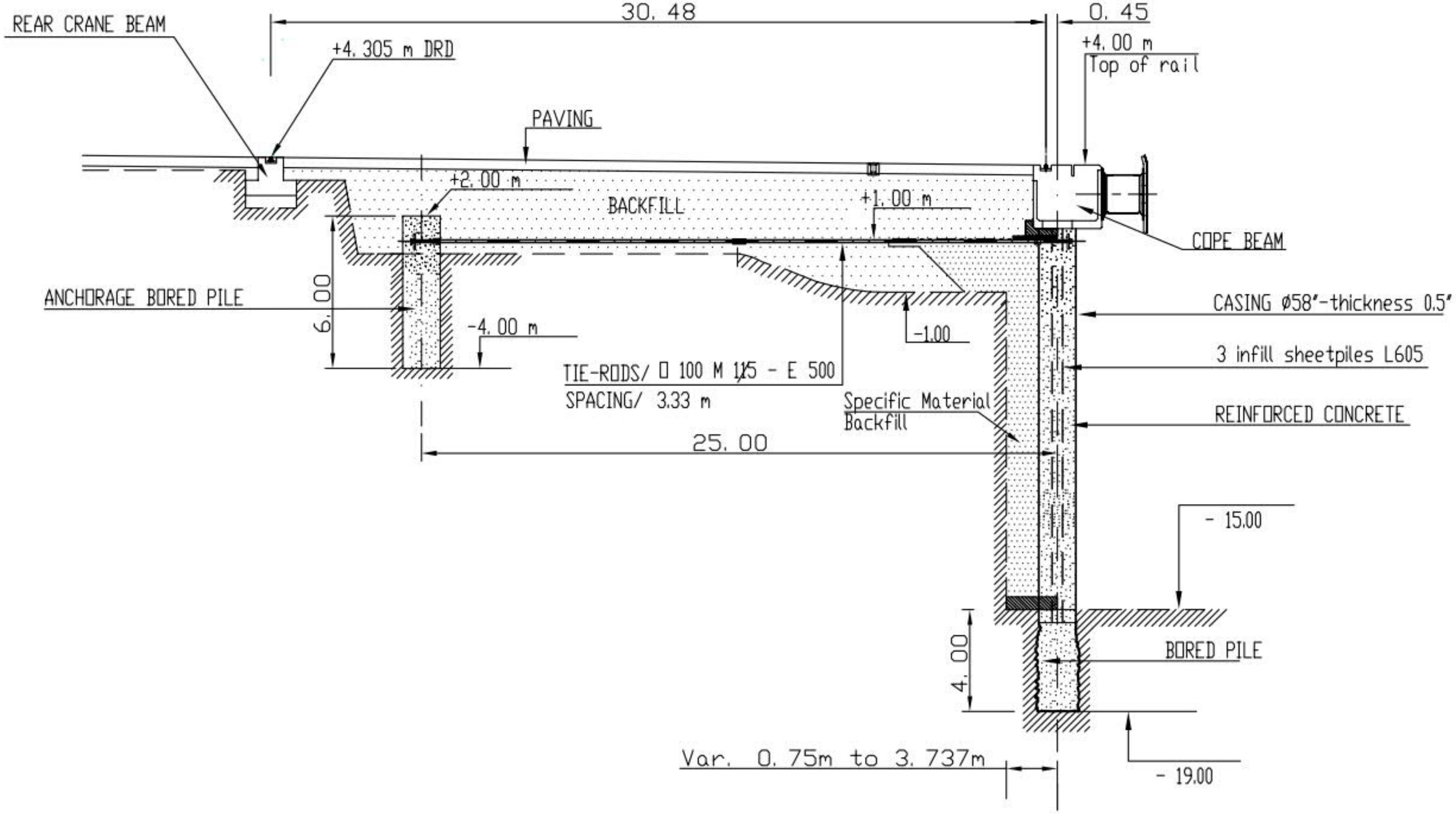
The Cranes

Condition	Original		Heightened	
	Landside t/m	Waterside t/m	Landside t/m	Waterside t/m
Operating	37	45	43	51
Stowed	58	51	66	59
Earthquake	52	60	TBD	TBD

- Up to 16% increase in vertical crane loads
- Structures were already >90% utilised
- End of story???

2.1 Project Background

The Infrastructure



3.0 Project Formulation

So how were going to get a better answer?

