Investigation of Bottom Roughness for Mechanical Clamshell Bucket Operations

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Presentation Outline

- Define Bottom Roughness
- Describe Process for Estimating Bottom Roughness
- Describe Algorithm Flow
- Describe Mechanical Derrick Dredging
- Describe Mechanical Bucket Types
- Share Results

Bottom Roughness

- A measurement of the peaks and troughs of bathymetry following a dredging event
- Dependent on the dredging means of excavation
- Mechanical derrick bottom roughness is dependent on the type of bucket used
- Understanding bottom roughness is critical for setting dredge template tolerance

Round nose bucket dredging in sands (Warwick 2022)

Bottom Roughness

$$\sum \text{Roughness} = \text{Dredge Type} + \text{Material} + \text{Sea State} + \text{Measurement} + \text{Template Design}$$

$$f(R_T) = \begin{cases} \text{Dredge Type} \\ \text{Measurement Accuracy} \\ \text{Template Design} \\ \text{Material Type} \\ \text{Sea State} \end{cases}$$

$$f(R_S) = \begin{cases} \text{Dredge Type} \\ \text{Measurement Accuracy} \\ \text{Material Type} \\ \text{Sea State} \end{cases}$$

$$R_T = \left(\frac{1}{N}\right) \int_0^N |Z(x) - n| \, dx$$

$$R_S = \left(\frac{1}{N}\right) \int_0^N |Z(x) - Zavg| \, dx$$

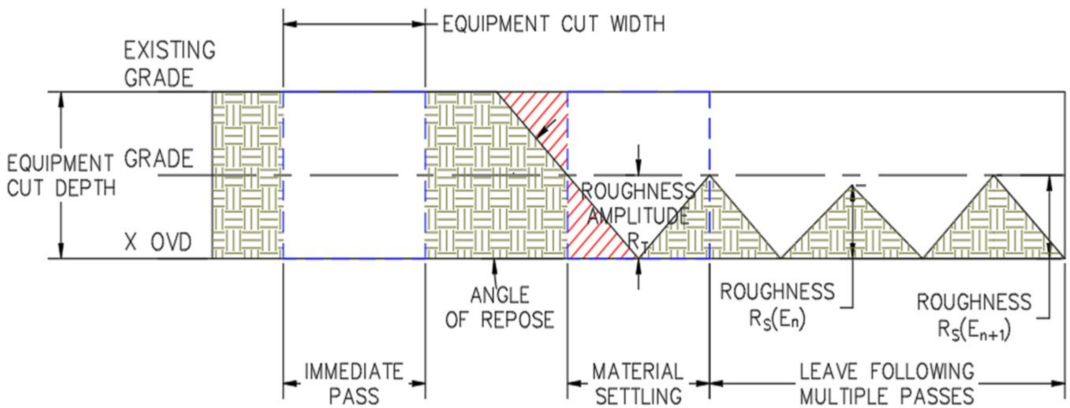
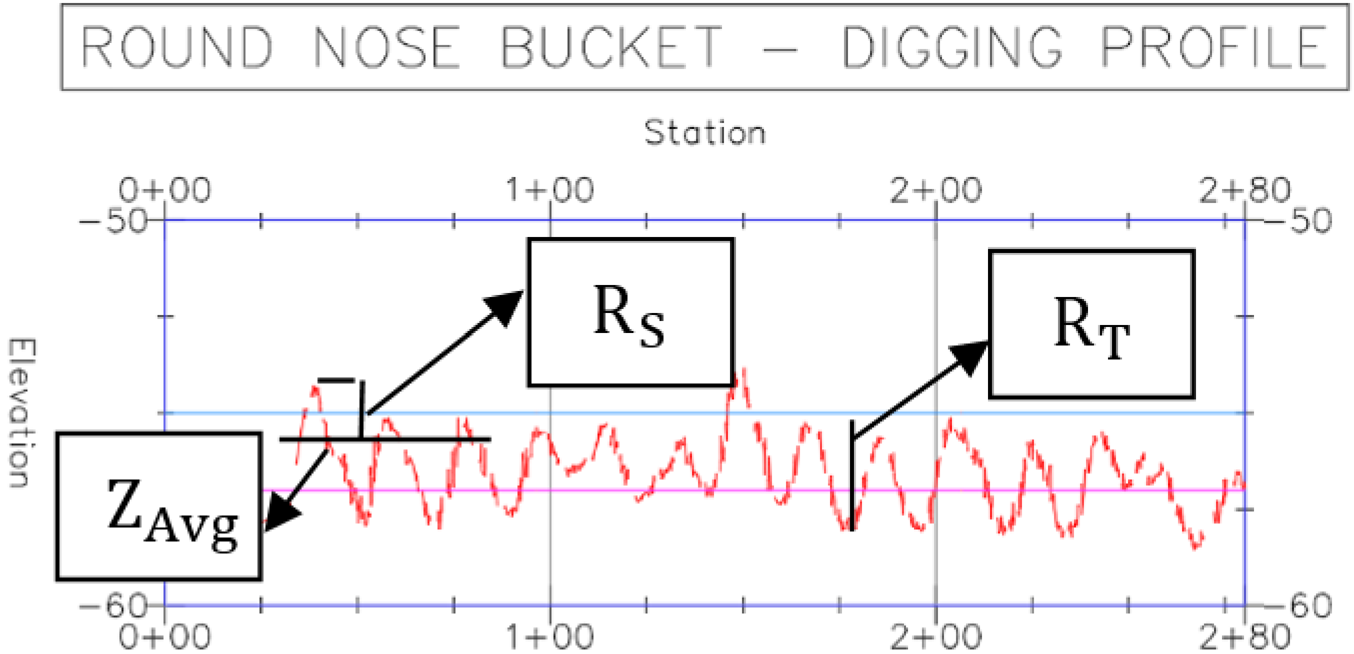


