Free Field Displacements Calculated with Green's Functions Implemented in SC-SASSI

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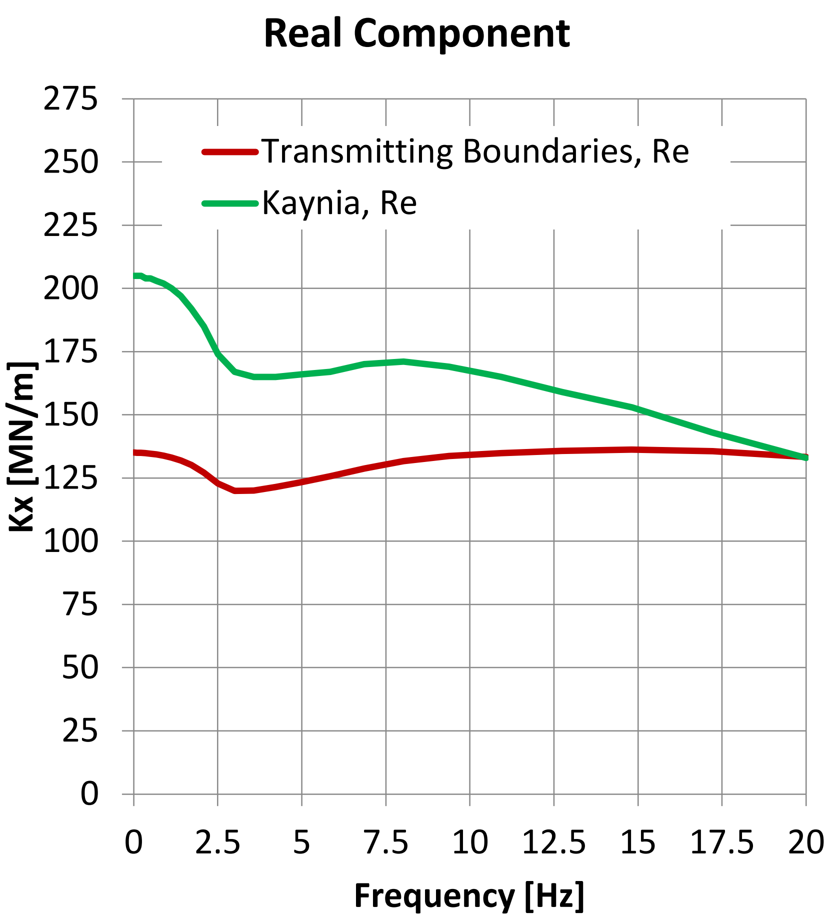
SC SOLUTIONS

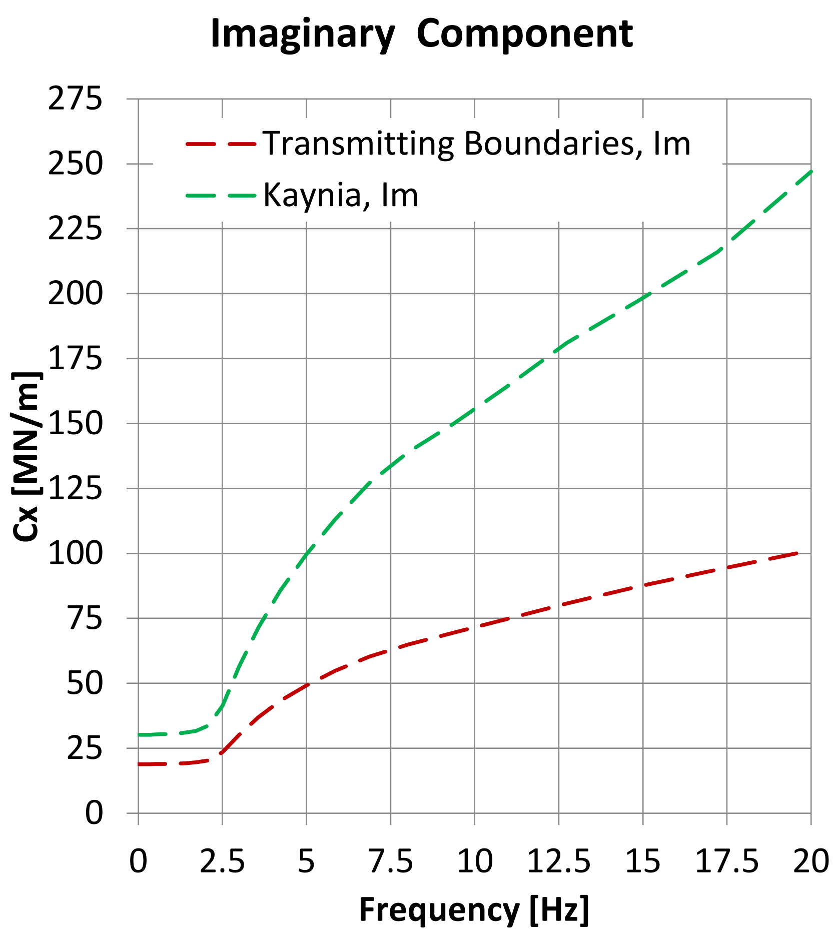
Value Through Innovation.

Motivation: Can we simulate piles with SASSI?

- SASSI: SSI analysis of shallow foundations
- Classic solutions for Piles (Thin Layer Method): Kaynia (1982), Hartmann (1985)
- Modeling shallow foundations vs pile foundations
- Calculation of soil displacements (flexibility) for one single node at each layer interface
- Semi-Analytical Displacement Formulation for:
  - Point Loads: Singularity (not defined) under the Load
  - Ring and Disk Loads: Defined under the load
- Green's Functions for distributed (Ring and Disk) loads approach represents better the load transfer from pile to soil than the Transmitting Boundaries (Point Load) approach.
- Focus of the presentation

Dynamic Stiffness of Single Pile with Transmitting Boundaries

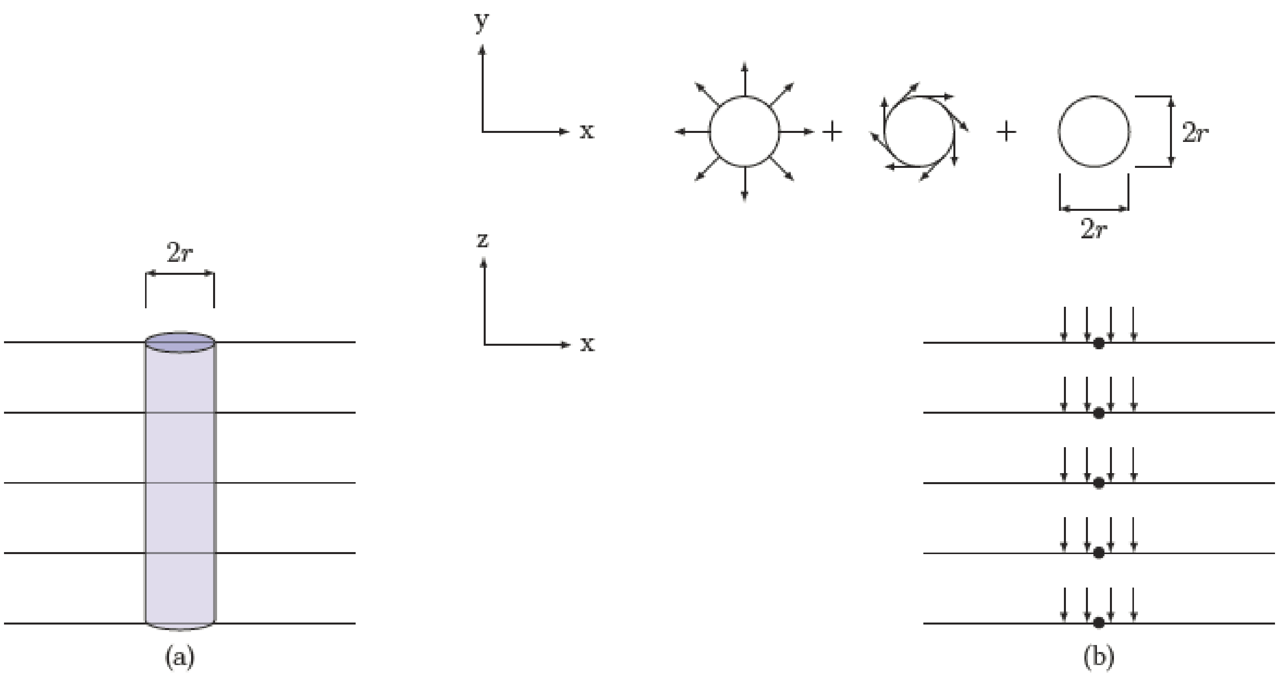




Transmitting Boundary (TB) approach underestimates the Dynamic Stiffness of Piles

