LRFD DESIGN OF PILES USING RSPILE SOFTWARE

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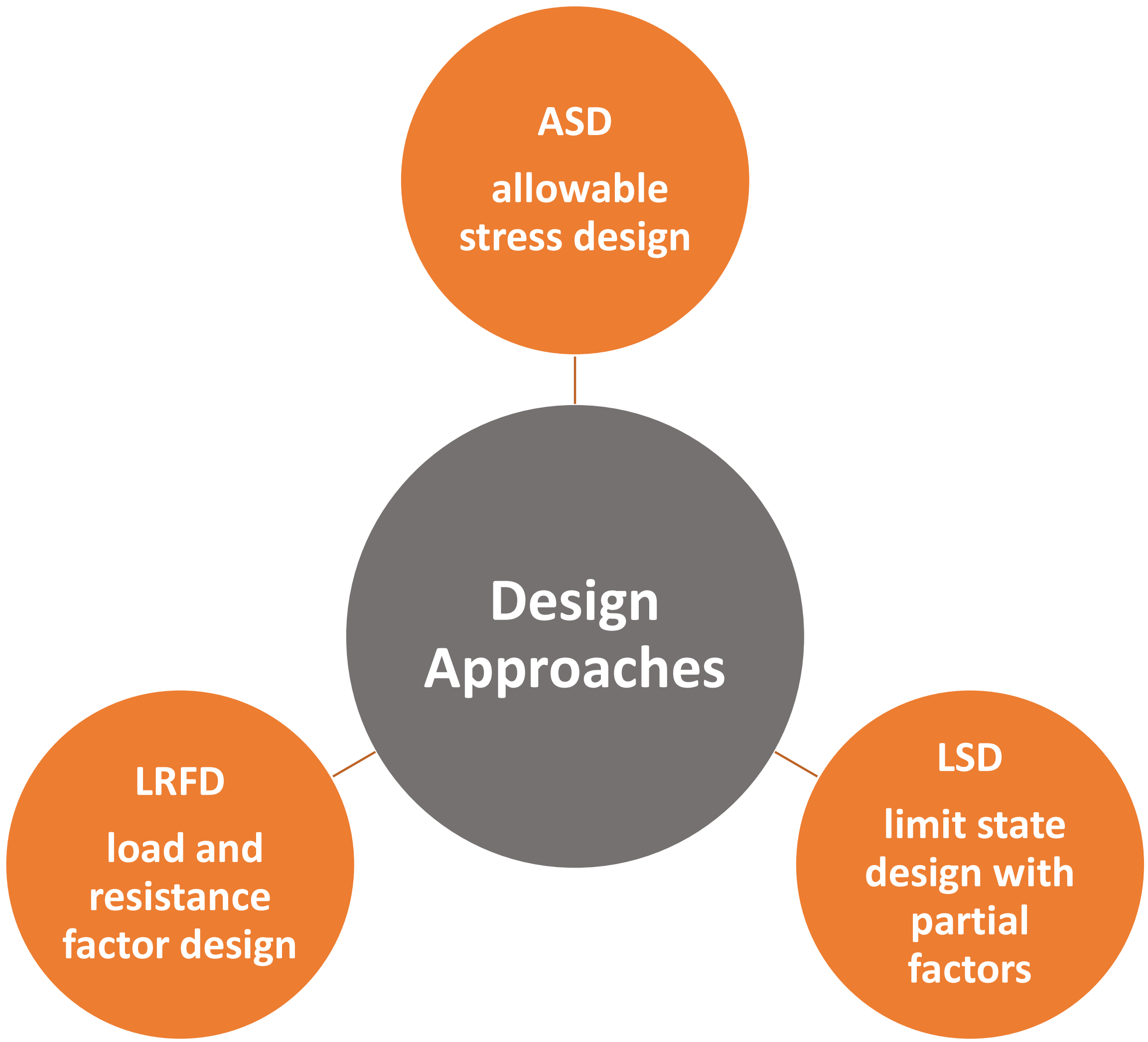