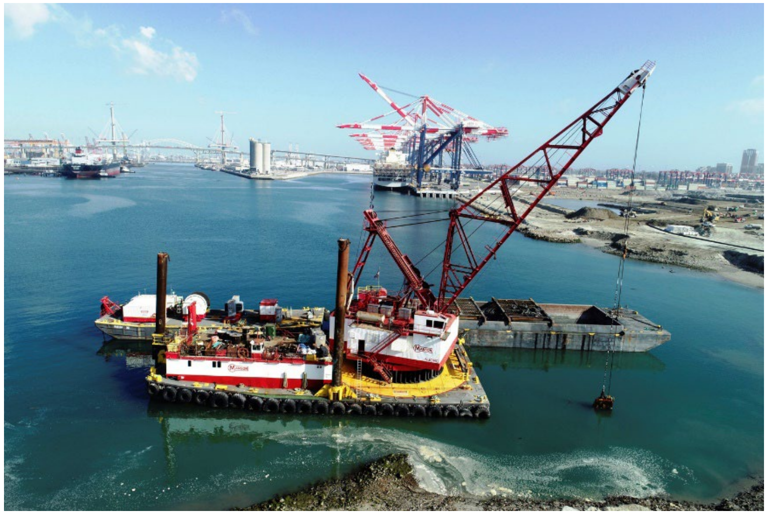
Diagram of Bottom Roughness (Warwick 2022)

Bottom Roughness



Mechanical Bucket Dredge

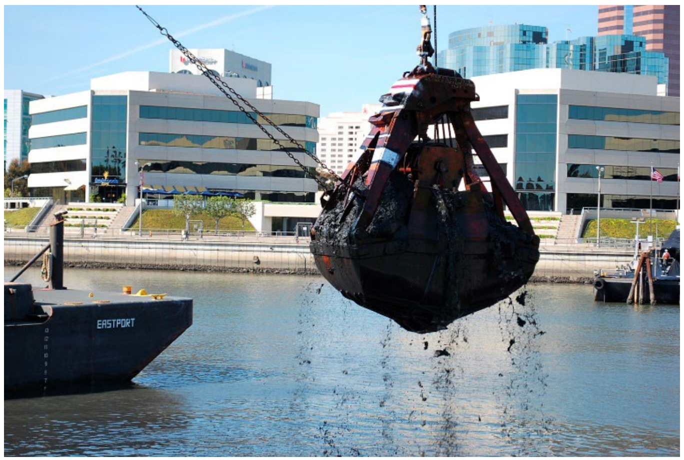
- Most common type of dredger
- Capable of accessing variety of work areas
- Mechanical bucket dredge is cyclical
- Size of the dredger determines the size of buckets for use



