GRIP Meeting 2023

Project BED26 TWO 977-07:

Vibrations and Ground Deformations due to Road Compaction

Start Date: March 2023

End Date: February 2025

Project Manager: Larry Jones (PM)

PRESENTED BY

Luis G. Arboleda-Monsalve
Univ. of Central Florida, Orlando, FL

UNIVERSITY OF
CENTRAL FLORIDA

PRESENTATION OUTLINE

- Benefits and implementation
- Objectives
- Technical considerations
- Technical background
- Progress in numerical modeling
- Review of tasks and deliverables

BENEFITS (EXPECTED) and IMPLEMENTATION

QUALITATIVE

- Reduce conservative limits for vibration monitoring protection of structures.
- Assist designers during preparation of project documents and plans. Time savings during construction due to more accurate estimate of extent of monitoring.
- Show relationships between construction equipment and vibration effects on soils.

QUANTITATIVE

- Project will provide computational framework currently unavailable to designers.
- Project will develop a model to estimate the zone of influence of activities associated with roadway construction.
- Project will produce a settlement chart or correlation due to road compaction equipment relating PPV, Dr, distance from source, and input energy.

IMPLEMENTATION

- Results will likely result in updates to Specifications for Roadway and Bridge Construction, Soils and Foundations Handbook, and FDOT Specifications: “monitoring existing structures.”

OBJECTIVES

- To develop a prediction method of dynamic ground deformations and vibrations caused by road compaction.

- To understand the mechanisms of near-field and far-field ground deformations during road compaction.

- To investigate relationships among four components: ground deformations, vibrations, input energy, and distance from source of road compaction. Affecting parameters: soil strength and stiffness, type of road compaction equipment, relative density, and characteristics of the energy source.

- To develop a ground deformation chart (or correlation or equation) caused by road compaction as a function of PPV, relative density of soil, distance from the source, soil shear strain, and/or input energy.

TECHNICAL CONSIDERATIONS

- Standard Specifications for Road and Bridge Construction (FDOT 2021), requires performing vibration monitoring on nearby structures for projects involving road compaction including asphalt compaction operations, and pile installations.

- Based on Chapter 108-2, during the construction of retaining walls and foundations for bridges, buildings, and structures, all nearby structures must be inspected, surveyed, and monitored for settlement: i) within 200 ft of sheet pile installation/extraction, ii) within 100 feet of soldier pile installation/extraction, iii) <u>within 75 feet when performing roadway compaction operations</u>, and iv) within certain limitation in terms of scale distance (i.e., square root of impact hammer energy) for pile driving operations.

- Chapter 108-2 also requires continuous vibration monitoring and recording ground vibration levels near structures during the operation of any equipment causing vibrations. Instrumentation must be capable of detecting velocities of 0.01 in/s or less. Upon detecting vibration levels reaching 0.5 in/s or damage to the structure, the source of vibration must immediately stop.

TECHNICAL CONSIDERATIONS

- Typical roadway construction involve the use of vibratory compaction equipment (e.g., rollers). These tools generate waves and generally result in a re-arrangement of the soil mass in the vicinity of construction activities.

- The re-arrangement of material and reduction in void ratio results from the repeated impact of the equipment. Those waves extend outward from the source and can have an effect on the soil volume.

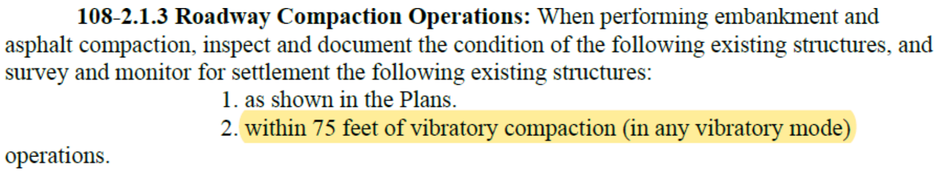
- The reduction in void ratio as a function of distance from the source is what will determine the settlement trough. In the past, the Department has dealt with claims involving either real or perceived damage to structures from typical roadway construction methods.

- This project aims to achieve a better computational model to assess the magnitude and geometry of settlement profile when vibratory rollers are used.

TECHNICAL BACKGROUND (Standards and Specifications)

FDOT Standard Specifications for Road and Bridge Construction (2021):

- Structures must be monitored within 75 ft of road compaction operations.
- Equipment must be capable of detecting vibrations of 0.01 in/s or less.
- Vibration limit (PPV) defined by FDOT is 0.5 in/s.



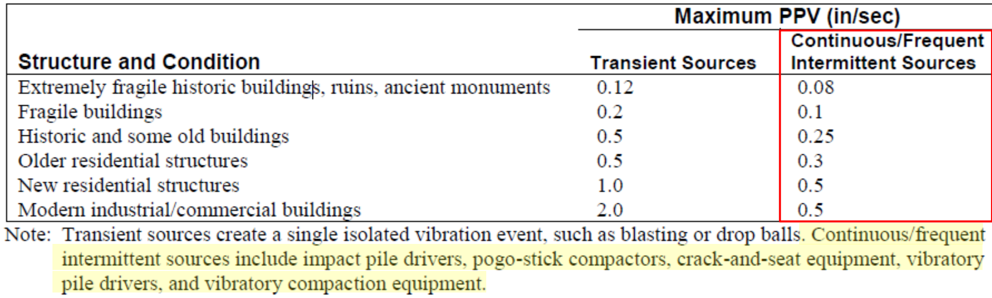
108-2.1.3 Roadway Compaction Operations: When performing embankment and asphalt compaction, inspect and document the condition of the following existing structures, and survey and monitor for settlement the following existing structures:

1. as shown in the Plans.
2. within 75 feet of vibratory compaction (in any vibratory mode) operations.

Section 108 Excerpt

Caltrans Transp. and Constr. Vibration Guidance Manual (2013):

- PPV limit criteria based on studies by Whiffin and Leonard (1971).
- Road compaction is categorized as a continuous sources of vibration.
- Several PPV limits defined depending on structure use and condition.



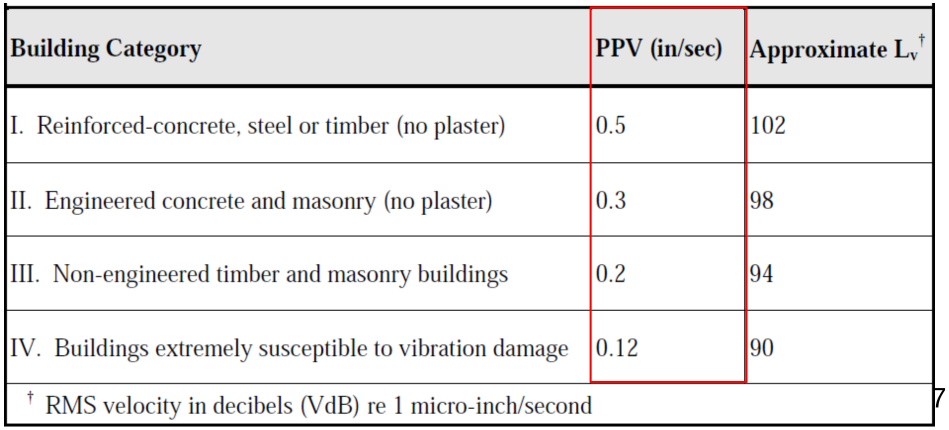
Structure and Condition	Maximum PPV (in/sec) Transient Sources	Continuous/Frequent Intermittent Sources
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

Guideline for Vibration Damage Potential

FTA Transit Noise and Vibrations Impact Assessment (2006):

- Damage criteria dependent on the structure type
- FDOT's limit can be compared to building category I: Reinforced concrete.



Building Category	PPV (in/sec)	Approximate L_v[†]
I. Reinforced-concrete, steel or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

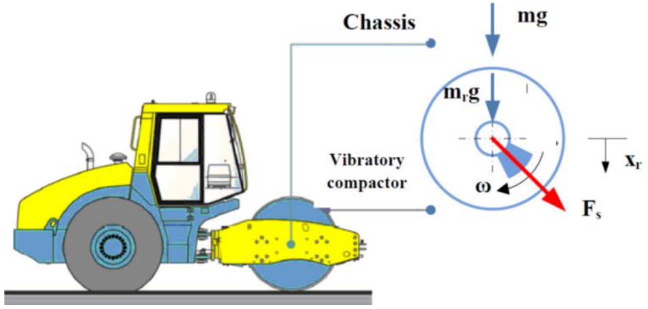
[†] RMS velocity in decibels (VdB) re 1 micro-inch/second

Construction Vibration Damage Criteria

TECHNICAL BACKGROUND (Triggering Mechanisms)

Xu et al. (2022)