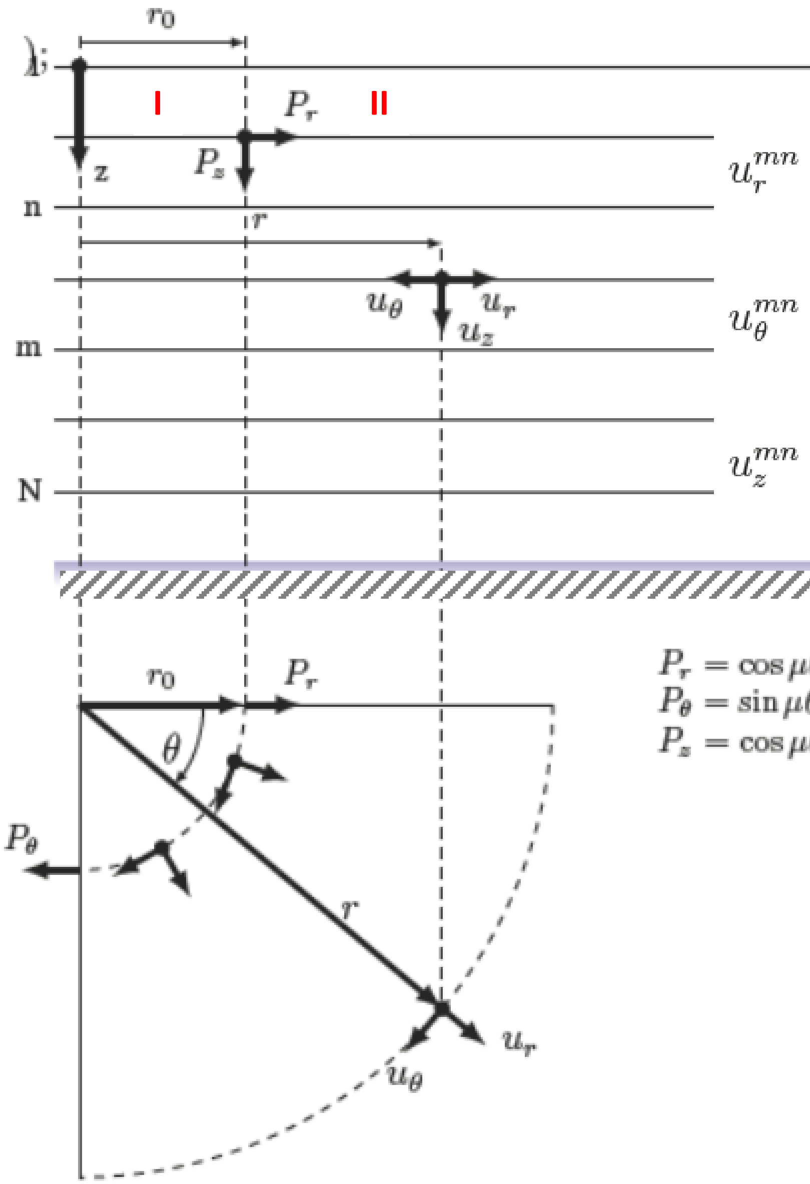
Motivation: Pile Simulations

Goals: **Realistic estimation of soil flexibility for piles**
Efficient computational approach to simulate piles



Theoretical Background

Displacements due to Ring/Disk Loads



$$P_r = \cos\mu\theta$$
$$P_\theta = \sin\mu\theta$$
$$P_z = \cos\mu\theta$$

Green's Functions

$$u_r^{mn} = \left\{ \sum_{l=1}^{2N} \alpha_R^{nl} \phi_x^{ml} \frac{\mathrm{d}}{\mathrm{d}r} f_l^R + \frac{\mu}{r} \sum_{l=1}^{N} \alpha_L^{nl} \phi_y^{ml} f_l^L \right\} \begin{bmatrix} \cos\mu\theta \\ \sin\mu\theta \end{bmatrix}$$

$$u_\theta^{mn} = \left\{ \frac{\mu}{r} \sum_{l=1}^{2N} \alpha_R^{nl} \phi_x^{ml} f_l^R + \sum_{l=1}^{N} \alpha_L^{nl} \phi_y^{ml} \frac{\mathrm{d}}{\mathrm{d}r} f_l^L \right\} \begin{bmatrix} -\sin\mu\theta \\ \cos\mu\theta \end{bmatrix}$$

$$u_z^{mn} = \left\{ - \sum_{l=1}^{2N} \alpha_R^{nl} \phi_z^{ml} f_l^R k_l \right\} \begin{bmatrix} \cos\mu\theta \\ \sin\mu\theta \end{bmatrix}$$

After Kausel (1981) and Waas (1980).

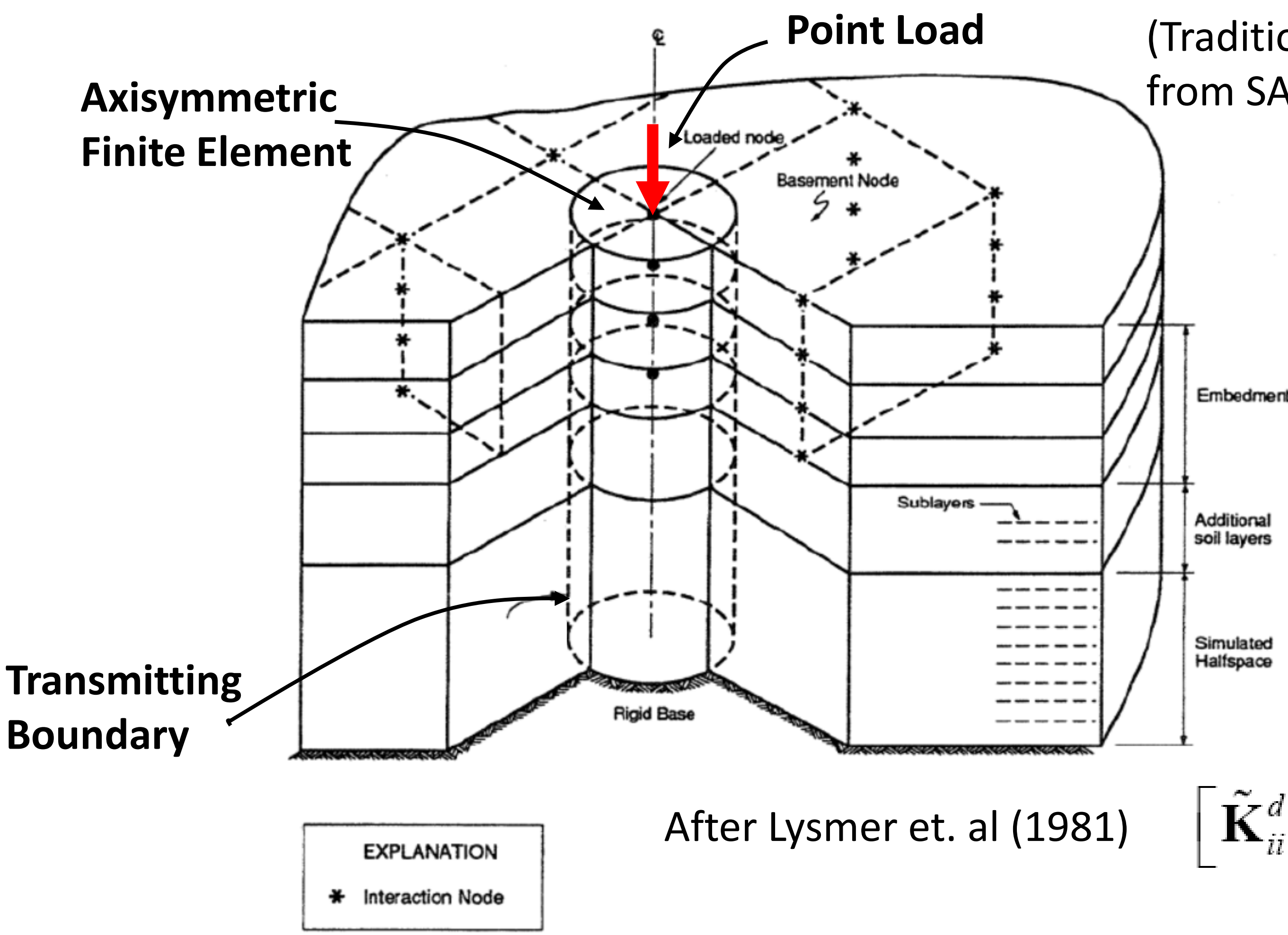
Impedance Analysis

$$\left[\tilde{\mathbf{K}}_{ii}^d \right] = \left[\tilde{\mathbf{F}}_{ii}^d \right]^{-1}$$

Recently implemented in SC-SASSI

Transmitting Boundaries (TB) and Finite Element

(Traditional) approach from SASSI



After Lysmer et. al (1981)