- Load Capacity Diagrams
- Load Combinations
- Seismic Design Damage Criteria

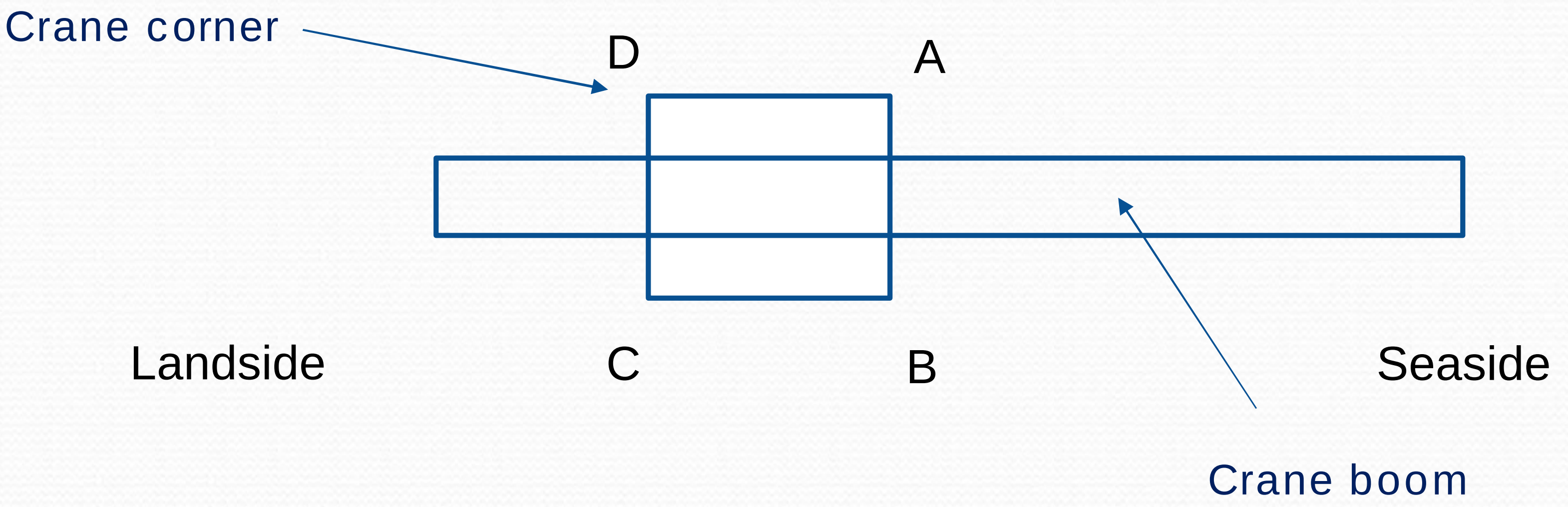
3.1 Project Formulation

Load Capacity Diagrams

Condition	Vertical t/m	Horizontal t/m
Stowed	58	7

<< Not possible

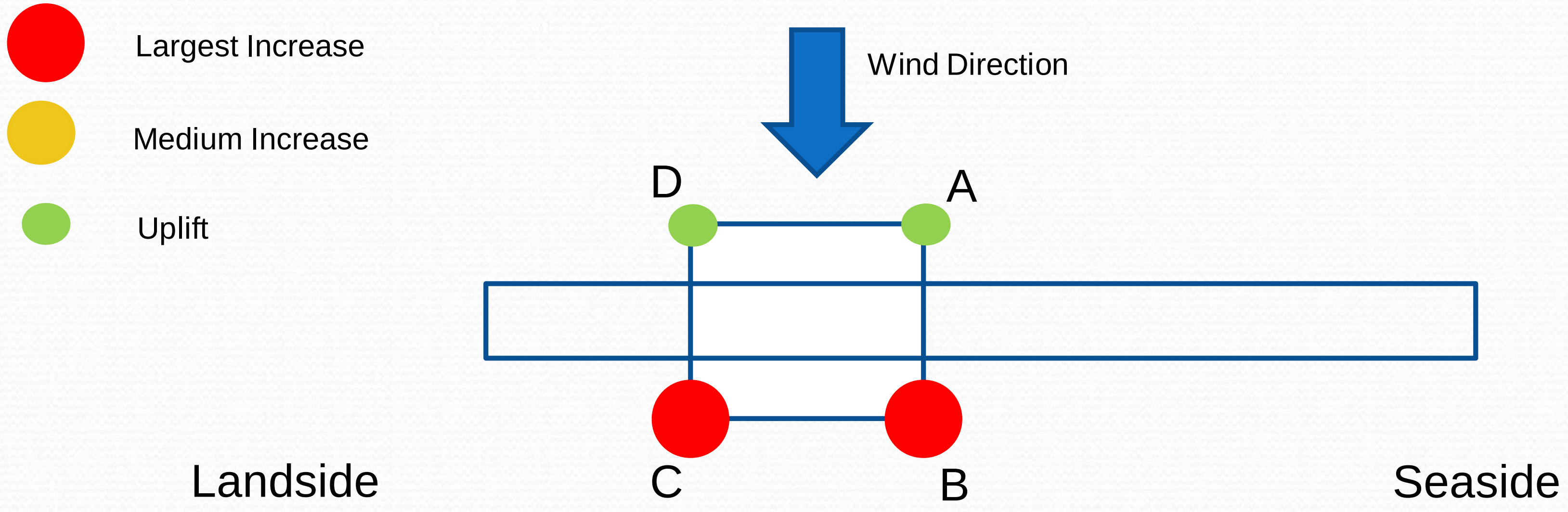
Note: Horizontal = Perpendicular to berthing line