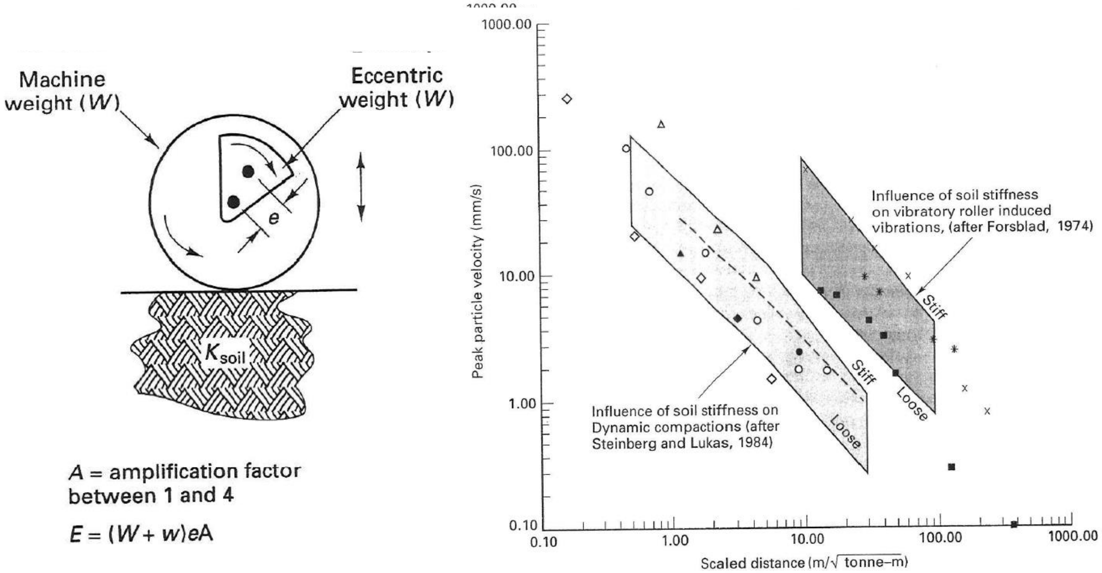
- Soil compaction is induced by combination of static forces (weights of frame and drum) and dynamic forces (rotation of the eccentric mass inside the drum).



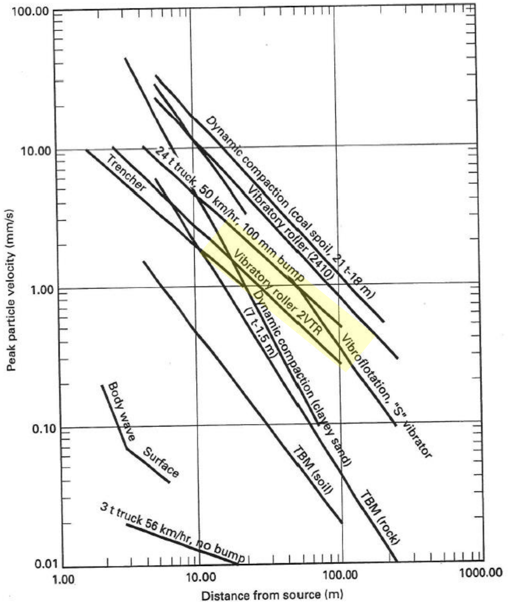
From Sergiu and Heriberto (2016)

Dowding (1996)

- Most studies focus on levels of PPV, ignoring energy transfer mechanisms.
- Stiff soils lead to a lower attenuation rate than soft soils due to inherent material damping.
- The energy transfer needs to consider relative masses of two components of the mechanism and the relative stiffness of the reaction medium and machinery.



From Dowding (1996)

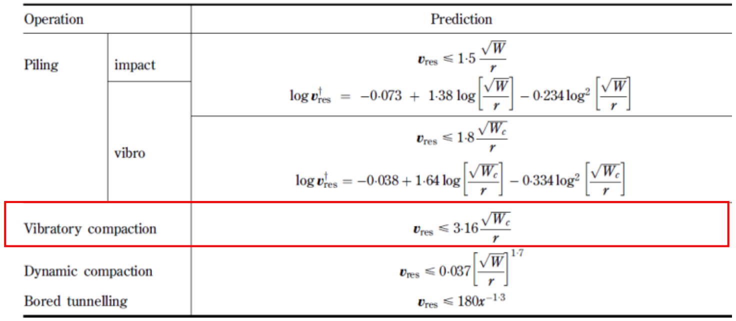


Attenuation of PPV with absolute distance for different construction equipment

TECHNICAL BACKGROUND (Prediction Methods)

Hiller and Hope (1998):

- Proposed attenuation equations depending on construction equipment.
- The equation depends on the energy input per cycle (W_0) and distance from the roller.
- Emphasizes that road compaction has the potential to damage buildings.

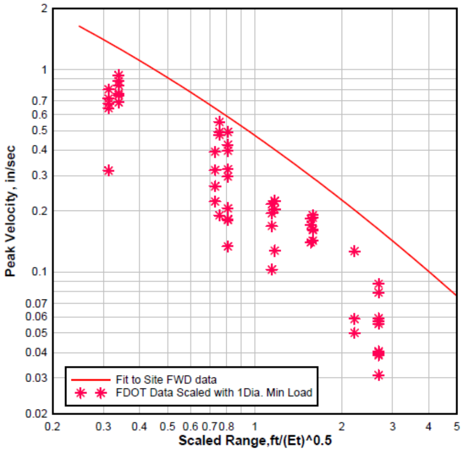


Operation		Prediction
Piling	impact	$v_{\text{res}} \leqslant 1{\cdot}5 \frac{\sqrt{W}}{r}$ $\log v^{\dagger}_{\text{res}} = -0{\cdot}073 + 1{\cdot}38 \log\left[\frac{\sqrt{W}}{r}\right] - 0{\cdot}234 \log^2\left[\frac{\sqrt{W}}{r}\right]$
	vibro	$v_{\text{res}} \leqslant 1{\cdot}8 \frac{\sqrt{W_c}}{r}$ $\log v^{\dagger}_{\text{res}} = -0{\cdot}038 + 1{\cdot}64 \log\left[\frac{\sqrt{W_c}}{r}\right] - 0{\cdot}334 \log^2\left[\frac{\sqrt{W_c}}{r}\right]$
Vibratory compaction		$v_{\text{res}} \leqslant 3{\cdot}16 \frac{\sqrt{W_c}}{r}$
Dynamic compaction		$v_{\text{res}} \leqslant 0{\cdot}037 \left[\frac{\sqrt{W}}{r}\right]^{1{\cdot}7}$
Bored tunnelling		$v_{\text{res}} \leqslant 180x^{-1{\cdot}3}$

Empirical predictors of ground-borne vibration levels from construction works in mm/s

Jackson et al. (2007)

- FDOT funded project using Falling Weight Deflectometer (FWD) to develop PPV prediction eq.
- This equation depends on the roller energy, its force, and the distance to the structure.



PPV attenuation curve validated with FWD results

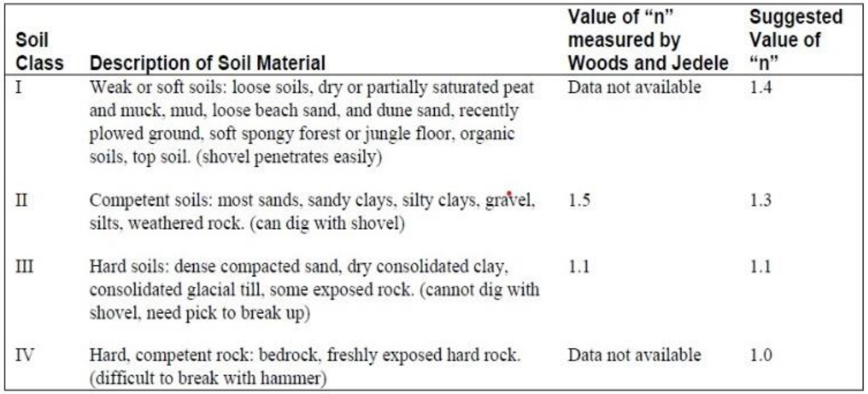
Caltrans Transp. and Constr. Vibration Guidance Manual (2013):

- Suggested a PPV prediction equation for different vibration equipment and soil conditions.
- Based on a reference value at a reference distance of 25 ft.

$$PPV_{vibratory\ roller} = PPV_{ref}(25/D)^n \quad [in/s]$$

Equipment	Reference PPV at 25 ft. (in/sec)
Vibratory roller	0.210
Large bulldozer	0.089
Caisson drilling	0.089
Loaded trucks	0.076
Jackhammer	0.035
Small bulldozer	0.003
Crack-and-seat operations	2.4

Reference vibration source amplitude



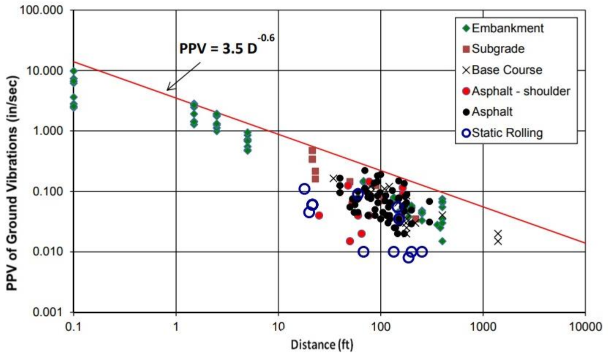
Soil Class	Description of Soil Material	Value of "n" measured by Woods and Jedele	Suggested Value of "n"
I	Weak or soft soils: loose soils, dry or partially saturated peat and muck, mud, loose beach sand, and dune sand, recently plowed ground, soft spongy forest or jungle floor, organic soils, top soil. (shovel penetrates easily)	Data not available	1.4
II	Competent soils: most sands, sandy clays, silty clays, gravel, silts, weathered rock. (can dig with shovel)	1.5	1.3
III	Hard soils: dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock. (cannot dig with shovel, need pick to break up)	1.1	1.1
IV	Hard, competent rock: bedrock, freshly exposed hard rock. (difficult to break with hammer)	Data not available	1.0

Suggested "n" values based on the soil class

TECHNICAL BACKGROUND (Case Histories)

Bayraktar et al. (2013):

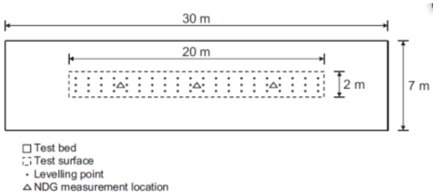
- FDOT-funded research project.
- Florida’s Turnpike- vibratory compaction projects.
- 40 different vibration monitoring- 170 data points.
- FDOT PPV limit of 0.5 in/s was not often exceeded beyond a distance of approximately 20 ft.