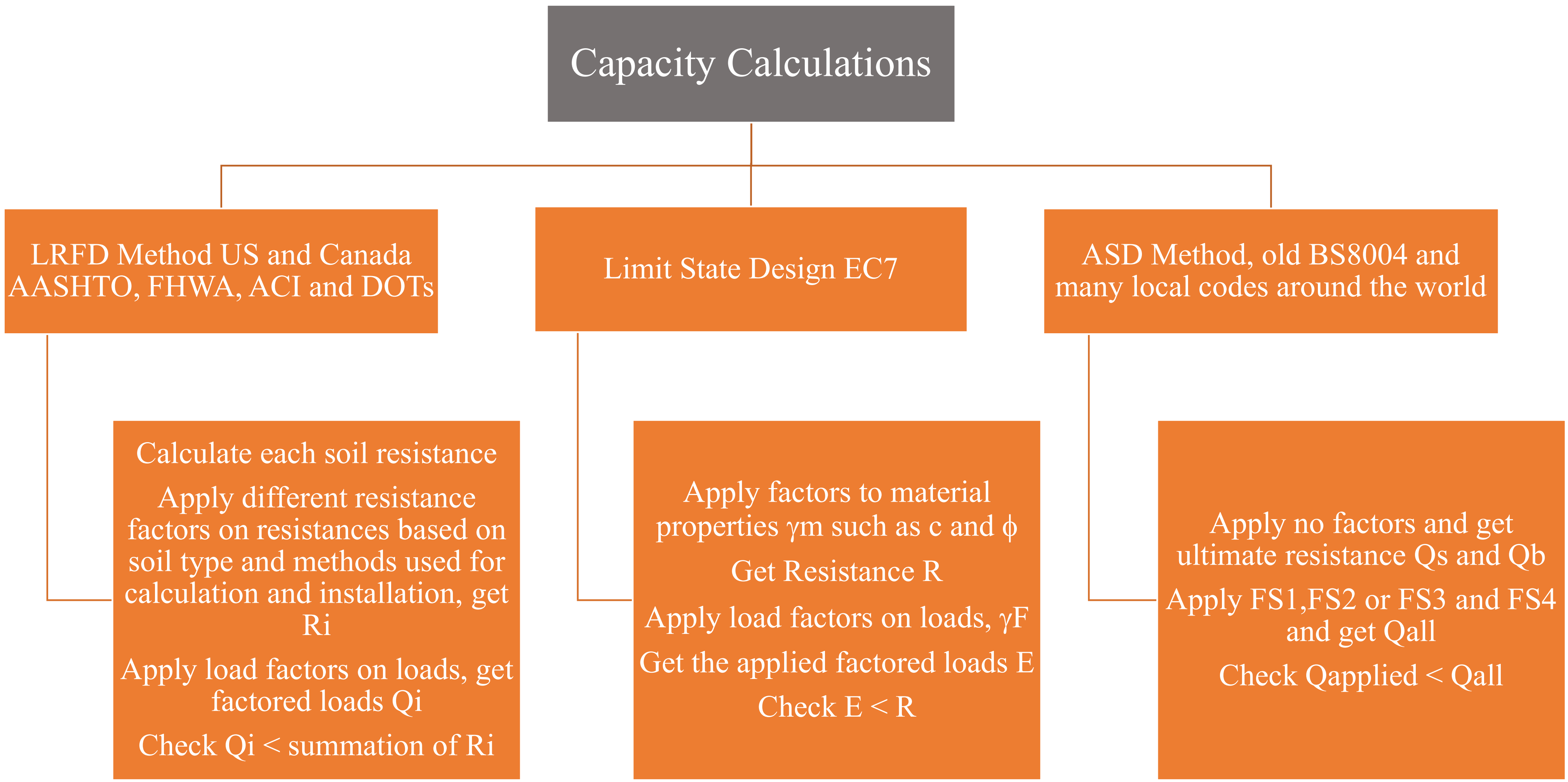
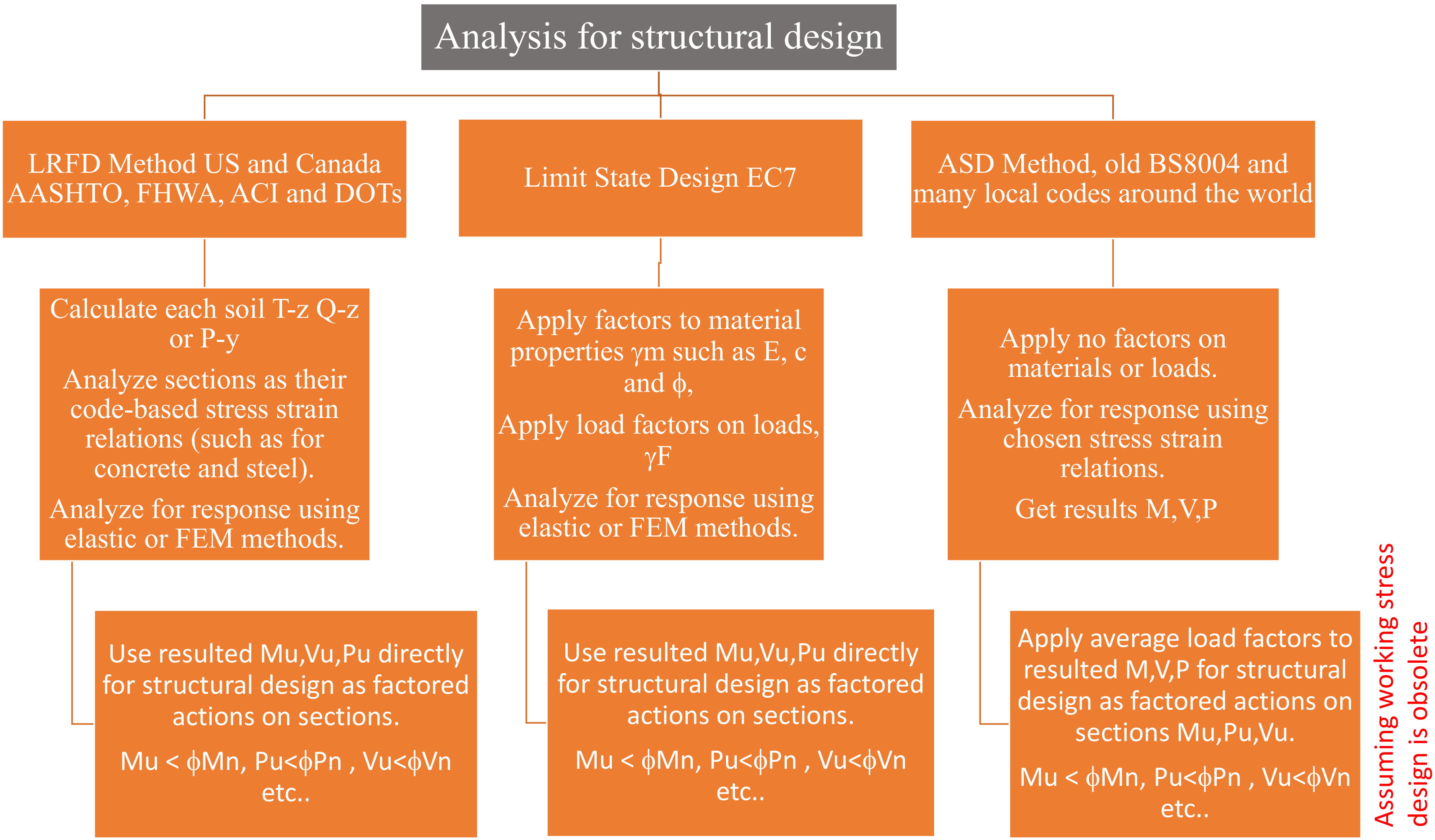