MCC's Derrick *Njord* dredging at Pier E Berth E22 Port of Long Beach, CA

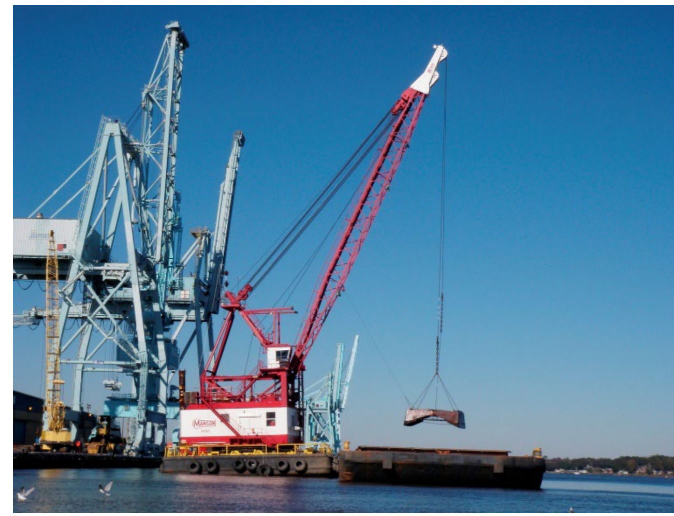
Bucket Types Considered

Round Nose Bucket



MCC's Derrick *Valhalla* dredging in Long Beach, CA with a Round Nose Style Bucket