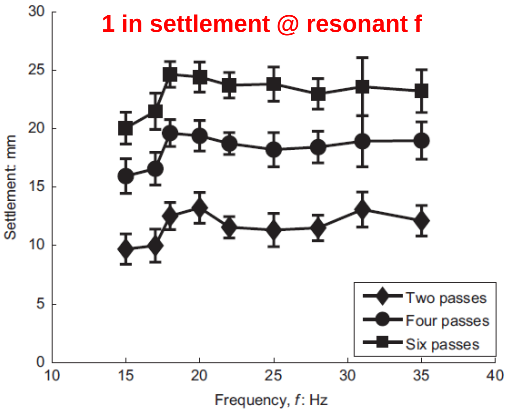


Distance versus PPV

Wersäll et al. (2017):

- Full-scale tests- influence of operating frequency of a vibratory roller on well-graded gravel (GW).
- Dynapac CA3500D single drum soil compaction roller.
- Tests: both fixed and variable frequencies (15-35 Hz).



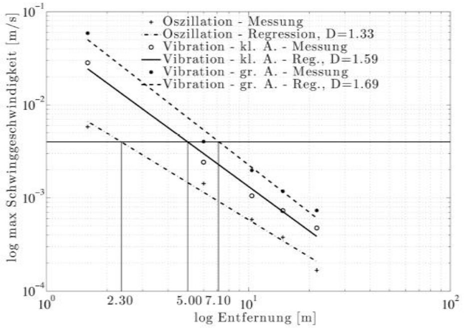


Settlement vs frequency

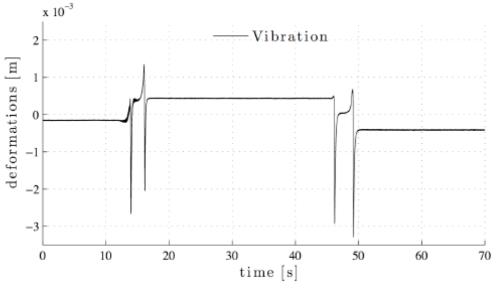
Pistrol et al. (2014):

- Vibratory and oscillatory drum on a gravel pit
- HAMM HD+90 VO tandem roller
- Amplitude of 0.013 in (f=50 Hz)
- Amplitude of 0.024 in (f=40 Hz)
- Oscillatory: Amplitude=0.06 in (f=39 Hz)
- Measured accelerations and integrated for PPV
- Largest PPV measured with the largest amplitude

Vibratory



PPV by vibratory and oscillatory drums

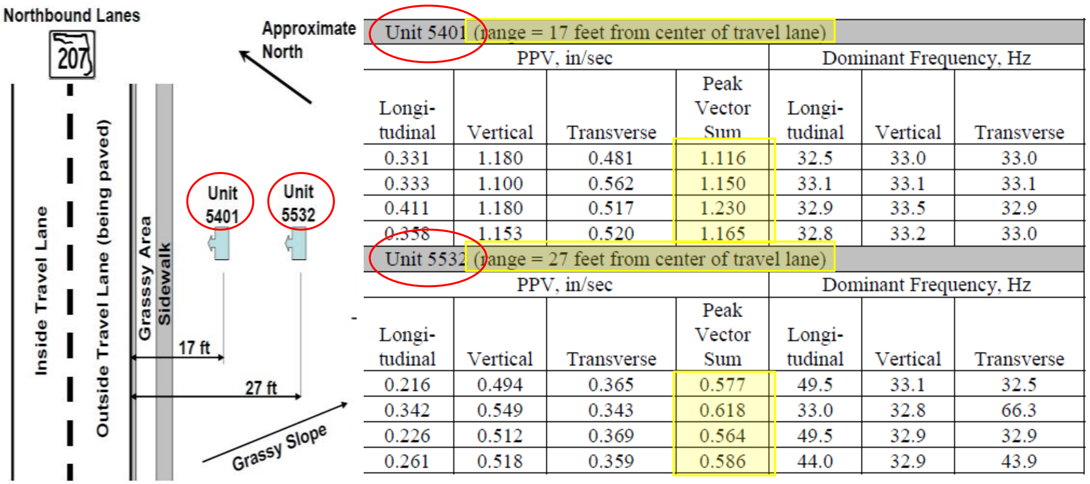


Vibratory drum-deformations in compacted soil

TECHNICAL BACKGROUND (Case History from FDOT Report)

Jackson et al. (2007):

- Ingersoll-Rand (IR) DD-110 HF vibratory asphalt compactor (f=42 Hz and amplitude=0.022 in)
- Vibratory compaction of 4 inches thick structural HMA layer over 12 inches limerock base and 12 inches of stabilized subgrade over a sand subgrade on SR 407
- Used triaxial geophones to monitor PPV
- PPVs as high as 1.23 in/s
- A list of some heavy vibratory drum rollers with their specifications was summarized in the study



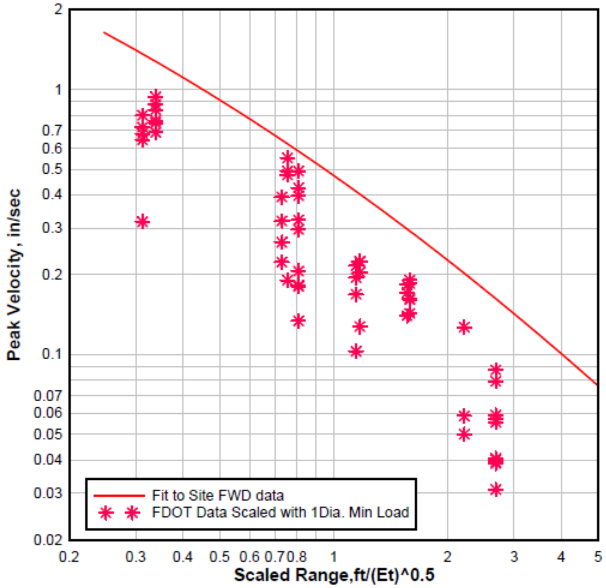
Unit 5401 (range = 17 feet from center of travel lane)

PPV, in/sec				Dominant Frequency, Hz		
Longitudinal	Vertical	Transverse	Peak Vector Sum	Longitudinal	Vertical	Transverse
0.331	1.180	0.481	1.116	32.5	33.0	33.0
0.333	1.100	0.562	1.150	33.1	33.1	33.1
0.411	1.180	0.517	1.230	32.9	33.5	32.9
0.358	1.153	0.520	1.165	32.8	33.2	33.0

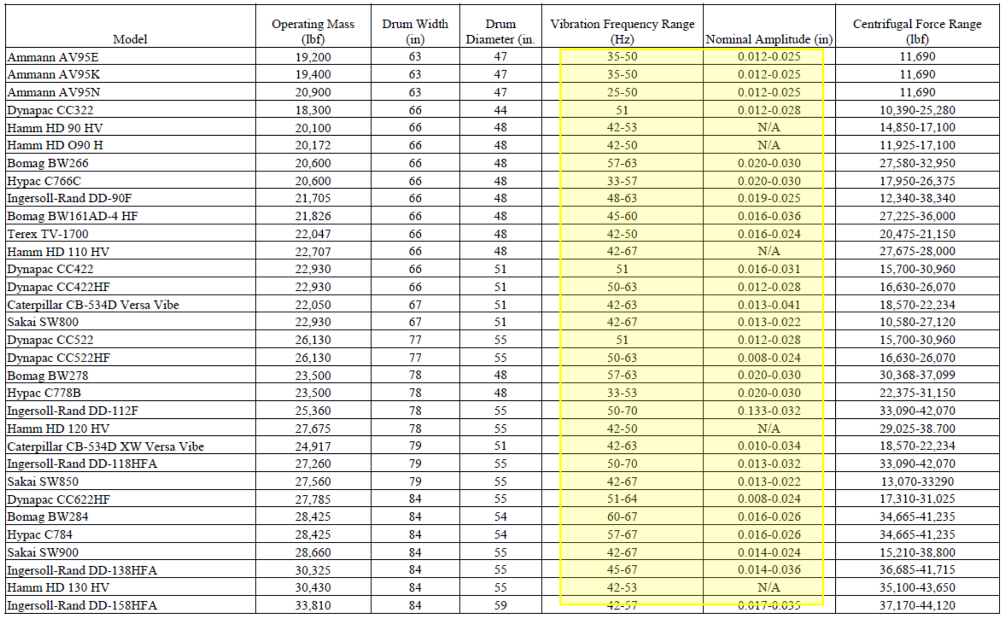
Unit 5532 (range = 27 feet from center of travel lane)