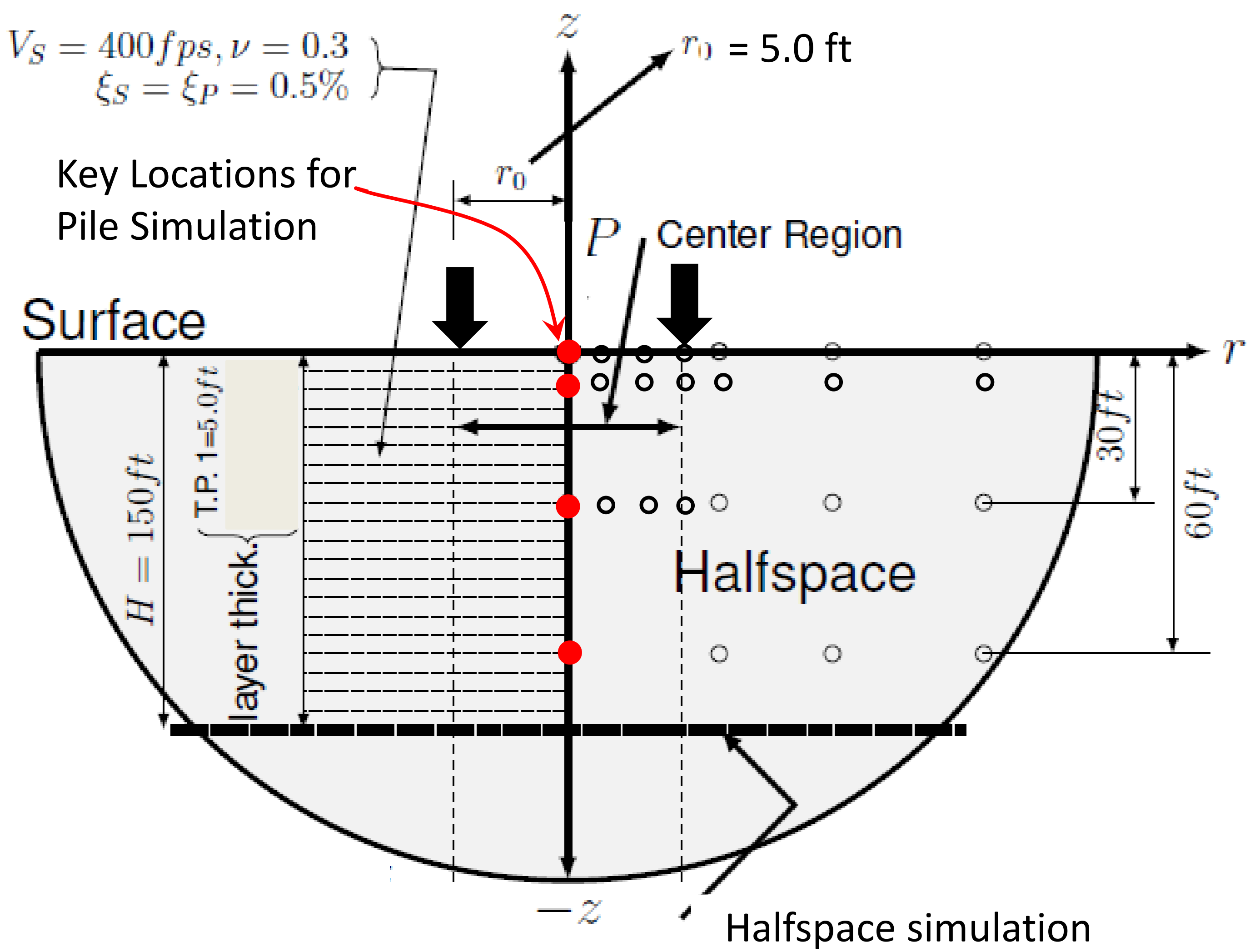
$$\left[\tilde{\mathbf{K}}_{ii}^{d}\right] = \left[\tilde{\mathbf{F}}_{ii}^{d}\right]^{-1}$$

Example: Soil Displacements

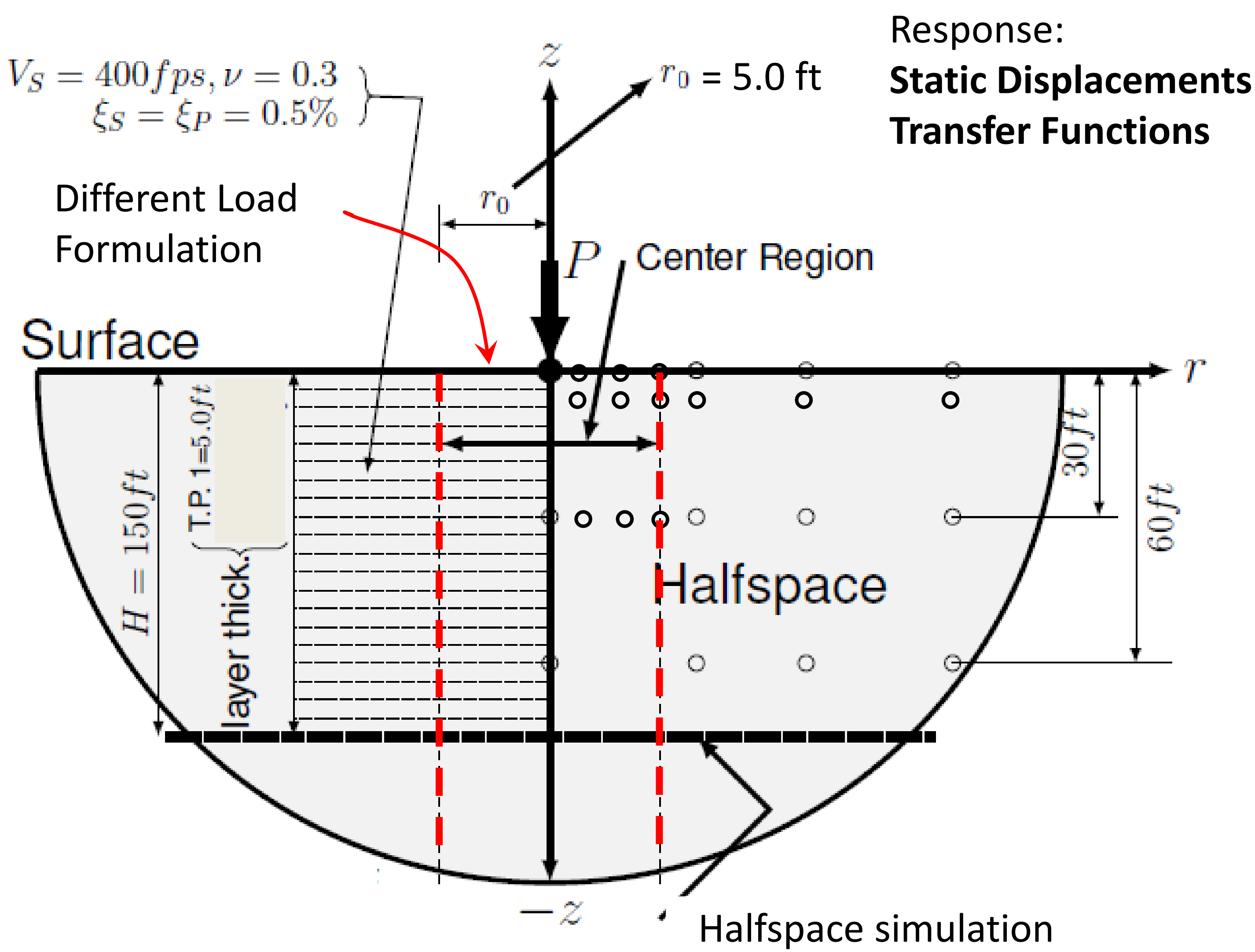
Objectives:

Limitations of Transmitting Boundaries inside the area of the load
Ring Load behaves like Point Load at distance and depth from load location