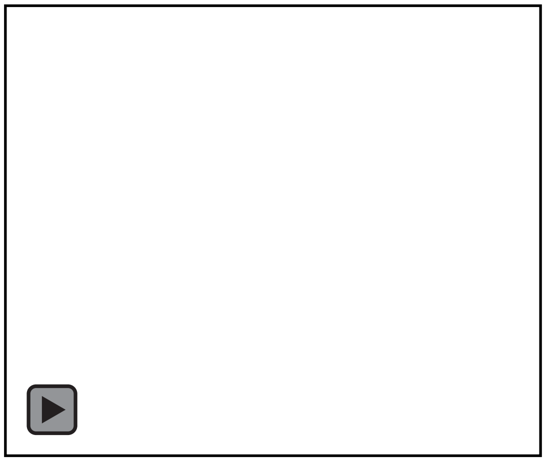
Suit-Case Style Bucket



MCC's Derrick *Vasa* dredging in Jacksonville, FL with a Suitcase Style Bucket

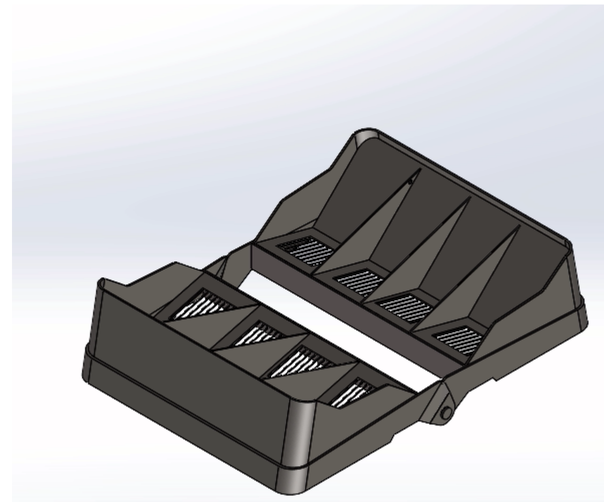
Bucket Types Considered

Round Nose Bucket



MCC 3D Model of Round Nose Bucket

Suit-Case Style Bucket



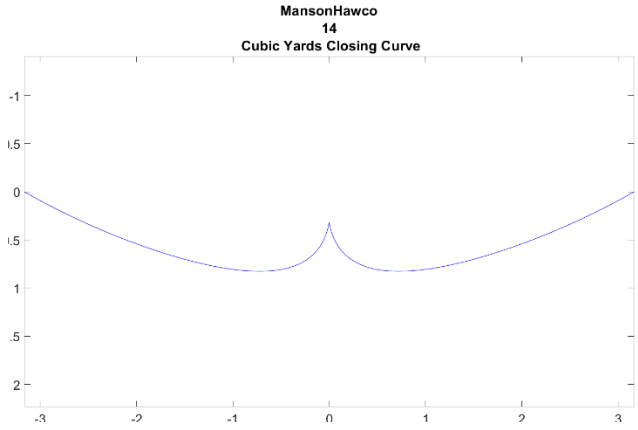
MCC’s 3D Model of Suit-Case Bucket

Algorithm Flow

Set	Bucket Parameters
Set	Soil Parameters
Determine	Kinematics of Bucket
Determine	Initial Penetration
Calculate	Digging Curve
Incorporate	Environmental Factors (Waves)
Output	Graphically Display Digging Pattern
Calculate	R_T and R_S values

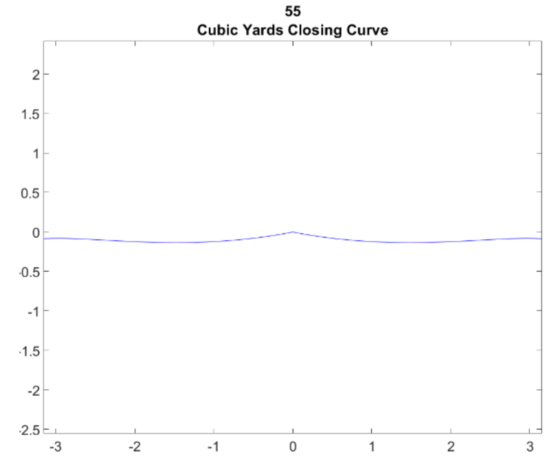
Bucket Types Closing Curves

Round Nose Bucket



MCC Round Nose 14cy Closing Curve

Suit-Case Style Bucket



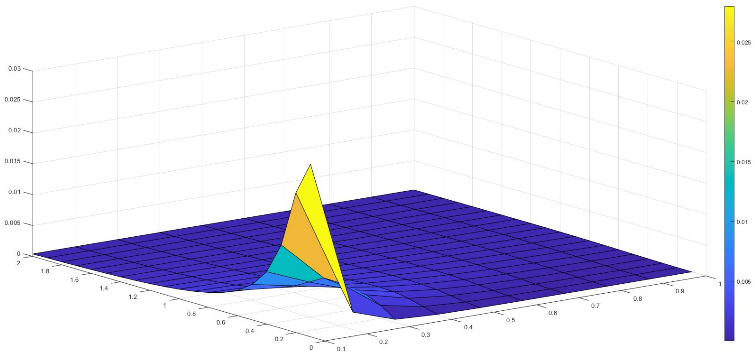
MCC Suit-Case 55cy Closing Curve

Initial Penetration

- Occurs as bucket settles into bottom and before closing action
- *Boussinesq's* can approximated the vertical stresses in soil

$$\Delta\sigma_v = \frac{3Q}{2\pi z^2}\left(\frac{1}{1+(1+(r/z)^2)}\right)^{5/2}$$

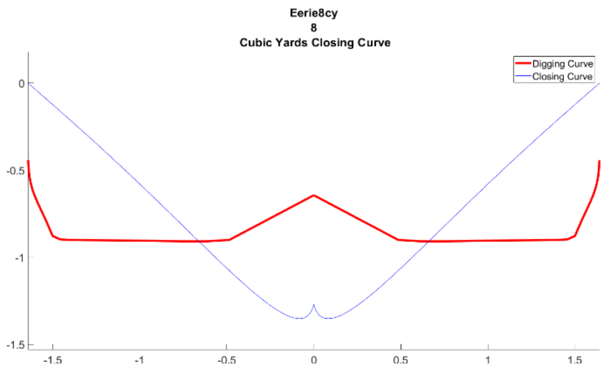
where $\Delta\sigma_v$ is change in vertical pressure, Q is the concentrated vertical load (bucket mass), r is the horizontal distance of the action of the load, and z is the vertical distance of the action of the load. Z is solved for determining the distance for initial penetration.