PPV, in/sec				Dominant Frequency, Hz		
Longitudinal	Vertical	Transverse	Peak Vector Sum	Longitudinal	Vertical	Transverse
0.216	0.494	0.365	0.577	49.5	33.1	32.5
0.342	0.549	0.343	0.618	33.0	32.8	66.3
0.226	0.512	0.369	0.564	49.5	32.9	32.9
0.261	0.518	0.359	0.586	44.0	32.9	43.9

Summary of PPV and dominant frequency results



Predictor validation results



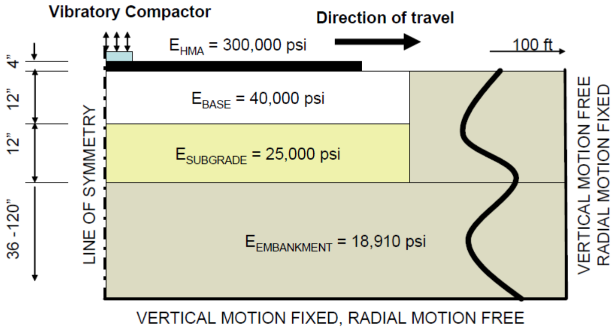
Model	Operating Mass (lbf)	Drum Width (in)	Drum Diameter (in.	Vibration Frequency Range (Hz)	Nominal Amplitude (in)	Centrifugal Force Range (lbf)
Ammann AV95E	19,200	63	47	35-50	0.012-0.025	11,690
Ammann AV95K	19,400	63	47	35-50	0.012-0.025	11,690
Ammann AV95N	20,900	63	47	25-50	0.012-0.025	11,690
Dynapac CC322	18,300	66	44	51	0.012-0.028	10,390-25,280
Hamm HD 90 HV	20,100	66	48	42-53	N/A	14,850-17,100
Hamm HD O90 H	20,172	66	48	42-50	N/A	11,925-17,100
Bomag BW266	20,600	66	48	57-63	0.020-0.030	27,580-32,950
Hypac C766C	20,600	66	48	33-57	0.020-0.030	17,950-26,375
Ingersoll-Rand DD-90F	21,705	66	48	48-63	0.019-0.025	12,340-38,340
Bomag BW161AD-4 HF	21,826	66	48	45-60	0.016-0.036	27,225-36,000
Terex TV-1700	22,047	66	48	42-50	0.016-0.024	20,475-21,150
Hamm HD 110 HV	22,707	66	48	42-67	N/A	27,675-28,000
Dynapac CC422	22,930	66	51	51	0.016-0.031	15,700-30,960
Dynapac CC422HF	22,930	66	51	50-63	0.012-0.028	16,630-26,070
Caterpillar CB-534D Versa Vibe	22,050	67	51	42-63	0.013-0.041	18,570-22,234
Sakai SW800	22,930	67	51	42-67	0.013-0.022	10,580-27,120
Dynapac CC522	26,130	77	55	51	0.012-0.028	15,700-30,960
Dynapac CC522HF	26,130	77	55	50-63	0.008-0.024	16,630-26,070
Bomag BW278	23,500	78	48	57-63	0.020-0.030	30,368-37,099
Hypac C778B	23,500	78	48	33-53	0.020-0.030	22,375-31,150
Ingersoll-Rand DD-112F	25,360	78	55	50-70	0.133-0.032	33,090-42,070
Hamm HD 120 HV	27,675	78	55	42-50	N/A	29,025-38.700
Caterpillar CB-534D XW Versa Vibe	24,917	79	51	42-63	0.010-0.034	18,570-22,234
Ingersoll-Rand DD-118HFA	27,260	79	55	50-70	0.013-0.032	33,090-42,070
Sakai SW850	27,560	79	55	42-67	0.013-0.022	13,070-33290
Dynapac CC622HF	27,785	84	55	51-64	0.008-0.024	17,310-31,025
Bomag BW284	28,425	84	54	60-67	0.016-0.026	34,665-41,235
Hypac C784	28,425	84	54	57-67	0.016-0.026	34,665-41,235
Sakai SW900	28,660	84	55	42-67	0.014-0.024	15,210-38,800
Ingersoll-Rand DD-138HFA	30,325	84	55	45-67	0.014-0.036	36,685-41,715
Hamm HD 130 HV	30,430	84	55	42-53	N/A	35,100-43,650
Ingersoll-Rand DD-158HFA	33,810	84	59	42-57	0.017-0.035	37,170-44,120

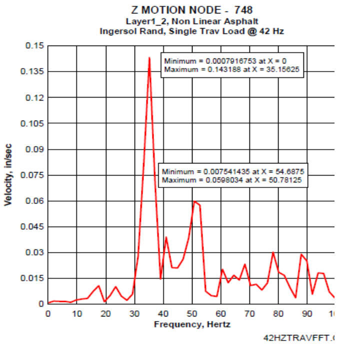
Summary of vibratory compactors and specifications

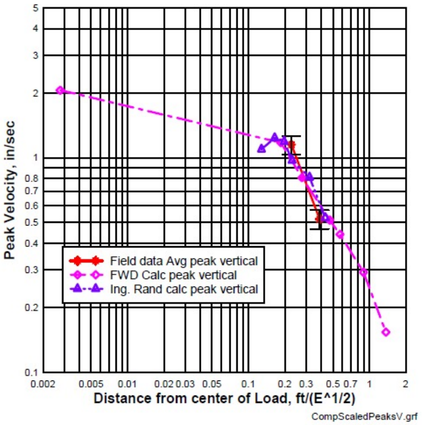
TECHNICAL BACKGROUND (Numerical Analyses)

Jackson et al. (2007):

- Plane strain FE model
- Validated with field data from St Augustine, FL
- Linear elastic material
- Matched the predominant frequency and PPV

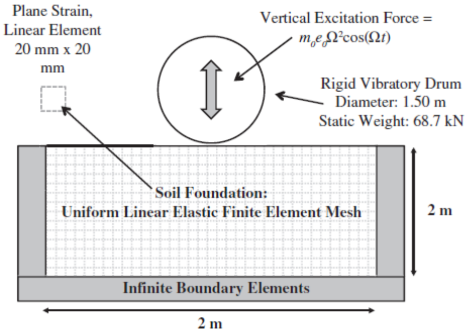






Kenneally et al. (2015):

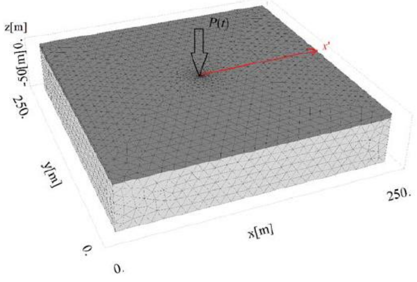
- Plane strain FE model
- Linear elastic
- Use of infinite boundaries to avoid wave reflection
- Static load: weight of drum
- Vertical harmonic excitation: eccentric loading



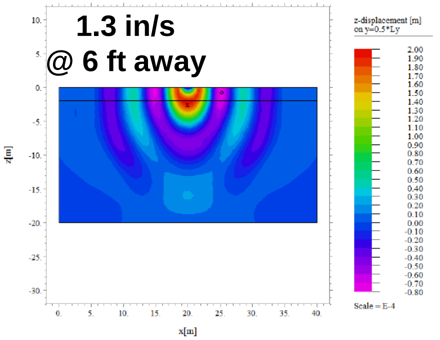
Schematic of 2D FE mesh in ABAQUS

Herbut et al. (2019):

- FE model in FlexPDE 3D
- Compaction of STAVOSTROJ vibratory roller
- Linear elastic (1% damping)
- Force applied in a rectangular region (1x10 ft)
- Analysis time: 10 x period of the excitation
- Computed changes in soil response after compaction

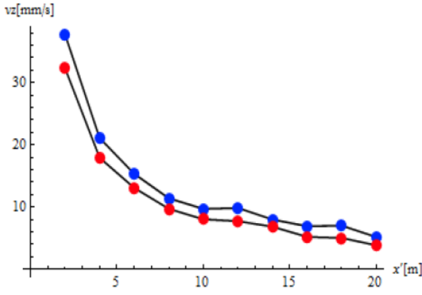


Harmonic loading
Force: 73 lbf (324 kN)
Frequency: 29 Hz



1.3 in/s
@ 6 ft away

Vertical displacements for t=0.072s

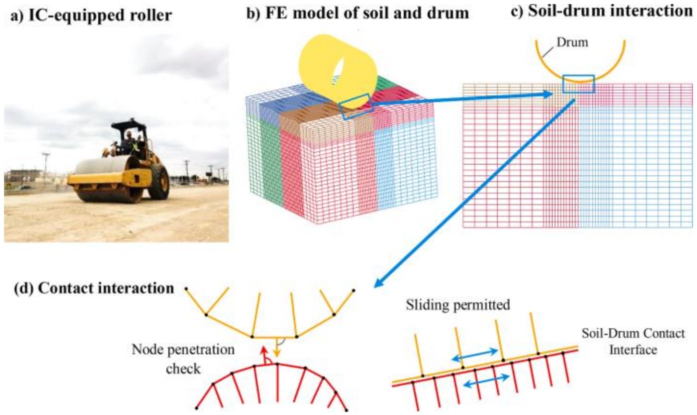


PPV attenuation before and after compaction

TECHNICAL BACKGROUND (Numerical Analyses)