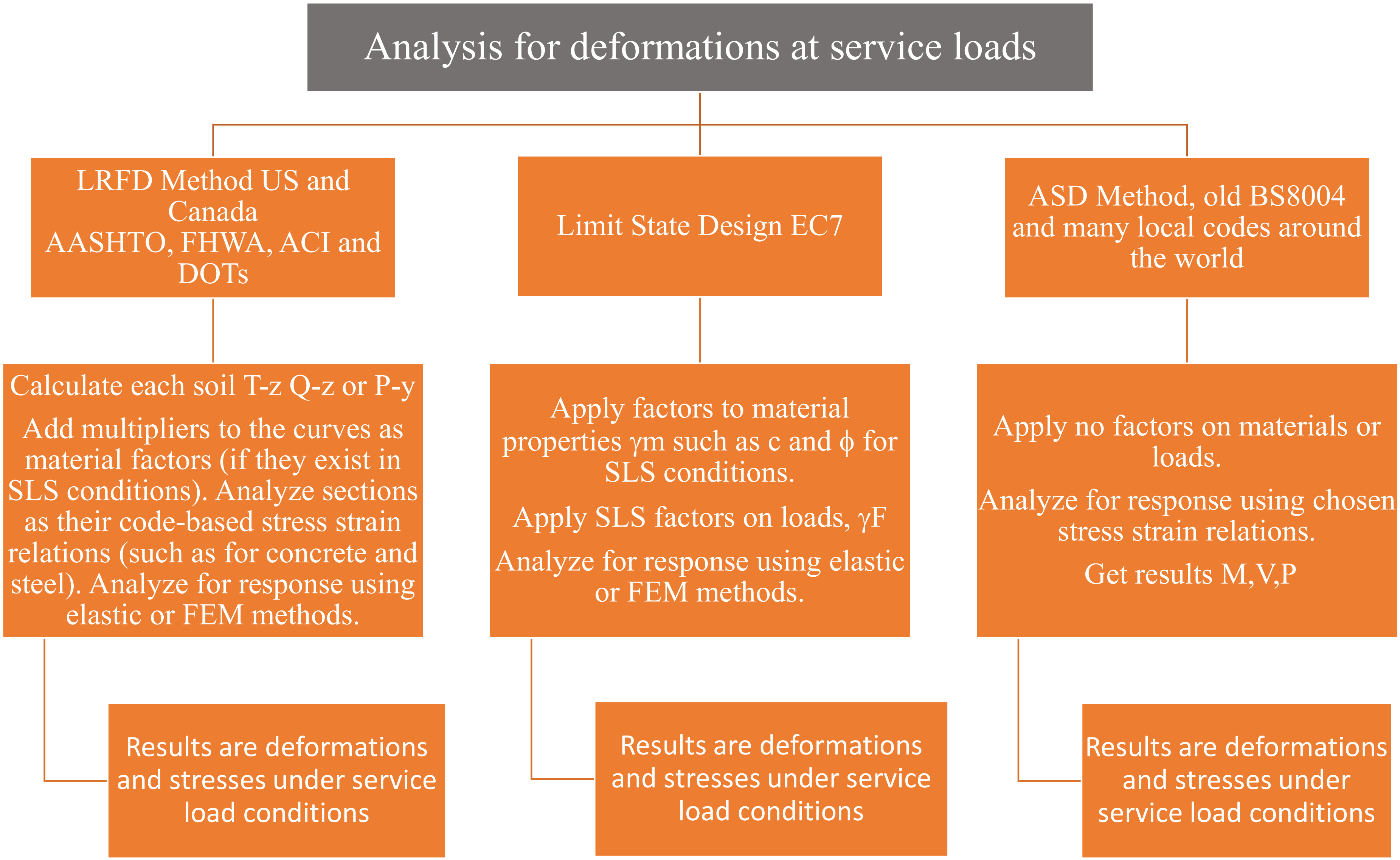
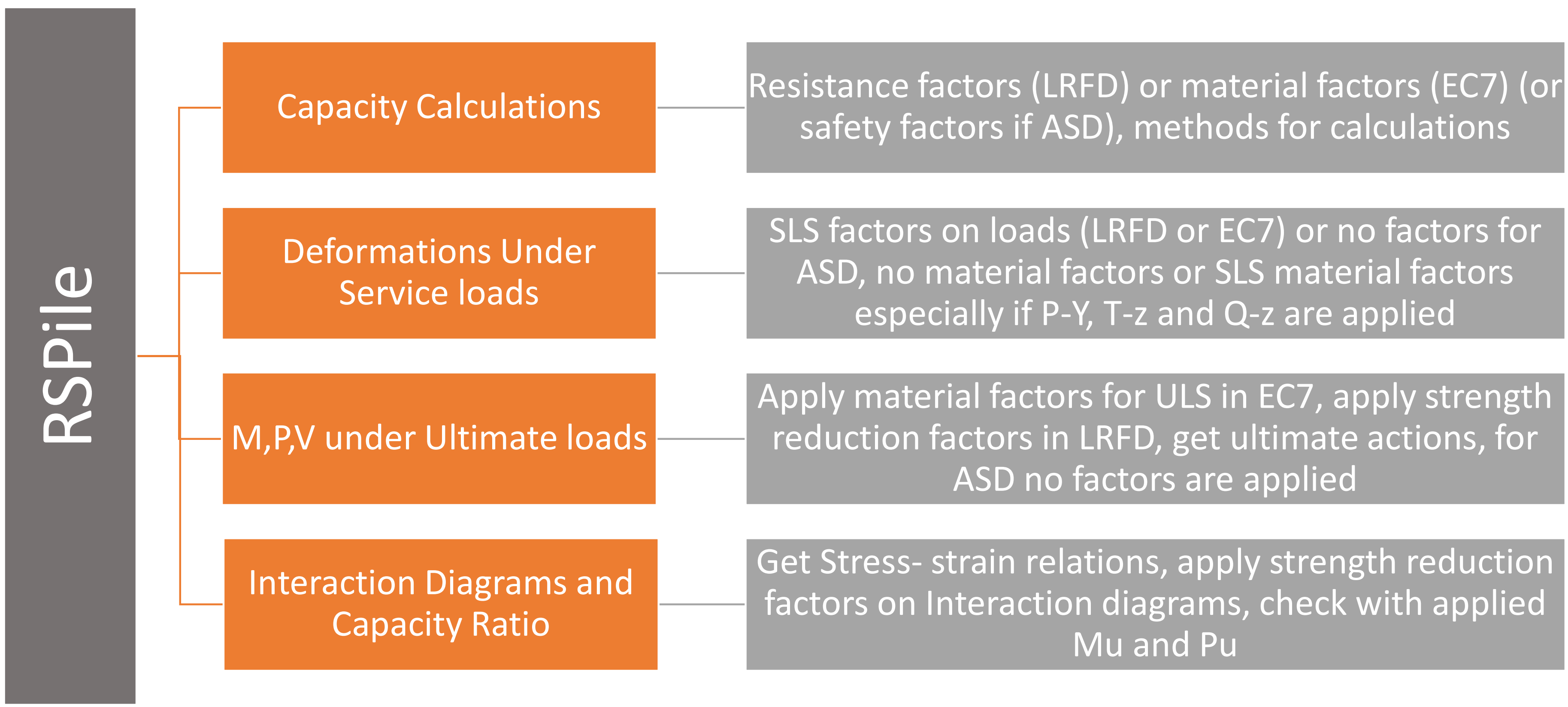