Settling Depth Based on Vertical Pressure of the Clamshell Lip

Digging Curve

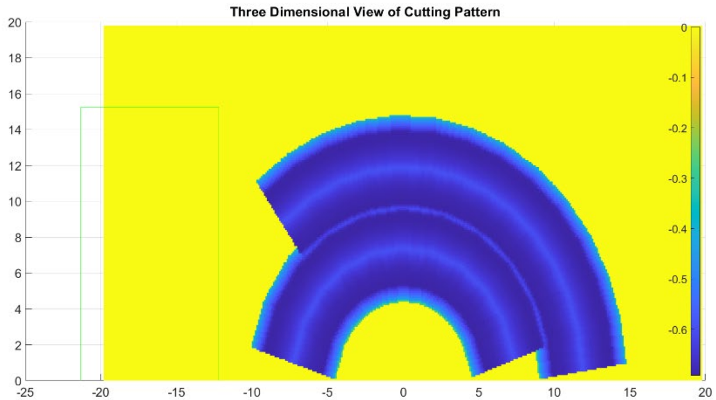
- Considers the forces acting against the bucket as the bucket closes
- Material type influences the reactions and moments on the bucket
- Material type influences how the leading edge cuts the material
- The weight of the bucket and wire closing force determine the bucket's vertical cutting force



8cy Round Nose Digging Curve in Saturated Sands

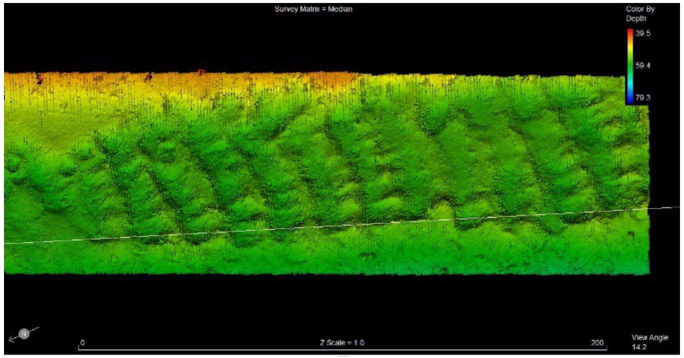
Results – Round Nose Bucket

Simulation Results



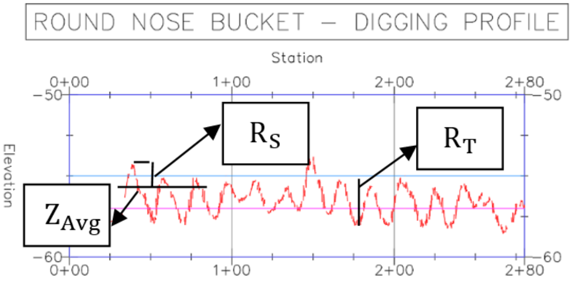
Simulation Results for 18cy Round Nose Bucket

Survey Results



Multibeam Survey of 18cy Round Nose Bucket

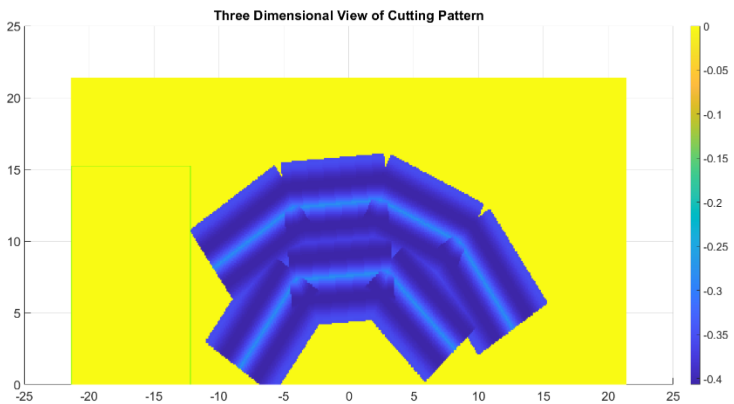
Description	Mat’l	Wave Height (ft)	Wave Period (s)	Warwick '22 Model R_T (ft)	Warwick '22 Model R_S (ft)	Tennant '23 Model R_T (ft)	Tennant '23 Model R_S (ft)	Survey R_T (ft)	Survey R_S (ft)
Port of LA – 18cy Round Nose Bucket	Dense Sand	0.5	10	-	-	1.07	0.73	2.35	1.96