Fathi et al. (2021):

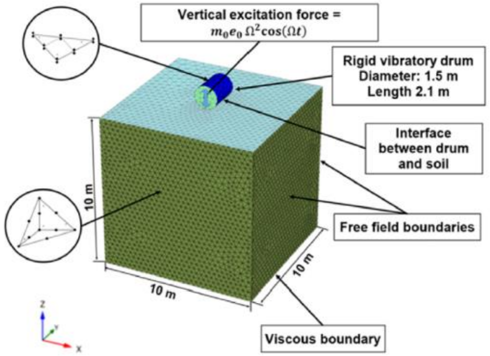
- Evaluation of depth of influence using 3D FE model in LS-DYNA.
- Drum considered as a rigid body.
- Single contact interface between pavement and drum.
- Results matched both displacement and vibrations at different depths



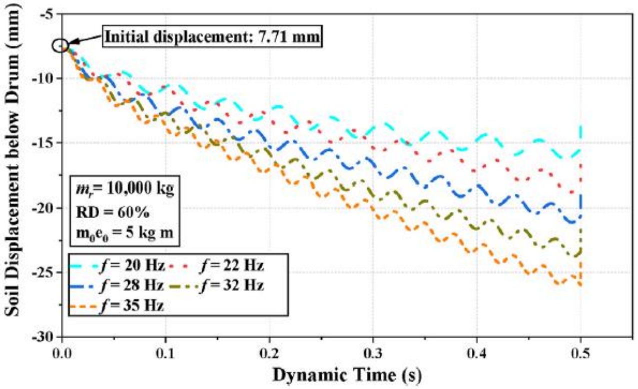
Schematic of drum/soil system

Xu et al. (2022):

- Estimated soil stiffness from drum response during compaction.
- More than 3000 simulations in PLAXIS 3D.
- Use of HS-Small constitutive model.
- Excitation modeled as harmonic
- Results showed increasing displacement as frequency increased



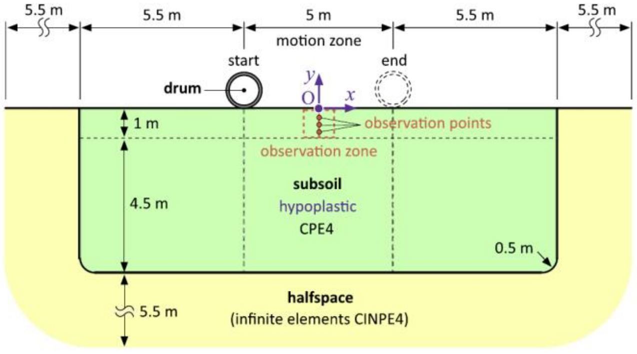
Adopted model



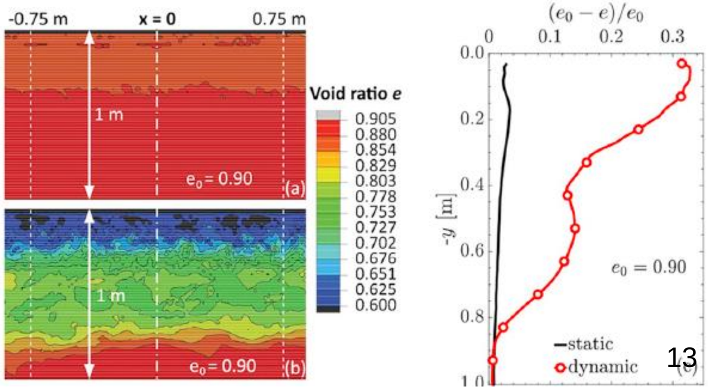
Soil settlement time history for different frequencies

Paulmichl et al. (2020):

- 2D FE model in ABAQUS.
- Plane strain.
- Hypoplasticity model for the soil to track void ratio changes!
- Contact between soil and drum using Coulomb's law.
- HAMM HD$^+$ 90 VO roller
- Frequency of 39 Hz



Sketch of the 2D FE model

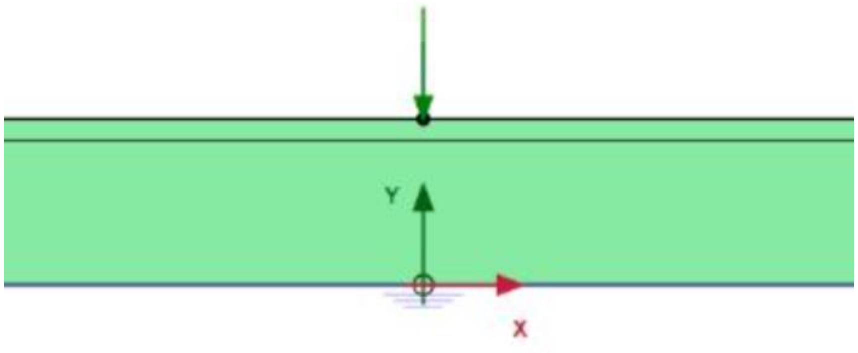


(a) static and (b) oscillatory roller pass

PROGRESS IN NUMERICAL MODELING (Model 1)

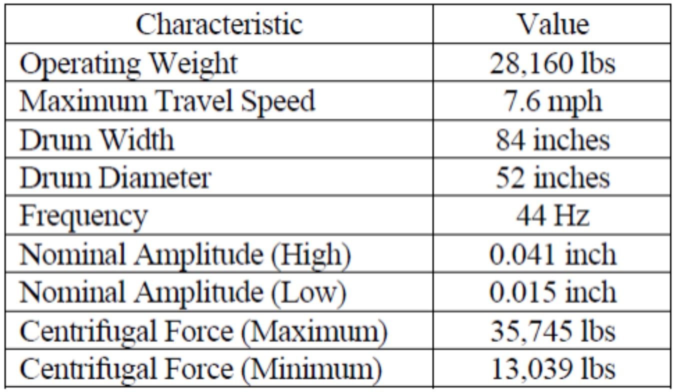
Numerical model started with the information from Jackson et al. (2007):

- Test conducted in Gainesville, Florida.
- Caterpillar CB-634C vibratory roller was used (modeled as a dynamic point load).
- PPV measurements were performed perpendicular to the direction of the roller.
- Plane strain conditions



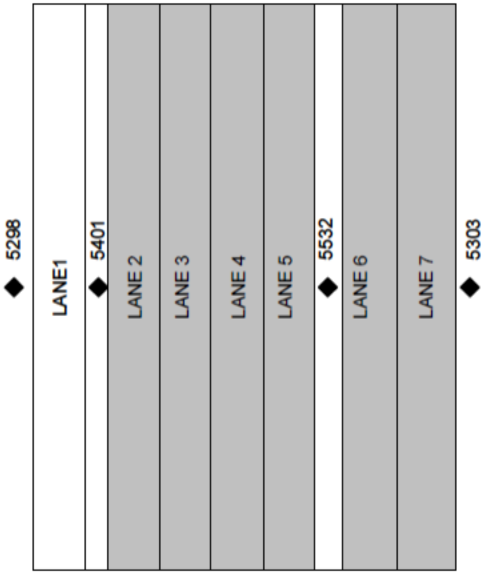
2D FE model view

$$F_c = \underbrace{(m_f + m_d)g}_{\text{Static axle load}} + \underbrace{m_o e_o w^2 (wt)}_{\text{Dynamic centrifugal force}}$$



Characteristic	Value
Operating Weight	28,160 lbs
Maximum Travel Speed	7.6 mph
Drum Width	84 inches
Drum Diameter	52 inches
Frequency	44 Hz
Nominal Amplitude (High)	0.041 inch
Nominal Amplitude (Low)	0.015 inch
Centrifugal Force (Maximum)	35,745 lbs
Centrifugal Force (Minimum)	13,039 lbs

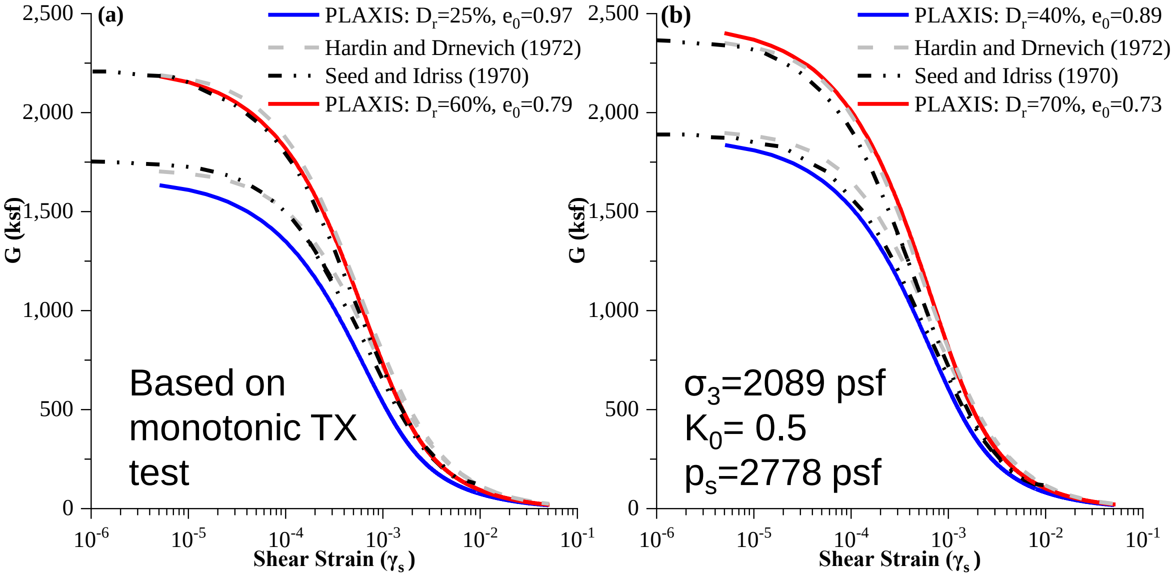
Vibratory roller specifications



Sensor location

PROGRESS IN NUMERICAL MODELING (Model 1)

- Hypoplasticity sand model was used to consider changes in void ratio due to vibrations.
- Target relative densities ranging from 25% to 75% are controlled with initial void ratio e_0 parameter.
- Parameters calibrated to match expected shear modulus degradation curves.