ASD
allowable stress design
Design Approaches
LRFD
load and resistance factor design
LSD
limit state design with partial factors


Capacity Calculations
LRFD Method US and Canada AASHTO, FHWA, ACI and DOTs
Limit State Design EC7
ASD Method, old BS8004 and many local codes around the world
Calculate each soil resistance
Apply different resistance factors on resistances based on soil type and methods used for calculation and installation, get Ri
Apply load factors on loads, get factored loads Qi
Check Qi < summation of Ri
Apply factors to material properties γm such as c and ϕ
Get Resistance R
Apply load factors on loads, γF
Get the applied factored loads E
Check E < R
Apply no factors and get ultimate resistance Qs and Qb
Apply FS1,FS2 or FS3 and FS4 and get Qall
Check Qapplied < Qall


Analysis for structural design
LRFD Method US and Canada AASHTO, FHWA, ACI and DOTs
Limit State Design EC7
ASD Method, old BS8004 and many local codes around the world
Calculate each soil T-z Q-z or P-y
Analyze sections as their code-based stress strain relations (such as for concrete and steel).
Analyze for response using elastic or FEM methods.
Apply factors to material properties γm such as E, c and ϕ,
Apply load factors on loads, γF
Analyze for response using elastic or FEM methods.
Apply no factors on materials or loads.
Analyze for response using chosen stress strain relations.
Get results M,V,P
Use resulted Mu,Vu,Pu directly for structural design as factored actions on sections.
Mu < ϕMn, Pu<ϕPn , Vu<ϕVn etc..
Use resulted Mu,Vu,Pu directly for structural design as factored actions on sections.
Mu < ϕMn, Pu<ϕPn , Vu<ϕVn etc..
Apply average load factors to resulted M,V,P for structural design as factored actions on sections Mu,Pu,Vu.
Mu < ϕMn, Pu<ϕPn , Vu<ϕVn etc..
Assuming working stress design is obsolete