Example: Displacements (GF) due to Ring Loads

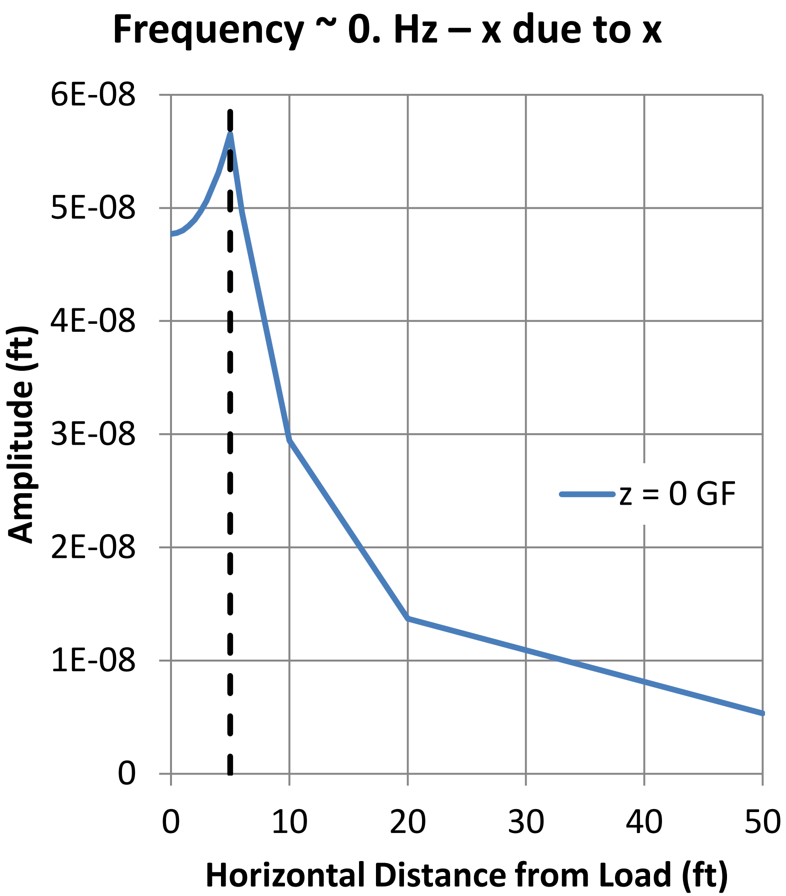


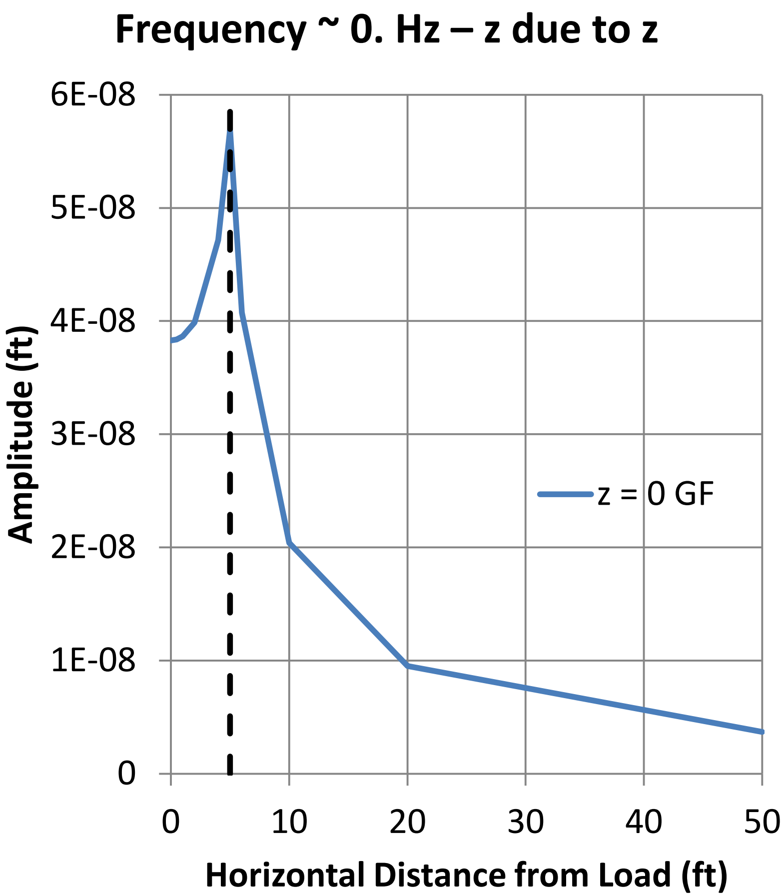
Displacements with Transmitting Boundaries (TB)



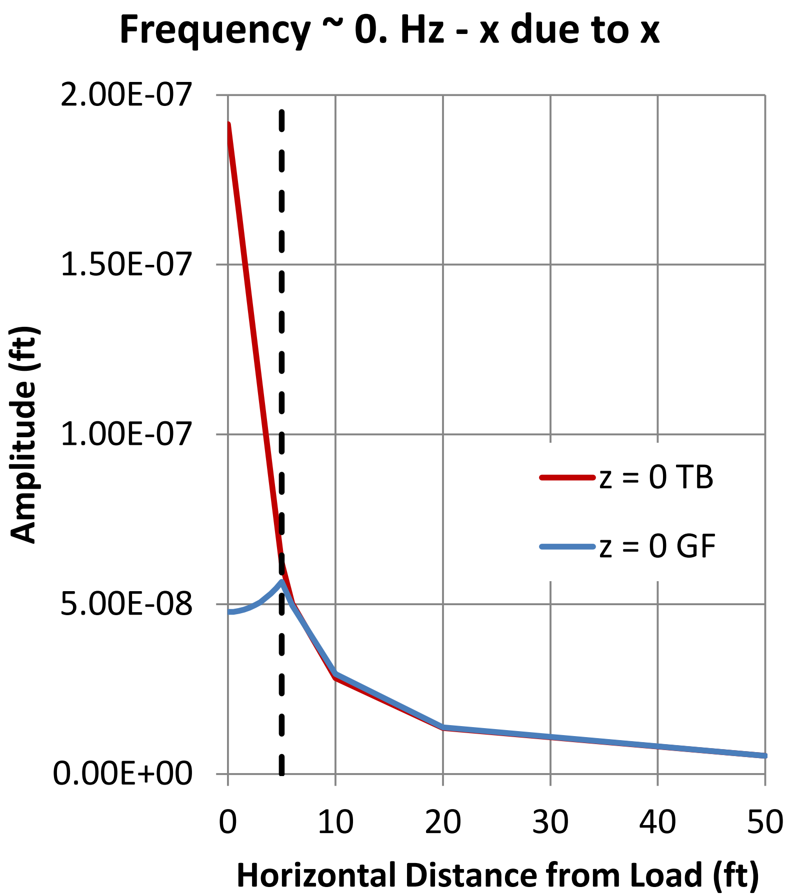
Static Displacements at Surface – GF

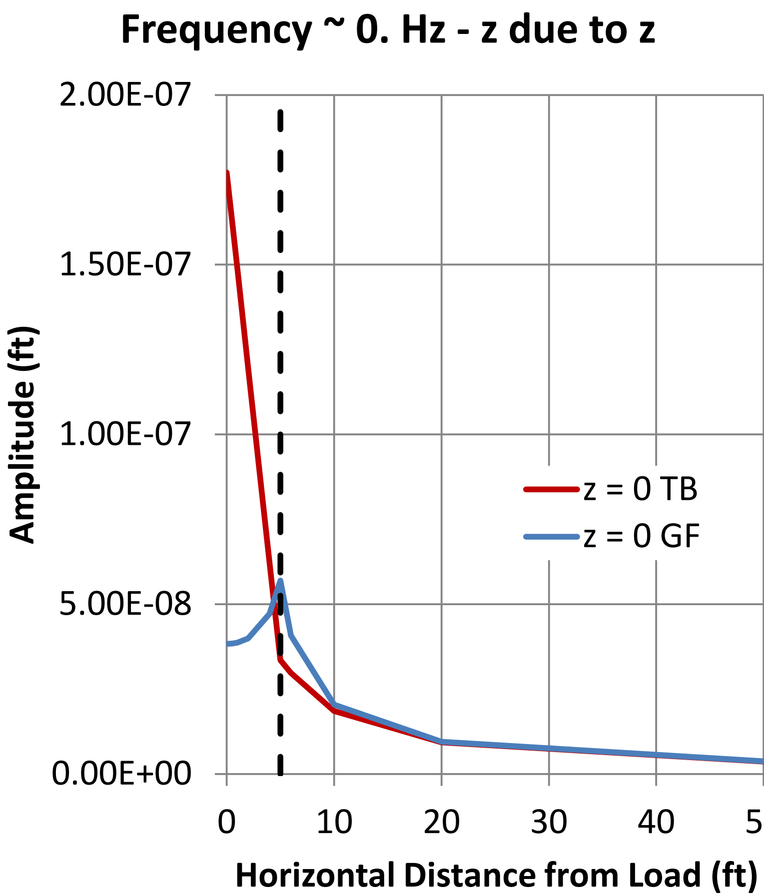
Investigate displacements under the load