3.1 Project Formulation

Load Capacity Diagrams

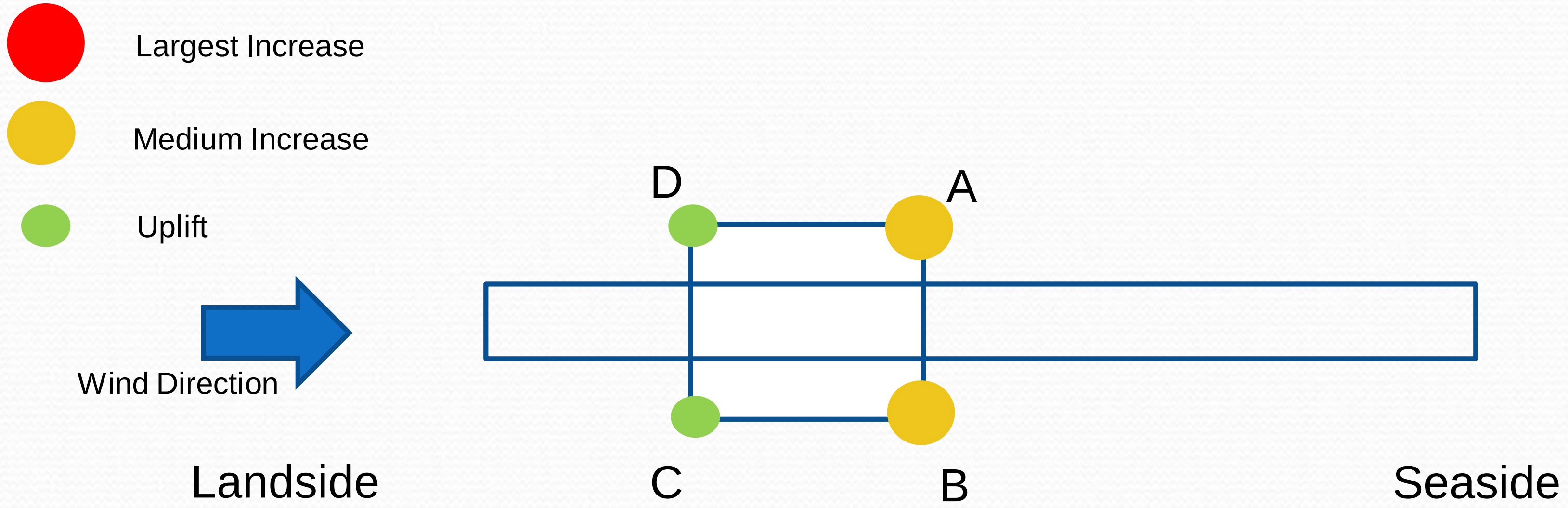
Condition	Vertical t/m	Horizontal t/m
Stowed	58	7