Based on monotonic TX test

σ_3=2089 psf
K_0= 0.5
p_s=2778 psf

e_{d0}=1.10 Maximum void ratio
e_{c0}=0.58 Minimum void ratio

From Lade et al. (1998) and Zapata-Medina et al. (2019): Poorly Graded Sands tested for similar relative densities

D_r (%)	e_0
25	0.97
40	0.89
50	0.84
55	0.81
60	0.79
70	0.73
75	0.71

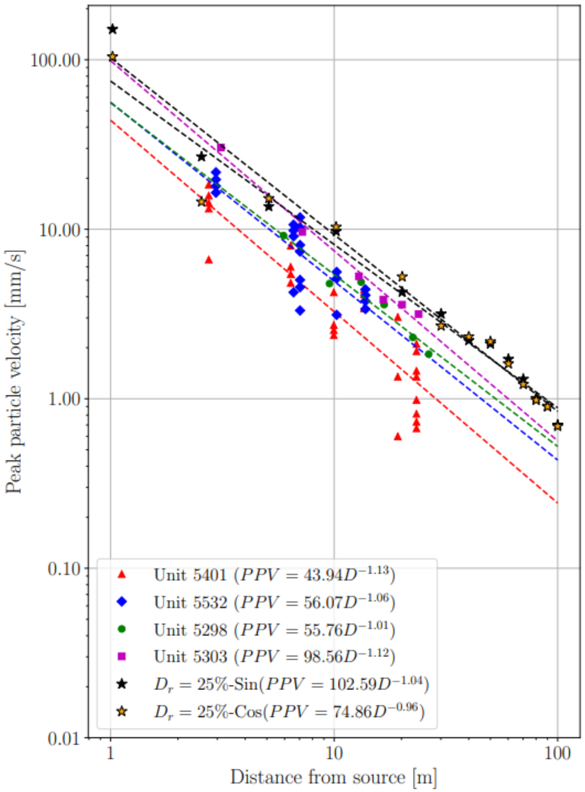
e_0 values corresponding to each relative density

No.	Parameter	Description	Value	Unit
1	ϕ_c	Critical state friction angle	31	°
2	pt	Shift of the mean stress due to cohesion	0	psf
3	h_s	Granular hardness	25062	ksf
4	n	Exponent for pressure sensitive of a grain skeleton	0.37	-
5	e_{d0}	Minimum void ratio at zero pressure (ps = 0)	0.58	-
6	e_{c0}	Critical void ratio at zero pressure (ps = 0)	1.096	-
7	e_{i0}	Maximum void ratio at zero pressure (ps = 0)	1.315	-
8	α	Exponent for transition between peak and critical stresses	0.05	-
9	β	Exponent for stiffness dependency on pressure and density	1.4	-
10	m_R	Stiffness increase for 180° strain reversal	5	-
11	m_T	Stiffness increase for 90° strain reversal	2	-
12	R_{max}	Size of elastic range	5.00×10^{-5}	-
13	β_r	Material constant representing stiffness degradation	0.1	-
14	χ	Material constant for evolution of intergranular strains	1.0	-

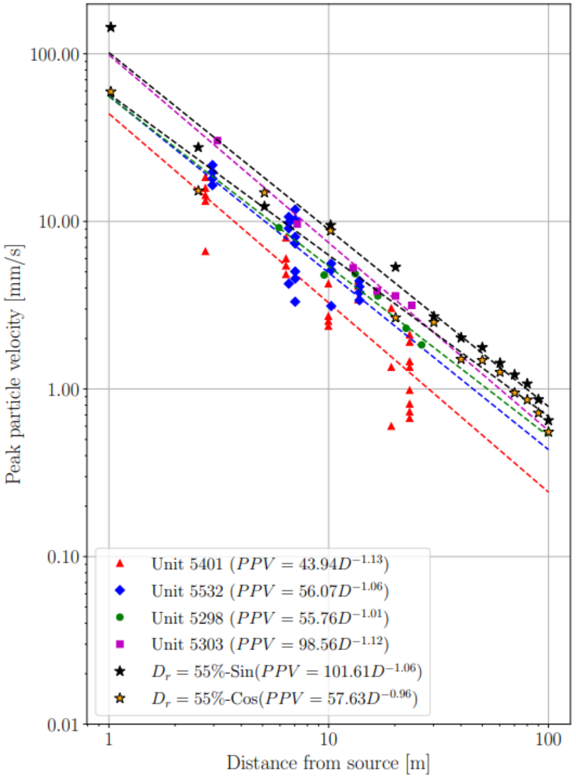
Hypoplasticity parameters

PROGRESS IN NUMERICAL MODELING (Model 1)

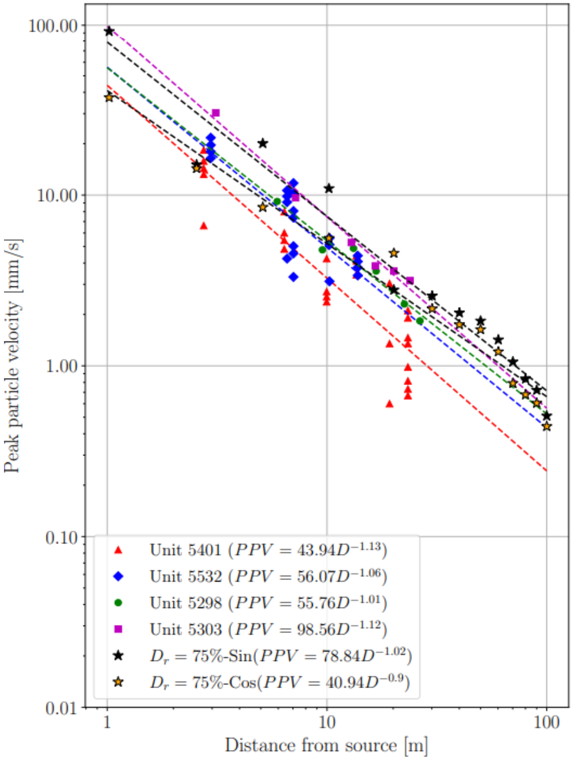
Loose
$(D_r = 25\%)$



Medium-dense
$(D_r = 55\%)$



Dense
$(D_r = 75\%)$



- Attenuation curves developed for different relative densities.
- Curves presented for each sensor in the field and modeled results.
- Model tends to overpredict the field measurements.
- Expected due to force applied at the same location (i.e., it doesn’t move away from the observation points).

PROGRESS IN NUMERICAL MODELING (Model 2)

Similar to model 1:

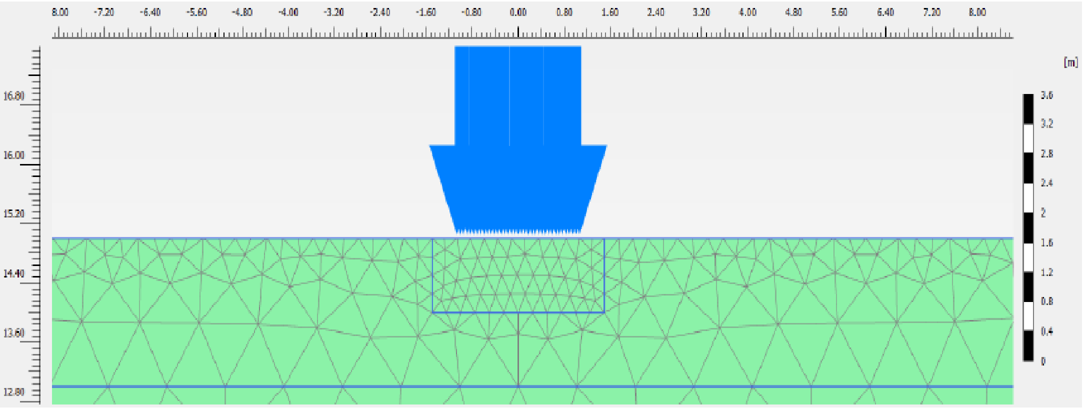
- 2D FE model.
- Plane strain conditions.
- Hypoplasticty used to model the soil.