Static Displacements at Surface – GF vs TB

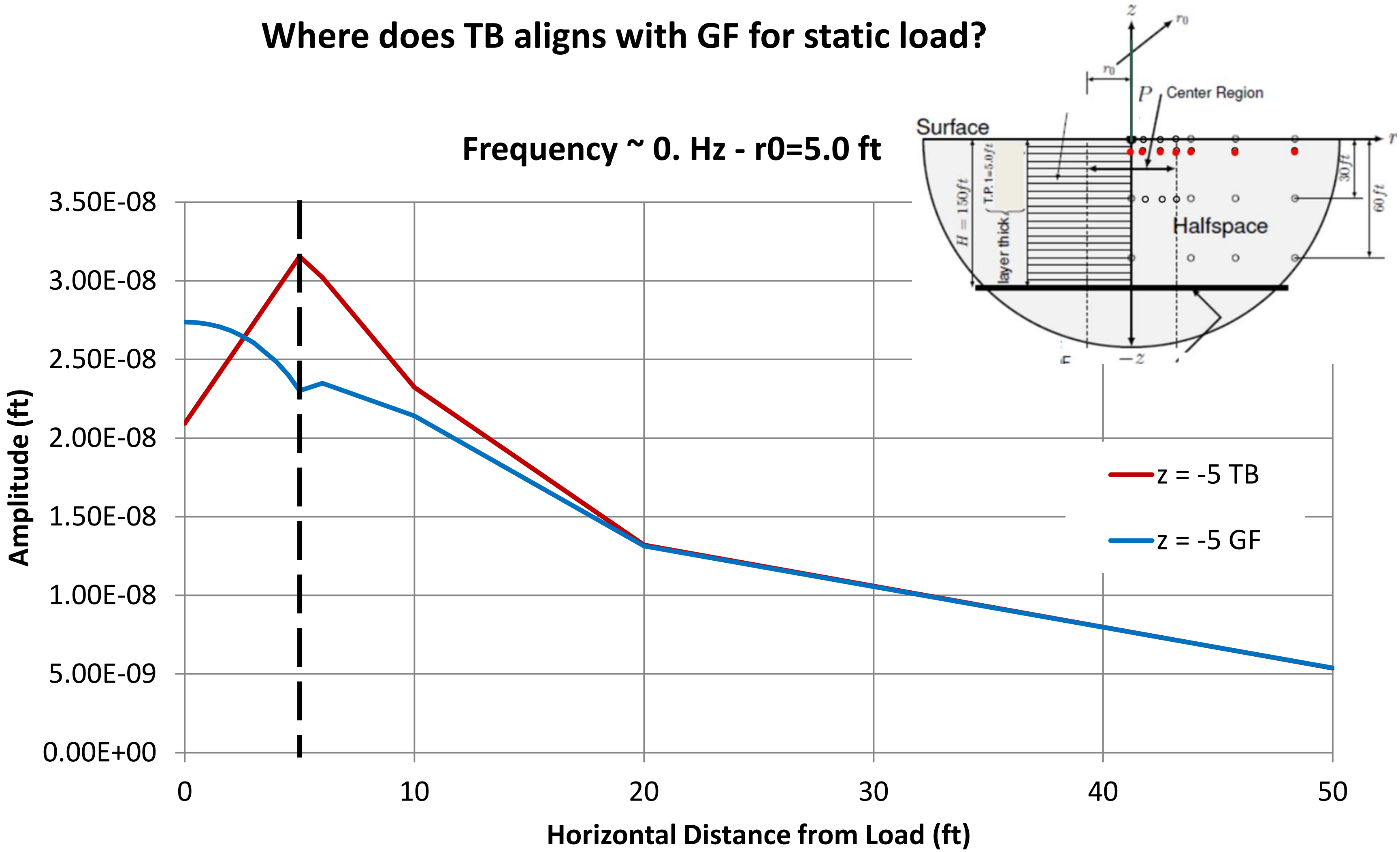




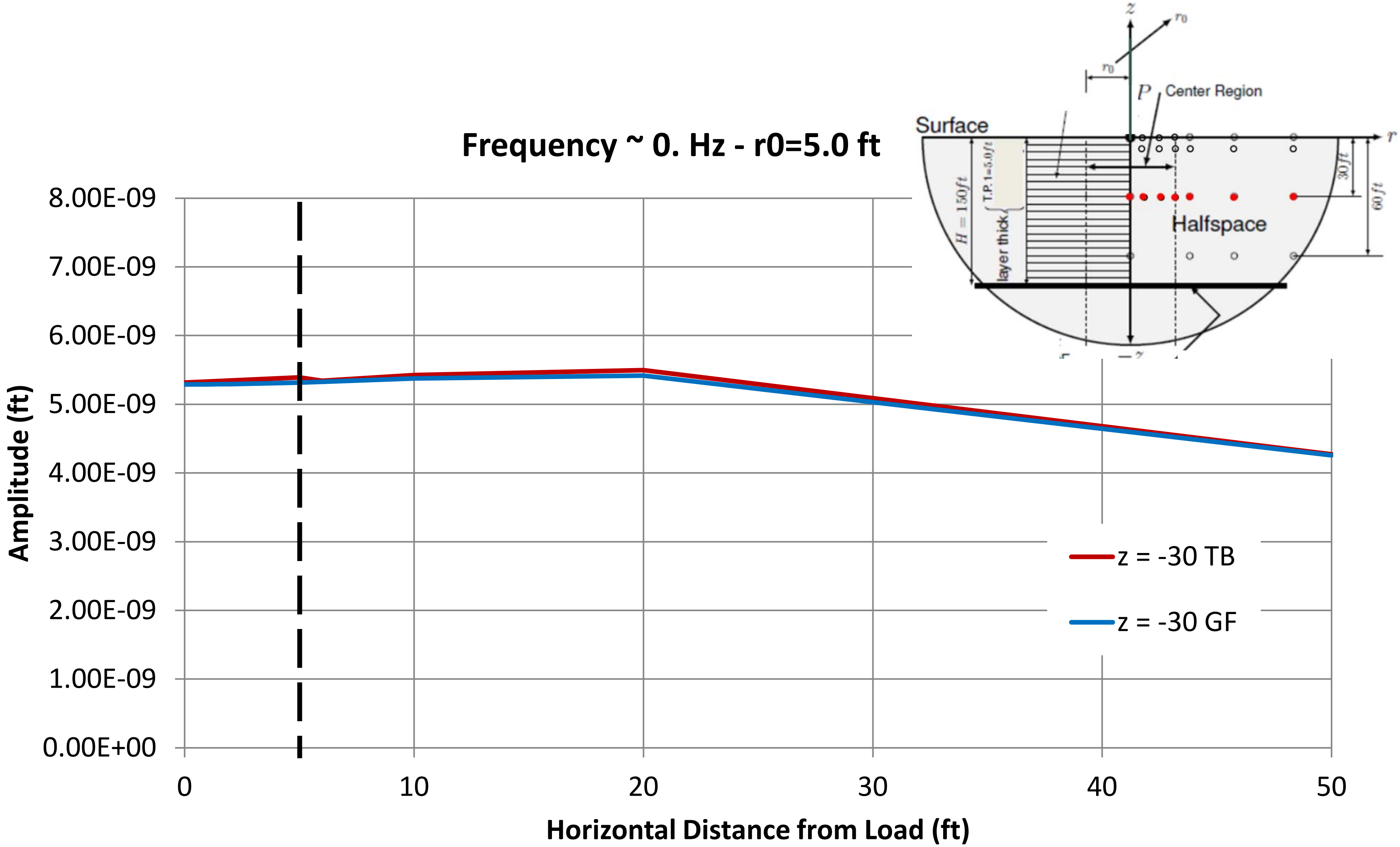
GF: Physically consistent within the loaded area (near field) and pile/soil load transfer

TB: (High amplitude) Pseudo-singularity under load: artificially high soil flexibility for piles

Static Displacements- x due to x– GF vs. TB



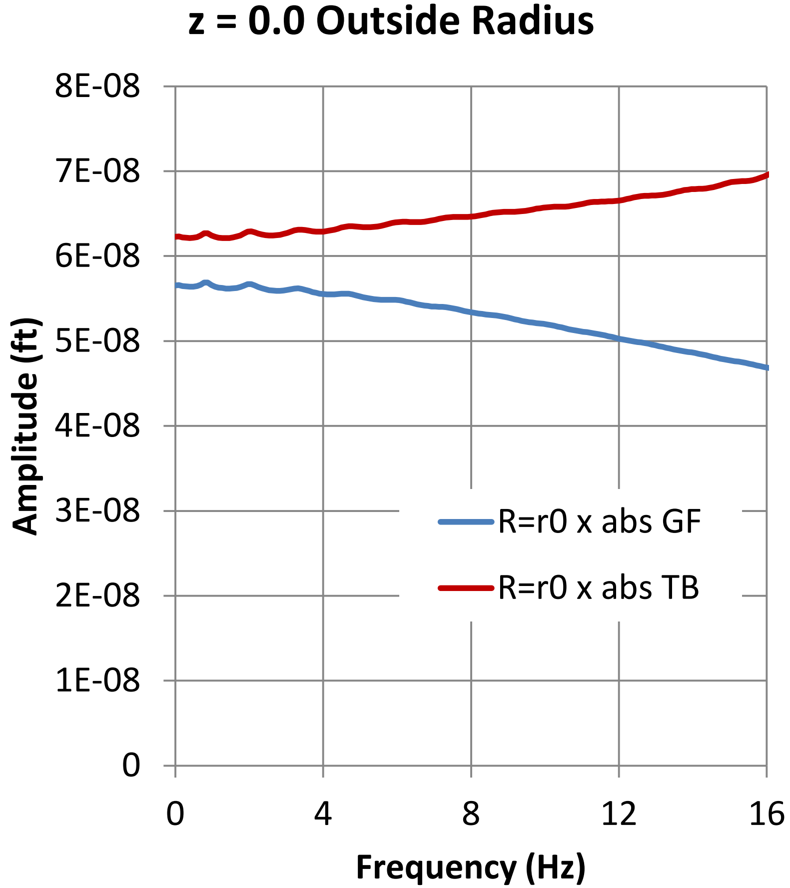
Static Displacements- x due to x– GF vs. TB