3.1 Project Formulation

Load Capacity Diagrams

Condition	Vertical t/m	Horizontal t/m
Stowed	58	7



3.1 Project Formulation

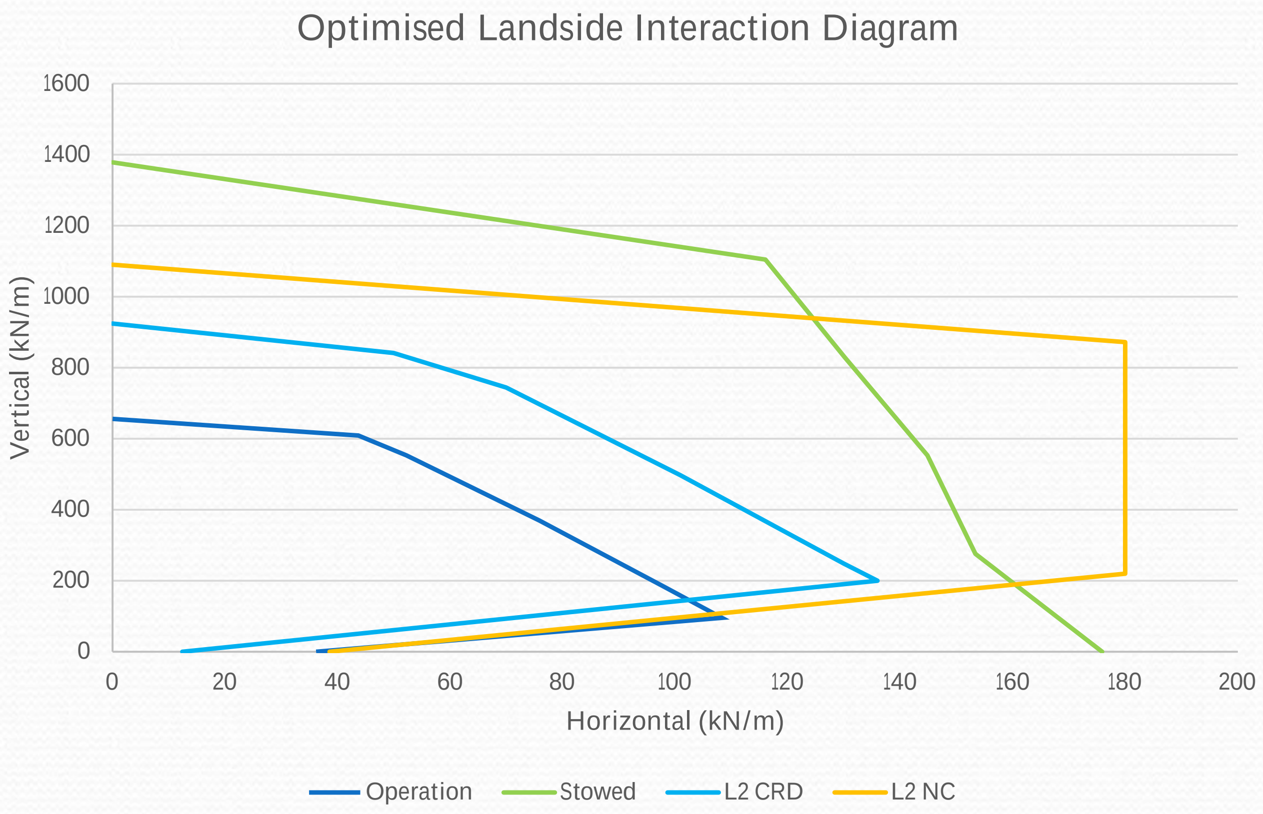
Load Capacity Diagrams

Condition	Vertical t/m	Horizontal t/m
Stowed Max Vertical	58	0
Stowed Max Horizontal	<58	7

- No singular set of horizontal and vertical loads can describe the crane loading.
- Therefore can be no single limit loading.