Cross Section of 18cy Round Nose Bucket

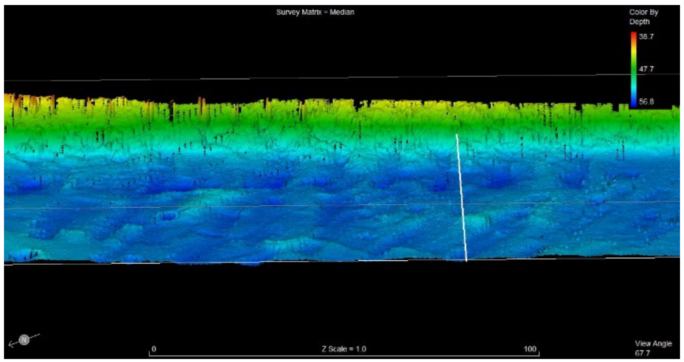
Results – Suitcase Style Bucket

Simulation Results



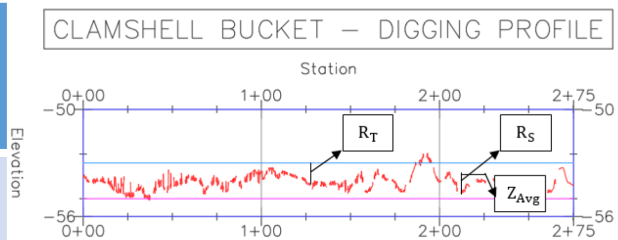
Simulation Results for 55cy Suitcase Style Bucket

Survey Results



Multibeam Survey of 55cy Suitcase Style Bucket

Description	Mat'l	Wave Height (ft)	Wave Period (s)	Warwick '22 Model R_T (ft)	Warwick '22 Model R_S (ft)	Tennant '23 Model R_T (ft)	Tennant '23 Model R_S (ft)	Survey R_T (ft)	Survey R_S (ft)
Port of LA – 55cy Suitcase Bucket	Fine Loose Sand	0.5	10	-	-	0.25	0.41	1.57	1.54



Cross Section of 55cy Suitcase Style Bucket

Results – Summary Table & Conclusions

Description	Mat'l	Wave Height (ft)	Wave Period (s)	Warwick '22 Model R_T (ft)	Warwick '22 Model R_S (ft)	Tennant '23 Model R_T (ft)	Tennant '23 Model R_S (ft)	Survey R_T (ft)	Survey R_S (ft)
Port of LA – 18cy Round Nose Bucket	Dense Sand	0.5	10	-	-	1.07	0.73	2.35	1.96
Port of LA – 55cy Suitcase Bucket	Fine Loose Sand	0.5	10	-	-	0.25	0.41	1.57	1.54
Jacksonville, FL – 8cy Round Nose Bucket	Sand	0.5	11	0.709	0.31	0.69	0.70	1.86	0.63
Jacksonville, FL – 18cy Suitcase Bucket	Silt	0.5	10	0.166	0.16	0.30	0.28	0.8	0.19

Future Considerations:

- Digging pattern and overlap
- Determining R_T and R_S value prior to dredging event
- Review determination of initial penetration of different bucket types
- Attempt other differential equation solver such as ODE45

Questions and Comments

Port of Anchorage, 2009

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References

Warwick, M., Henriksen, J., Quinones, K., Howell, K., Tennant, C., and Vazquez, N. “Exploration of the factors that influence bottom roughness created by dredging processes,” Proceedings of the Western Dredging Association Dredging Summit & Expo ’22, Houston, TX, USA, July 25-28, 2022.

Nomenclature

MCC – Manson Construction Co.

ODE – Ordinary Differential Equation

MANSON OPERATIONS