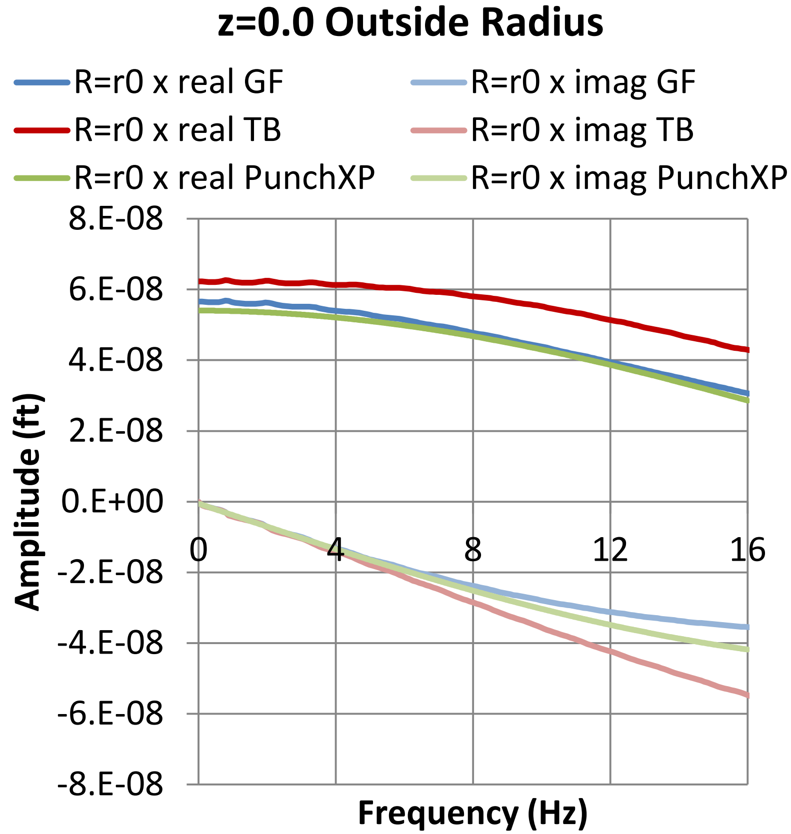


At depth from the load, static displacements TB aligns with GF

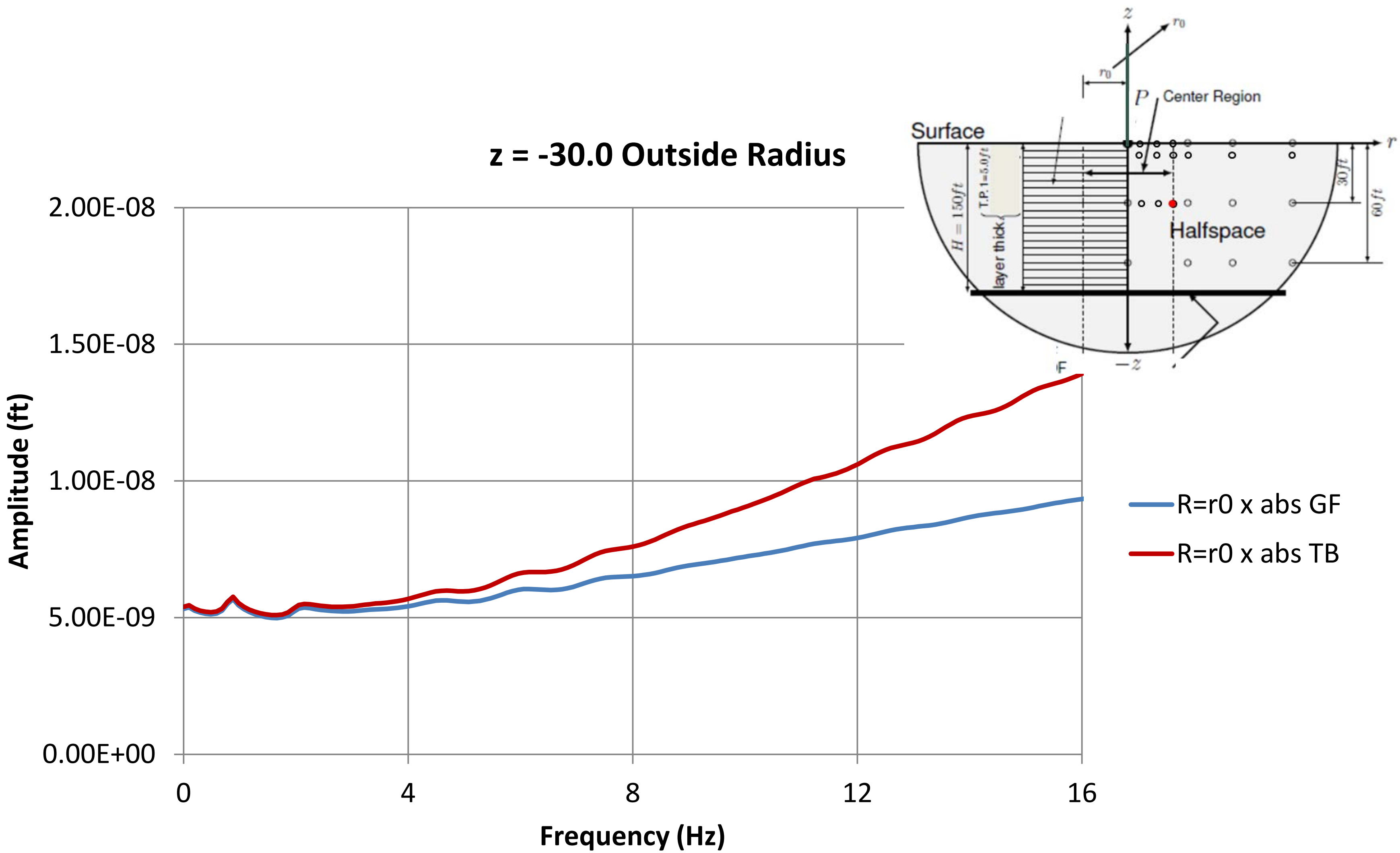
Transfer Functions-x due to x–GF vs. TB

Where does a Ring Load behave like a Point Load for dynamic load?