Differences:

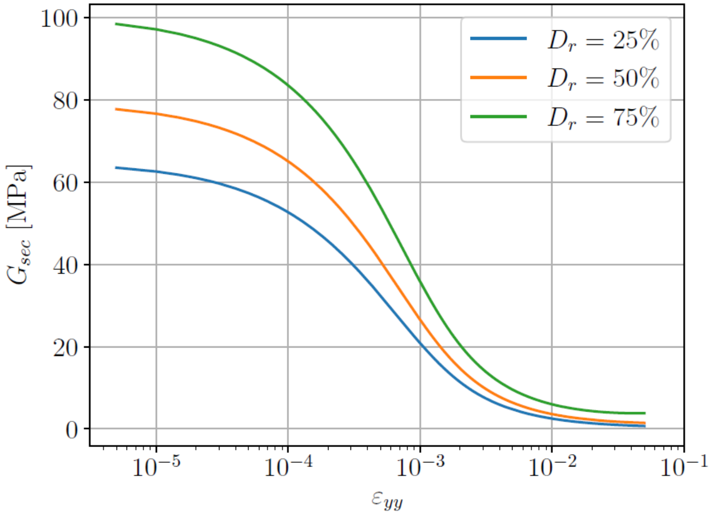
- Roller was modeled as a dynamic distributed load instead of point load.
- Dynamic analysis for 10 seconds.
- A more refined mesh.

Model	Ingersoll-Rand SD1500
Drum width [ft]	7
Weight [lbs/ft]	2935
Frequency [Hz]	26.5
Centrifugal force [lbf]	27652

Vibratory roller specifications

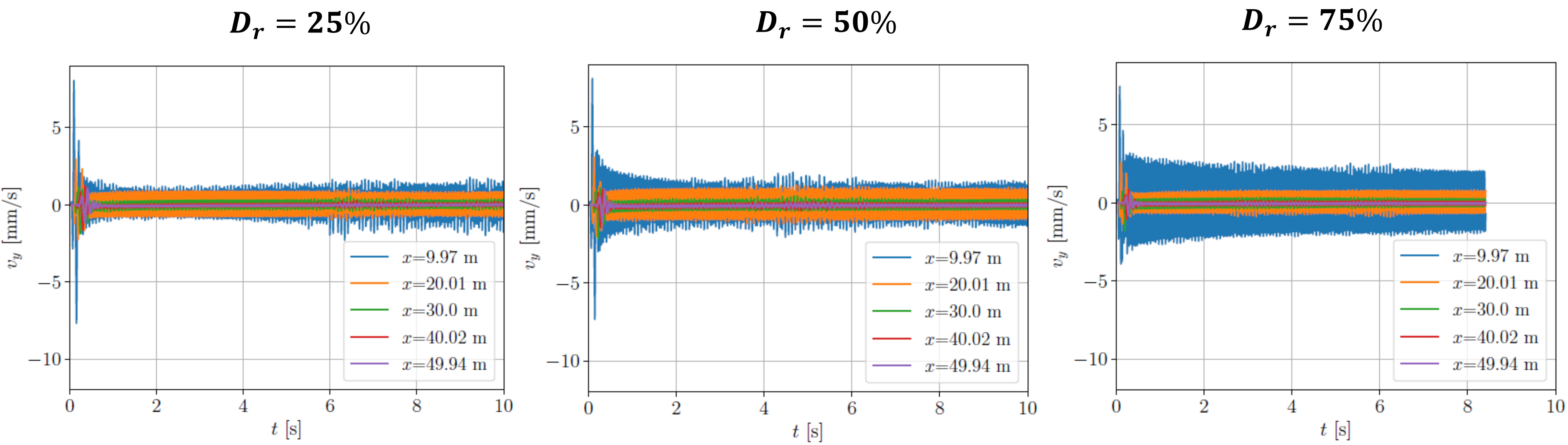


Improved FE model



Stiffness degradation curves

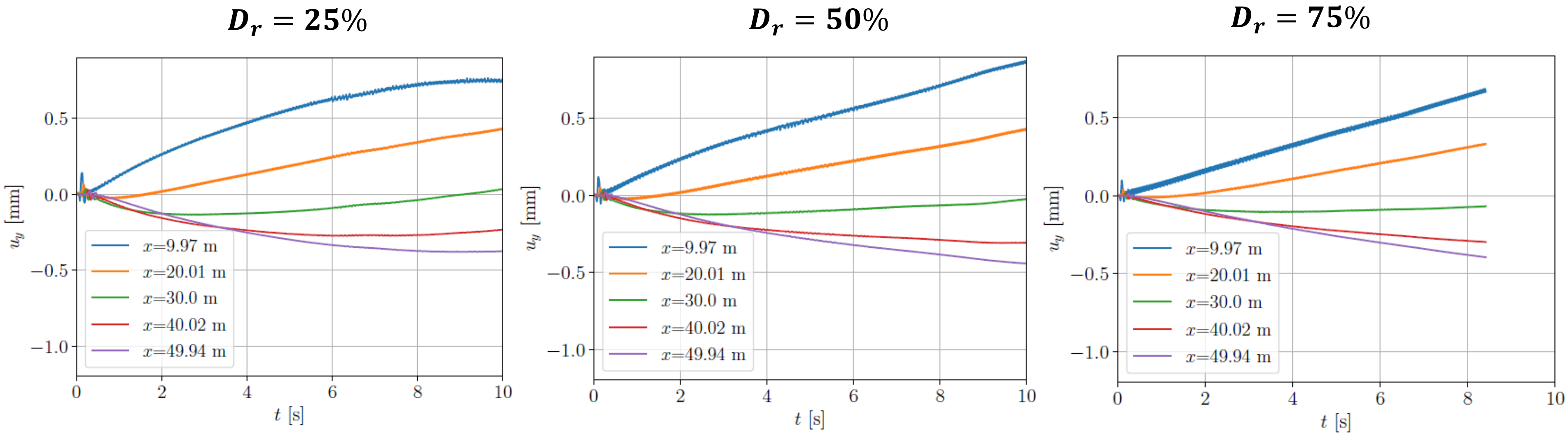
PROGRESS IN NUMERICAL MODELING (Model 2)


D_r = 25%

D_r = 50%

D_r = 75%

Velocity time histories for three relative densities
(Points up to 164 ft away from the roller location)


D_r = 25%

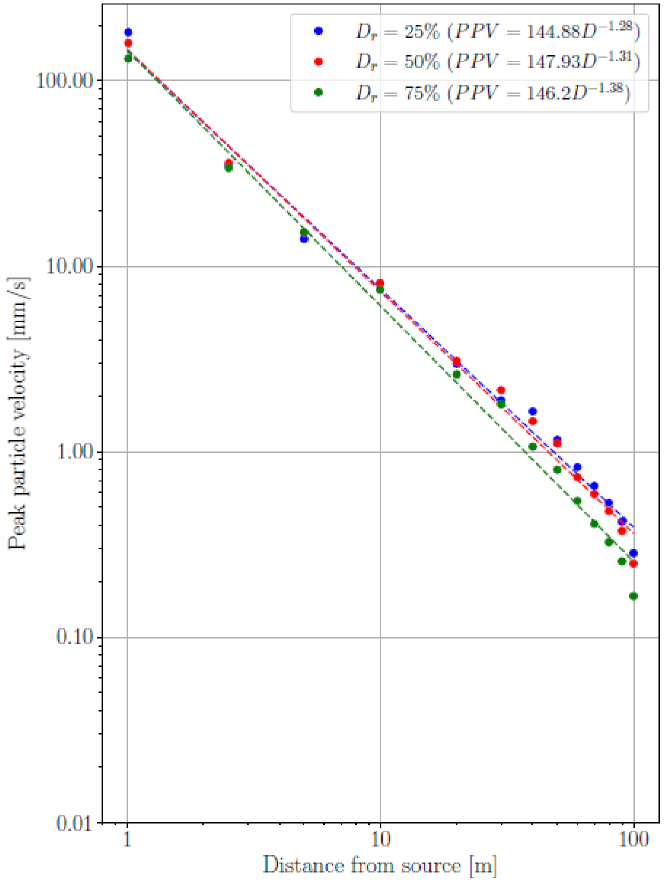
D_r = 50%

D_r = 75%

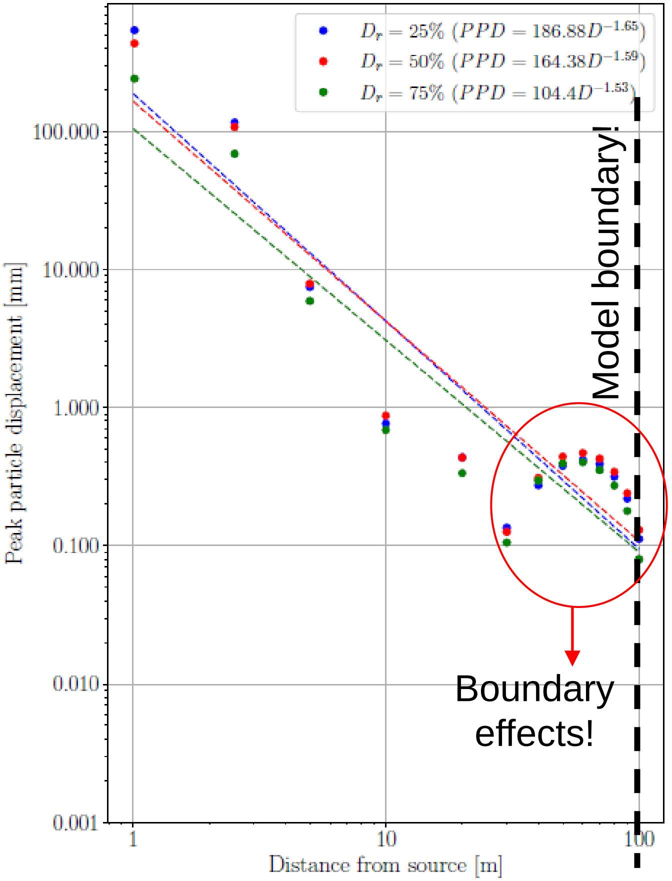
Deformation time histories for three relative densities
(Points up to 164 ft away from the roller location)