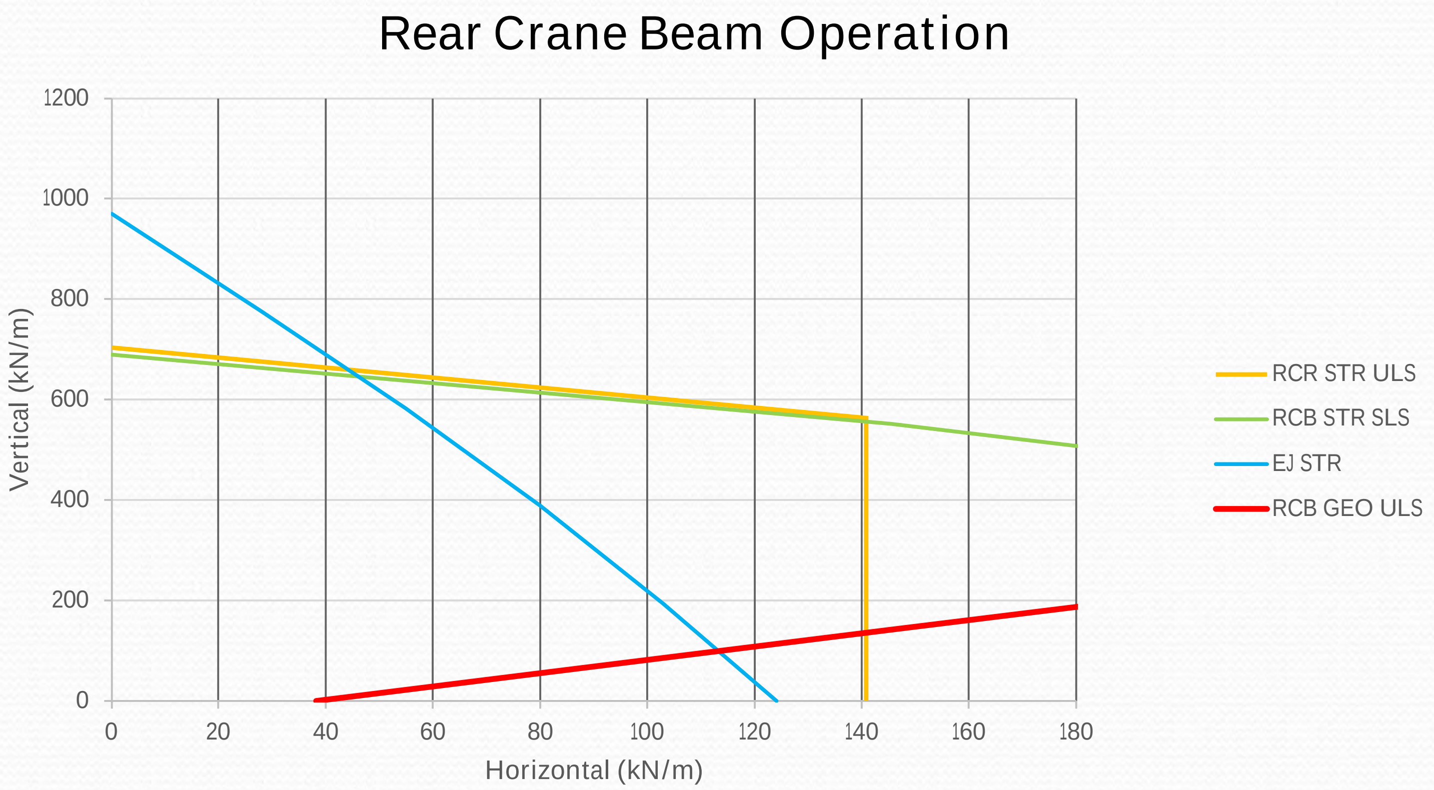
3.1 Project Formulation

Load Capacity Diagrams



3.1 Project Formulation

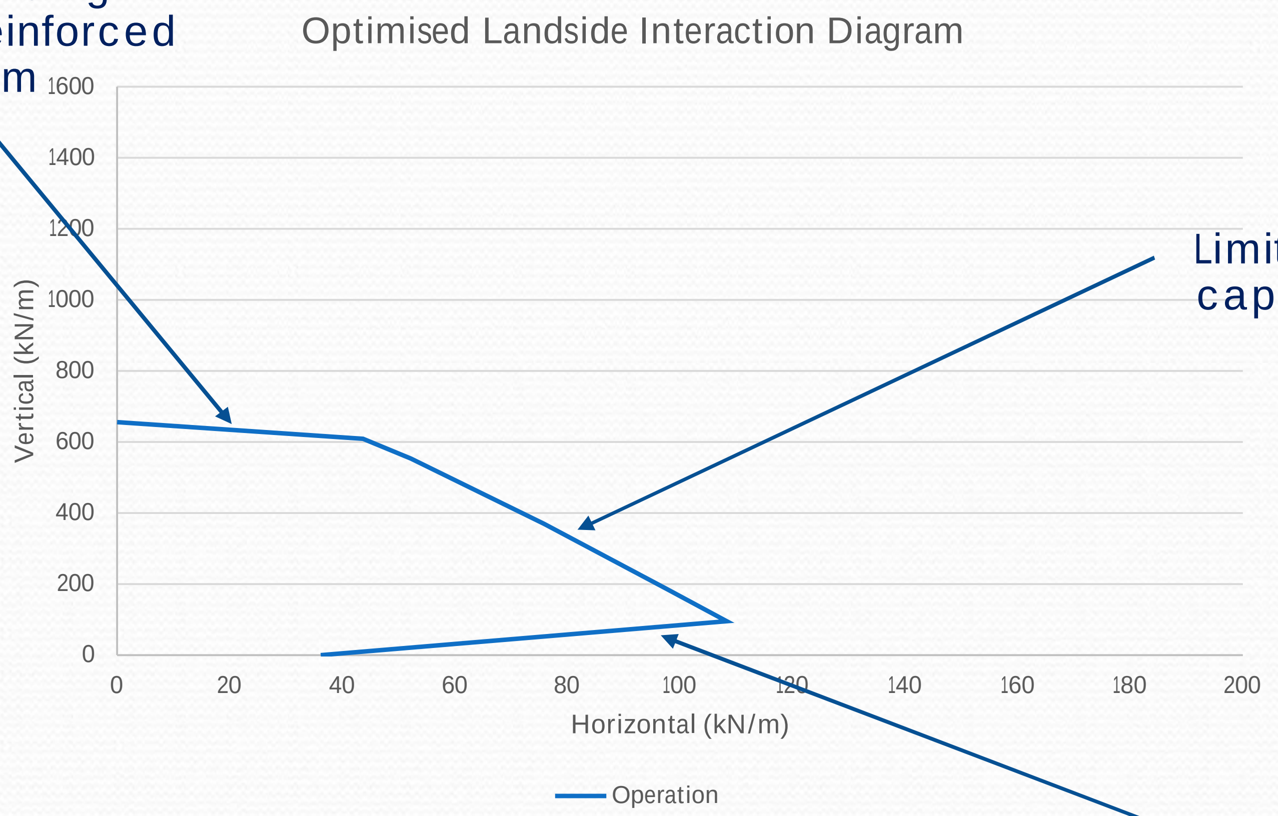
Load Capacity Diagrams



3.1 Project Formulation

Load Capacity Diagrams

Limited by bending capacity of reinforced concrete beam



Limited by dowel capacity at joints

Limited by sliding capacity

3.2 Project Formulation

Load Combinations

Original Crane Conditions

- Operation
- Stowed
- Earthquake

- But what are these conditions in a structural design context

3.2 Project Formulation

Load Combinations

- Wheel load combination table typically defined in crane specification with no reference to the civils designer

- Inconsistent approach to factoring between crane and civils designer

WHEEL LOAD COMBINATION TABLE

			Boom up	Boom level			Boom up	Boom level		
Mode	Operating		Stowed	Stowed	Operating		Stowed	Stowed	Operating	
Name	OP1	OP2	WS1	WS2	EOP1	EOP2	EWS1	EWS2	EOP3	EOP4
DL	1	1	1	1	1	1	1	1	1	1
TL	1	1	1	1	1	1	1	1	1	1
LS	1	1	1	1	1	1	1	1	1	1
LL	1	1			0.5	0.5			0.5	0.5
WLO		1				0.5				0.5
WLS			1	1			0.5	0.5		
EQ1					1	1	1	1		
EQ2									1	1

- BS 6349-1-2 suggests 0.7

3.2 Project Formulation

Load Combinations

- Project specific
- Fully consistent with chosen design approach

Table 4.1: SLS Wheel load combinations table

Load Item	OPERATING				OVERLOAD				STOWED			
	SW	WOP1	WOP2	WOP3	WOL1	WOL2	WOL3	WOL4	WS1	WS2	WS3	WS4
Crane Weight	1	1	1	1			1		1	1	1	
Trolley Weight	1	1	1	1			1		1	1	1	
Lift System Weight	1	1	1	1			1		1	1	1	
Lifted Load		1	0.7	1			0.7					