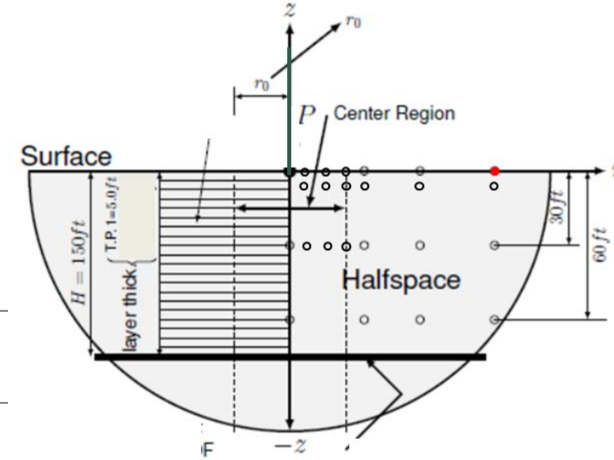


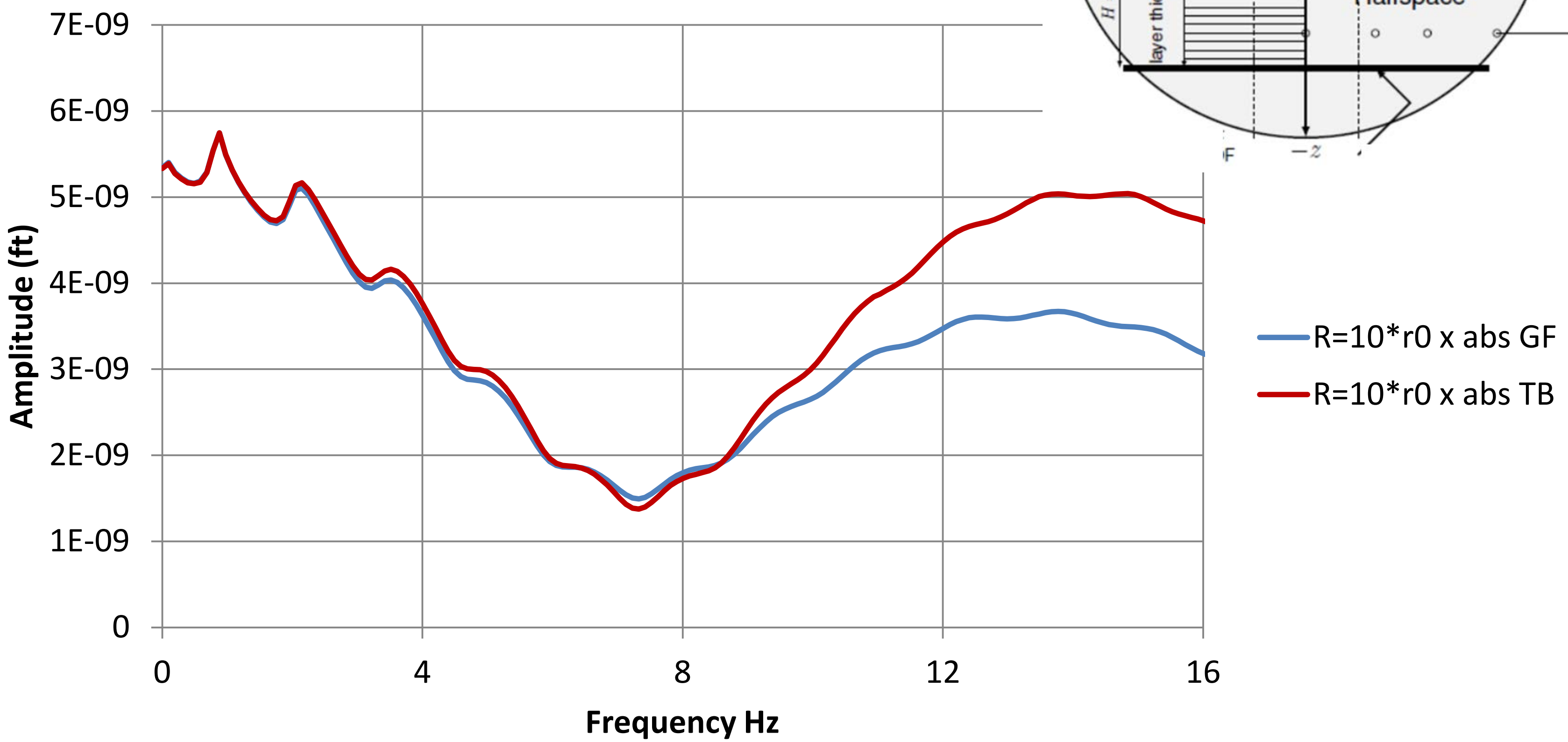


Transfer Functions -x due to x– GF vs. TB

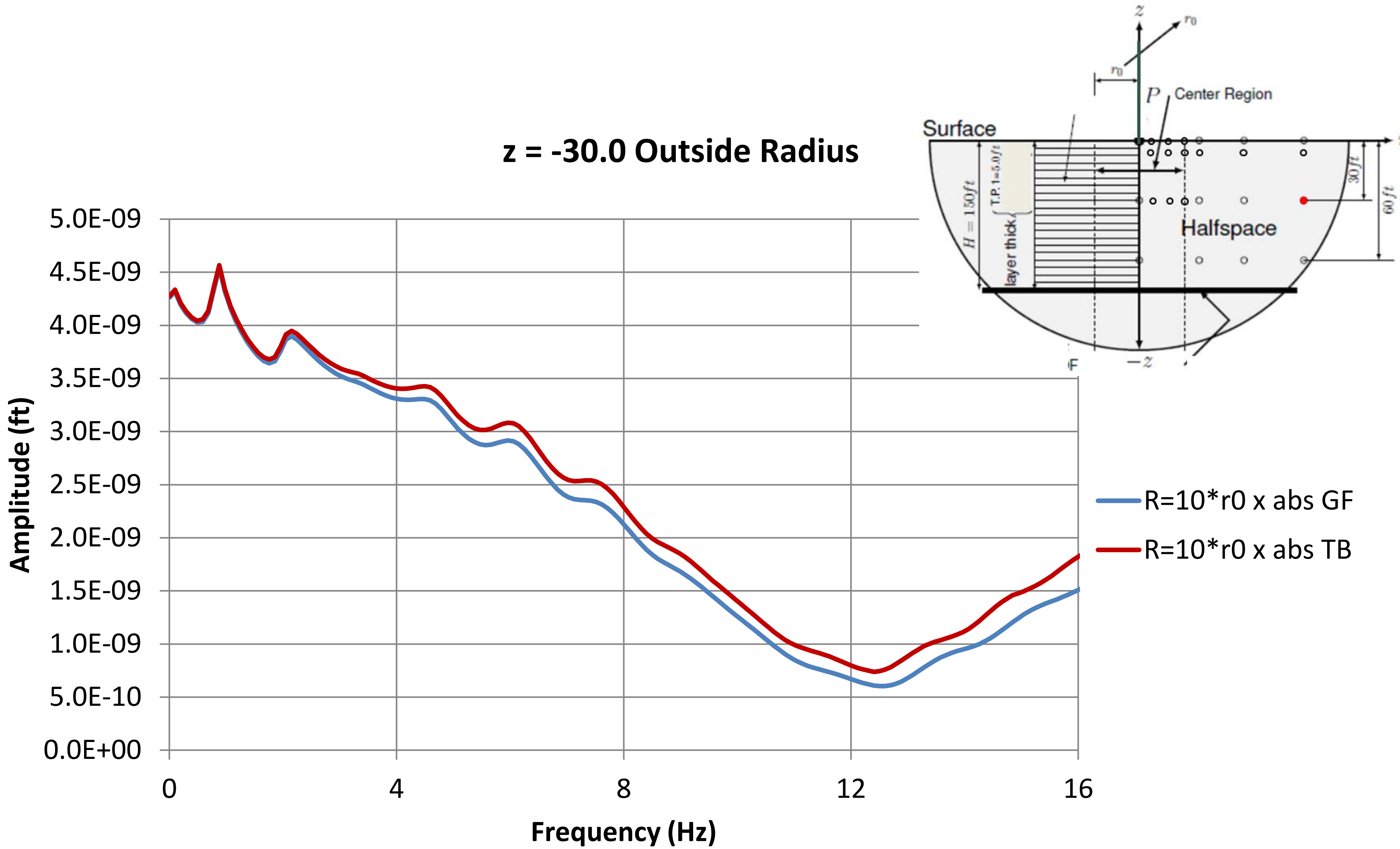


Transfer Functions-x due to x–GF vs. TB





Transfer Functions-x due to x–GF vs. TB

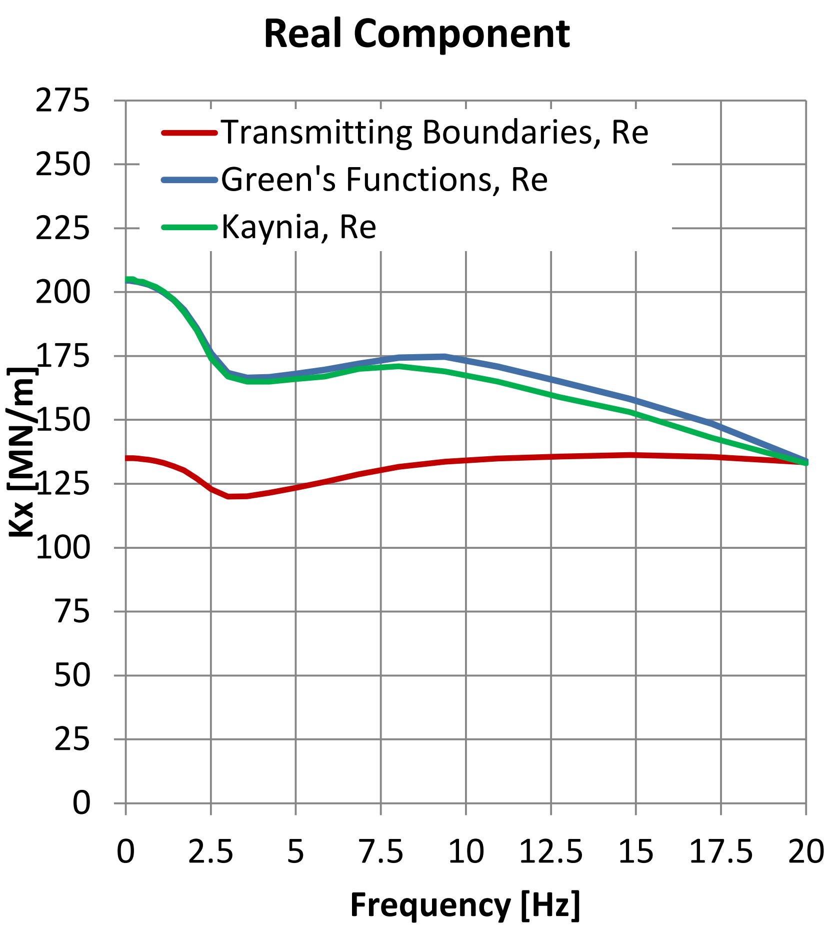


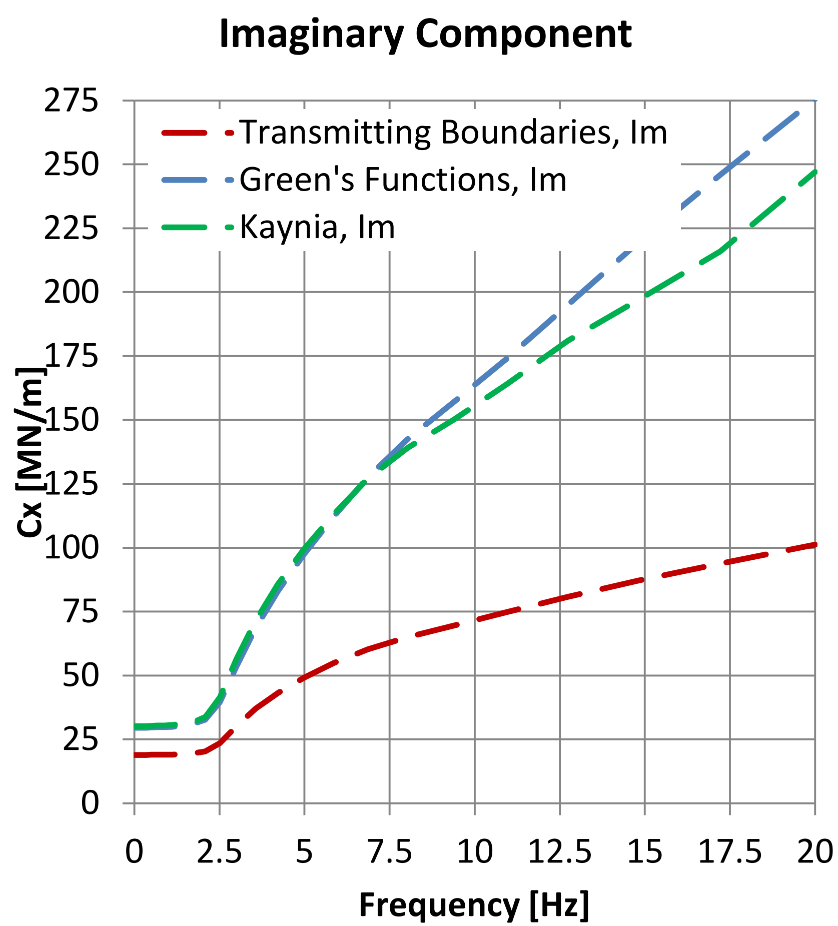
Ring Load behaves similarly to Point Load at distance and depth from the load