PROGRESS IN NUMERICAL MODELING (Model 2)

Peak Particle Velocity (PPV)



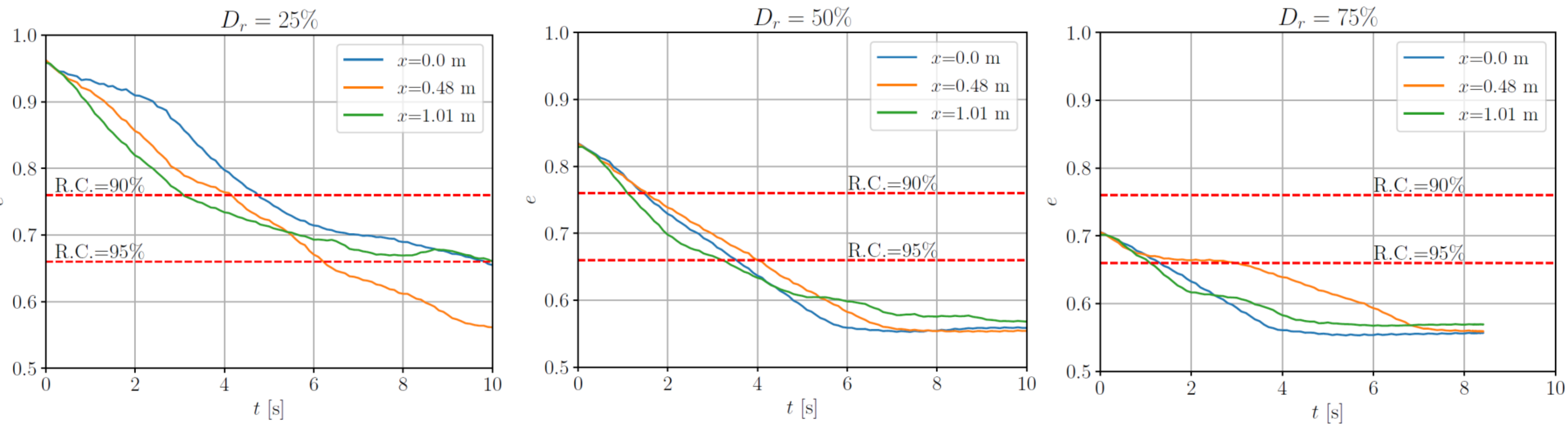
Peak Particle Displacement (PPD)



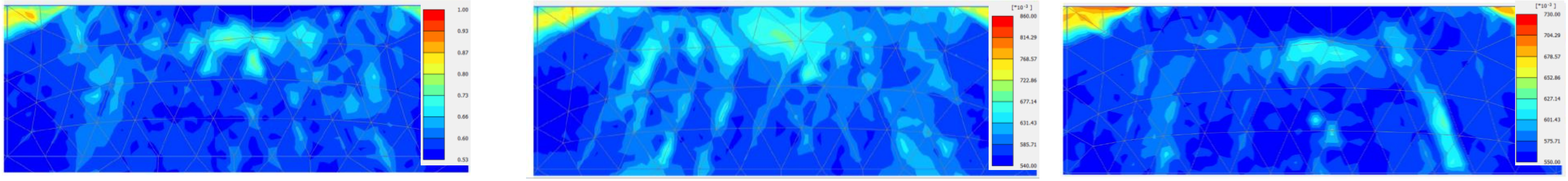
- PPV and Peak Particle Displacement (PPD) obtained for 3 relative densities were similar.
- PPV had a better fit to a linear regression than PPD.
- Dense sands tend to have less PPDs than loose materials.
- PPVs are obtained just after the roller begins to vibrate.
- Most PPDs correspond to the last step of the analysis. This value needs to be analyzed in depth also in relation to the target relative compaction (RC).

PROGRESS IN NUMERICAL MODELING (Model 2)

Relationship RC and Void Ratio: $R.C. = \dfrac{1+e_{min}}{1+e}$



Void ratio time histories for three relative densities
(Points under the roller)



Void ratio distribution under the roller at the end of the simulation for three relative densities

- Relative compaction could be used to numerically determine when the compaction process ends. It can be computed from the void ratio.
- Void ratio under the roller varies with depth and distance.
- Research team plans to apply this approach to the results of upcoming models.

REVIEW OF TASKS AND DELIVERABLES

Task 1 and 2: Technical Background and Survey Instrument

Task 1: Technical background on vibrations and ground deformations due to road compaction. Conduct a literature review of current methods for determination of the proposed effects.

The research team analyzed section 334 (i.e., superpave asphalt concrete) of the FDOT standard specifications, and in particular those cases when static rolling is required to control vibrations in urban environments.

Deliverable 1: Report on technical background 07/2023

Task 2: Survey of practitioners and district geotechnical engineers developed and disseminated to geotechnical consultants and FDOT district geotechnical engineers for their input.

Survey topic: experience, current practice, and most typical equipment used in Florida. A meeting with bituminous engineers in the districts to gather their experience on the requirement of static rollers to control vibrations in urban environments.

Deliverable 2: Report summarizing responses to the survey 11/2023

Task 3: Field Tests

Task 3: Field data collection at road compaction sites. Perform at least 2 field tests to measure ground vibrations (PPVs) and ground deformations, including asphalt compaction operations. Field test data will be used to validate the FE models proposed in Task 4 and develop correlations and prediction models in Task 5.

- In selecting the test sites, the road compaction equipment and method and the geotechnical site conditions will be considered. One test site will be selected for the case of asphalt compaction operations.

- Ground deformations are affected by: soil relative density, geotechnical characteristics of compacting material, number of passes and rolling velocity of compaction equipment, presence of geostructures, soil degree of saturation, characteristics of the input energy caused by compaction equipment, influence depth of compaction equipment and characteristics of transmitted waves.

Deliverable 3: Report summarizing field testing program 04/2024

Task 4 and 5: Numerical Modeling and Correlations

Task 4: Numerical modeling to determine ground vibrations and deformations due to road compaction, including asphalt compaction operations.

- The selection of a constitutive soil model will depend on: the soil type, density, stress history, confinement, and characteristics of the input energy source. Soil models need to reasonably predict behavior of soils under dynamic loadings. The models are restricted to those implemented into commercial computer codes and with published record of calibrations with field and laboratory tests. Critical state-based models are considered since they can update void ratios as road compaction occurs.

Deliverable 4: Report describing numerical modeling and conclusions 07/2024

Task 5: Develop empirical correlation (formula or chart). Similar correlations were proposed by the PI for pile driving induced settlements (FDOT project BDV24 TWO 977-33). An empirical site-specific dynamic settlement equation or chart will be developed as a function of distance from the source, PPV, soil relative density, and input energy.

Deliverable 5: Report presenting empirical correlation (formula or chart) for the dynamic settlement 10/2024

SUMMARY OF TASK/DELIVERABLE SCHEDULE

TASK AND ASSOCIATED DELIVERABLE	DATE
Kickoff teleconference	03/2023
Deliverable 1: A technical report presenting the results of the technical background on vibrations and ground deformations due to road compaction including asphalt compaction operations and other past case studies.	07/2023
Deliverable 2: A survey instrument and analysis of the data collected from consultants in Florida and from the survey directed to bituminous engineers in the districts to gather their experience on the requirement of static rollers to control vibrations in urban environments.	11/2023
Deliverable 3: A technical report summarizing the results of the field tests, including: (i) details and sequence of road compaction, (ii) soil properties at the selected sites and of the compacted material, (iii) specification of the compaction equipment used during the road compaction, and (iv) measured vibrations and ground deformations during the field visits.	04/2024
Deliverable 4: A technical report summarizing the results of the finite element numerical models and parametric studies developed in this research.	07/2024
Deliverable 5: A technical report summarizing the proposed correlations and recommendations regarding the vibrations and ground deformations due to road compaction.	10/2024
Deliverable 6a Draft final report.	11/2024
Deliverable 6b: Closeout teleconference meeting and PowerPoint presentation	02/2025
Deliverable 7: Final report	02/2025

PRESENTED BY
Luis G. Arboleda-Monsalve
Univ. of Central Florida, Orlando, FL.

UNIVERSITY OF
CENTRAL FLORIDA