Trolley Lateral		1										
Gantry Lateral		1										
Operating Wind			1	0.5	N/A	N/A	0.5	N/A			1	N/A
Mooring Wind									1			
Stall Torque												
Collision												
Stowed Wind										1		
Earthquake (L2 CRD)							1				1	
Earthquake (L2 NC)												
Boom	U/D	D	D	D			D		U	U	U	

Note: U/D = boom up or down, D = boom down only and U = boom up only.

3.2 Project Formulation

Load Combinations

- Project specific
- Fully consistent with design approach

Table 4.2: ULS Wheel load combinations table

Load Item	OPERATING				OVERLOAD				STOWED			
	SW	WOP1	WOP2	WOP3	WOL1	WOL2	WOL3	WOL4	WS1	WS2	WS3	WS4
Crane Weight	1.20	1.20	1.20	1.20	1.00	1.00		1.00	1.20	1.20		1.00
Trolley Weight	1.35	1.35	1.35	1.35	1.00	1.00		1.00	1.35	1.35		1.00
Lift System Weight	1.35	1.35	1.35	1.35	1.00	1.00		1.00	1.35	1.35		1.00
Lifted Load		1.50	1.05	1.50	0.70			1.00				
Trolley Lateral		1.50										
Gantry Lateral		1.50										
Operating Wind			1.50	0.75	0.50	0.50	N/A				N/A	
Mooring Wind									1.50			
Stall Torque						1.00						
Collision					1.00							
Stowed Wind										1.50		
Earthquake (L2 CRD)												
Earthquake (L2 NC)								1.00				1.00
Boom	U/D	D	D	D	U/D	D		D	U	U		U

Note: U/D = boom up or down, D = boom down only and U = boom up only.

3.3 Project Formulation

Seismic Design Damage Criteria

Original Earthquake Criteria:

- 0.41g Horizontal
- 0.21g Vertical

Too vague:

- Bedrock or surface acceleration?
- Return period?
- Allowable damage/ performance requirements?
- Response spectrum?