Ring/Disk Loads Green's Functions Implemented in SC-SASSI for pile simulations

Dynamic Stiffness of Piles with Green's Functions using SC-SASSI

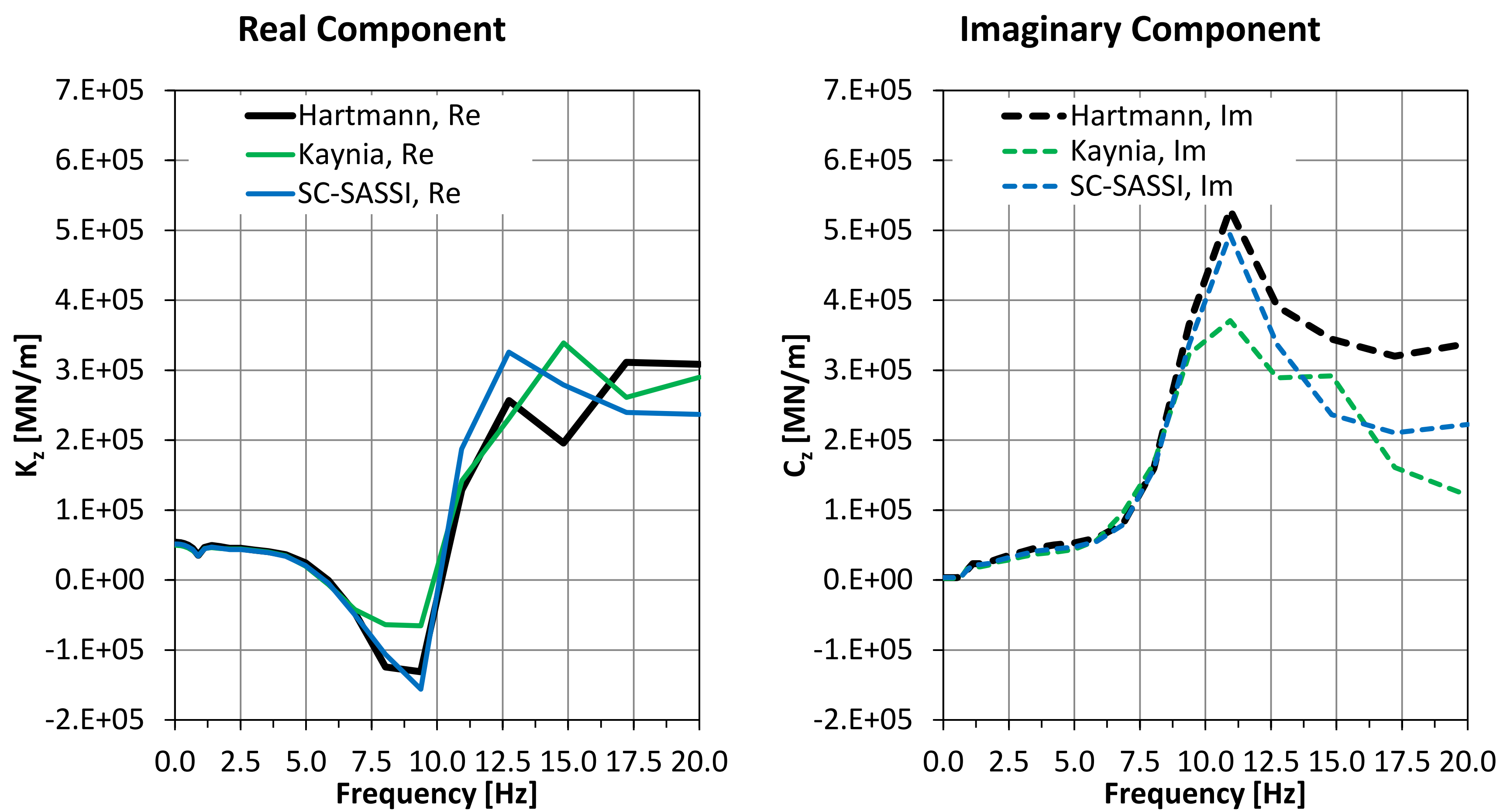
Dynamic Stiffness of Single Pile, Stratified Soil





Green's Functions: Realistic estimate of dynamic stiffness of pile

Dynamic Stiffness of Group with 430 Piles

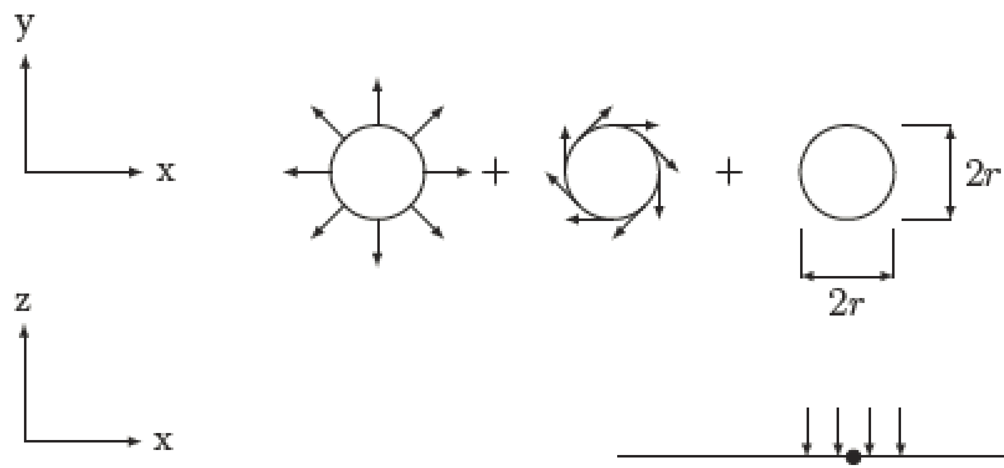


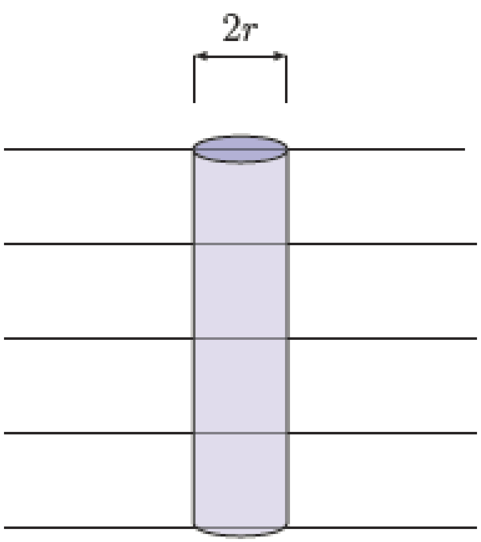
SC-SASSI PILE simulation (GF) compares well with other independent software tools

Summary and Conclusions

- Transmitting Boundary approach underestimates the Dynamic Stiffness of Piles
- Transmitting Boundary shows typical singularity (high displacement amplitude) for (concentrated) Point load formulation, inconsistent with load transfer from pile to soil.
- Green's Functions for Ring and Disk (distributed) Loads show consistent behavior in near field, provides a realistic estimation of soil flexibility for piles and confirmed a suitable approach to simulate pile foundations.
- Green's Functions implementation in SC-SASSI is computationally efficient to simulate pile foundations.

Thank you!





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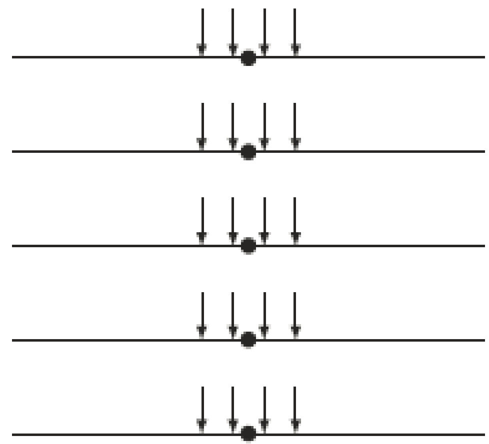
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