3.3 Project Formulation

Seismic Design Damage Criteria

BS 6349-1-2 supplemented PIANC WG34

Property	Level 1 Event – Serviceability	Level 2 Event – Controlled and Repairable Damage	Level 2 Event – No Collapse
Nominal Return Period	95 years	475 years	975 years
Surface pga **(BS EN 1998-1, Type 1, Class D)**	0.159g	0.284g	0.362g
Performance Criteria	Degree I Serviceable criteria to WG34 Table 3.1: • Quay structural elements - elastic behaviour of limited residual displacements of apron or wall elements as PIANC 34 Table 4.1 or as required to maintain crane operability without derailment as Table 4.5 & 4.6 of PIANC 34.	Degree II repairable criteria to WG34 & controlled and repairable to BS6349: • Quay structural elements - ductile behaviour, limited inelastic response for elements that are repairable, and loss of serviceability for no more than several months. • Damage and deformation criteria as PIANC 34 Table 4.2 and consistent with crane damage and reparability as PIANC 34 Table 4.5.	No collapse verified by ultimate limit state check with combinations of actions to BS6349/ Eurocodes.

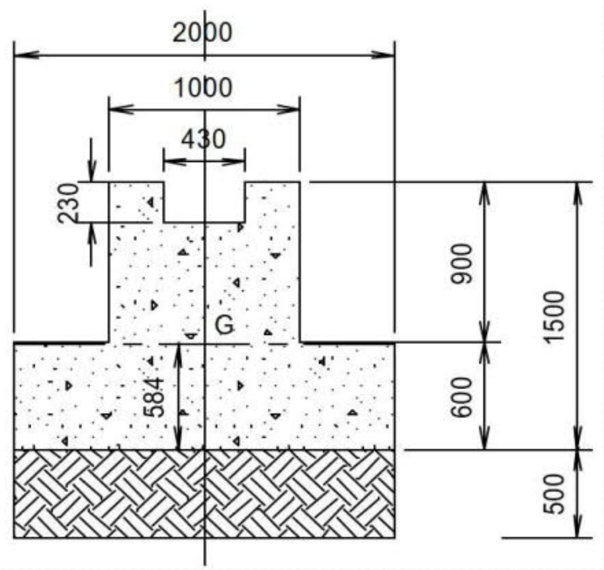
3.3 Project Formulation

Seismic Design Damage Criteria

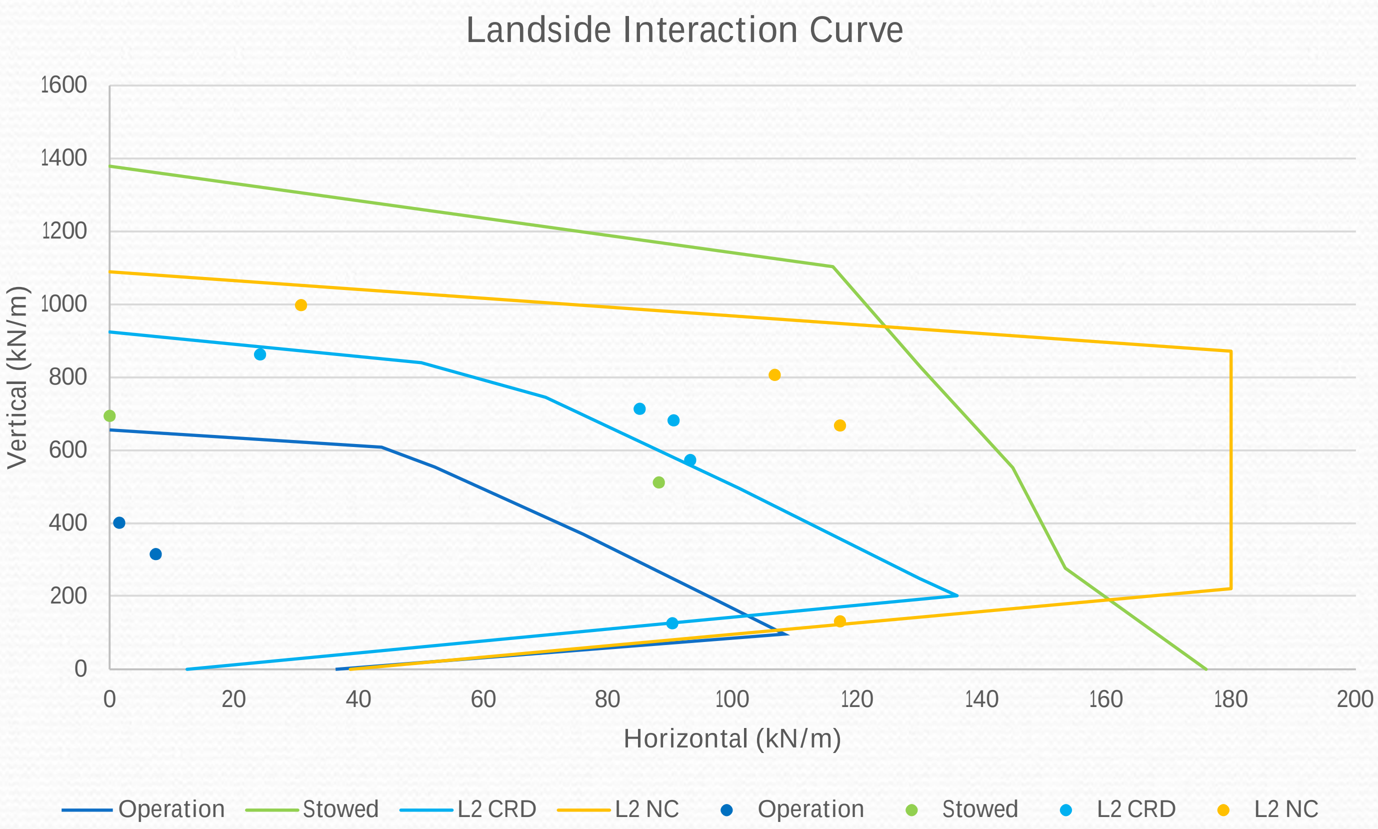
Practical example: Rear Crane Beam

L2 Controlled and Repairable Damage:
- Linear Elastic structural analysis
- Yield of reinforcement capacity check considered
- Cracks but no large permanent deformations

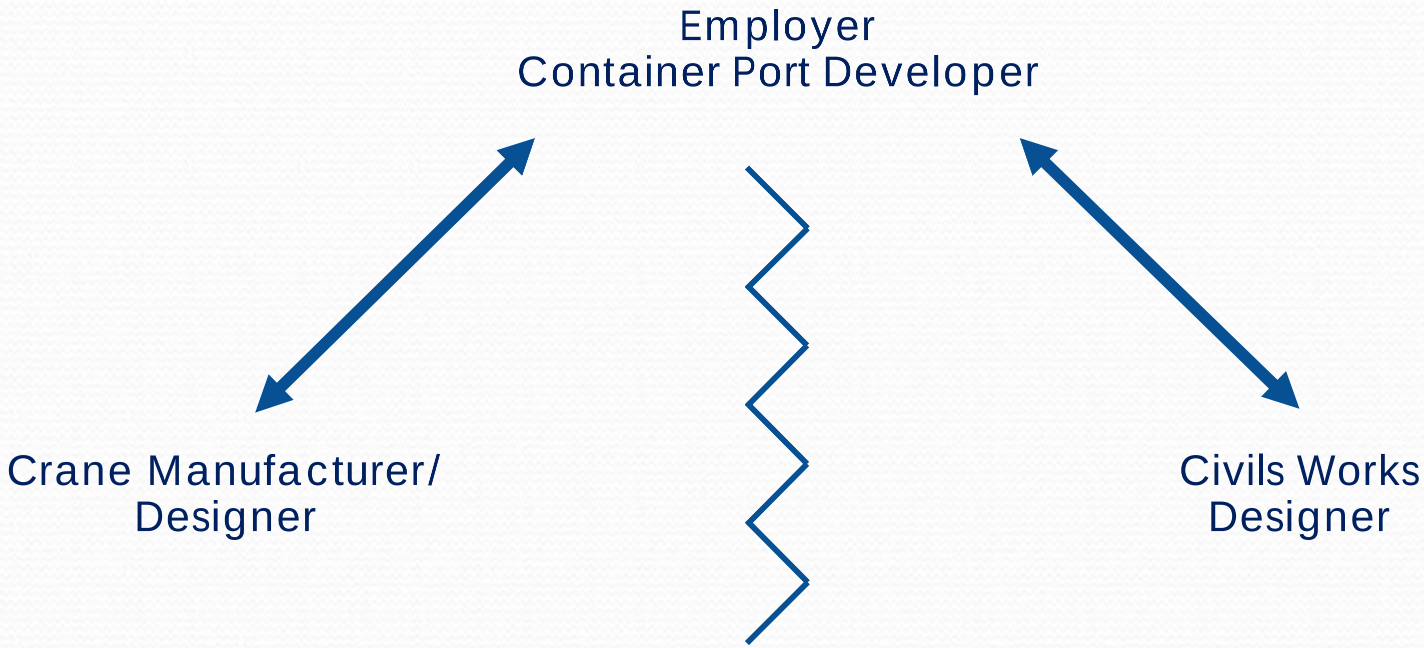
L2 No Collapse
- Plastic analysis structural analysis
- Only ULS capacity checks considered
- Permanent deformation and damage would occur



4.0 Project Solution



5.0 Conclusion



THANK YOU

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Q&A