Analysis for deformations at service loads
LRFD Method US and Canada AASHTO, FHWA, ACI and DOTs
Limit State Design EC7
ASD Method, old BS8004 and many local codes around the world
Calculate each soil T-z Q-z or P-y
Add multipliers to the curves as material factors (if they exist in SLS conditions). Analyze sections as their code-based stress strain relations (such as for concrete and steel). Analyze for response using elastic or FEM methods.
Apply factors to material properties γm such as c and ϕ for SLS conditions.
Apply SLS factors on loads, γF
Analyze for response using elastic or FEM methods.
Apply no factors on materials or loads.
Analyze for response using chosen stress strain relations.
Get results M,V,P
Results are deformations and stresses under service load conditions
Results are deformations and stresses under service load conditions
Results are deformations and stresses under service load conditions


RSPile
Capacity Calculations
Resistance factors (LRFD) or material factors (EC7) (or safety factors if ASD), methods for calculations
Deformations Under Service loads
SLS factors on loads (LRFD or EC7) or no factors for ASD, no material factors or SLS material factors especially if P-Y, T-z and Q-z are applied
M,P,V under Ultimate loads
Apply material factors for ULS in EC7, apply strength reduction factors in LRFD, get ultimate actions, for ASD no factors are applied
Interaction Diagrams and Capacity Ratio
Get Stress- strain relations, apply strength reduction factors on Interaction diagrams, check with applied Mu and Pu

$$\sum \eta_i \gamma_i Q_{ni} \leq \varphi R$$

$where$

γ_i *is a load factor for the load case i specified for the load case in the load combinateion of i cases*

Q_{ni} *is the nominal load of case i*

R *is the nominal resistance estimated by traditional theoretical, or empirical methods or from a load test*

φ *is a resistance factor specified by the local code of practice*

η_i *is a ductility factor that gives weight to different load cases*

$for\ groups$:

$$\sum \gamma_i Q_{ni} \leq \varphi \sum \eta R_j$$

Table 3.4.1-1—Load Combinations and Load Factors

										Use One of These at a Time				
Load Combination Limit State	*DC DD DW EH EV ES EL PS CR SH*	*LL IM CE BR PL LS*	*WA*	*WS*	*WL*	*FR*	*TU*	*TG*	*SE*	*EQ*	*BL*	*IC*	*CT*	*CV*
Strength I (unless noted)	γ_p	1.75	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength II	γ_p	1.35	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength III	γ_p	—	1.00	1.00	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength IV	γ_p	—	1.00	—	—	1.00	0.50/1.20	—	—	—	—	—	—	—
Strength V	γ_p	1.35	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Extreme Event I	1.00	γ_{EQ}	1.00	—	—	1.00	—	—	—	1.00	—	—	—	—
Extreme Event II	1.00	0.50	1.00	—	—	1.00	—	—	—	—	1.00	1.00	1.00	1.00
Service I	1.00	1.00	1.00	1.00	1.00	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service II	1.00	1.30	1.00	—	—	1.00	1.00/1.20	—	—	—	—	—	—	—
Service III	1.00	γ_{LL}	1.00	—	—	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service IV	1.00	—	1.00	1.00	—	1.00	1.00/1.20	—	1.00	—	—	—	—	—
Fatigue I—*LL*, *IM* & *CE* only	—	1.75	—	—	—	—	—	—	—	—	—	—	—	—
Fatigue II—*LL*, *IM* & *CE* only	—	0.80	—	—	—	—	—	—	—	—	—	—	—	—

Note: For Service I, the load factor for *EV* equals 1.2 for Stiffness Method Soil Failure as shown in Table 3.4.1-2.

Table 10.5.5.2.3-1—Resistance Factors for Driven Piles

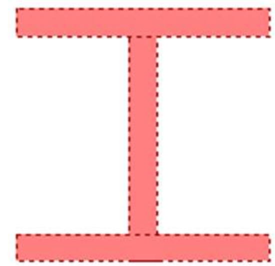
Condition/Resistance Determination Method		Resistance Factor
Nominal Bearing Resistance of Single Pile—Dynamic Analysis and Static Load Test Methods, φ_{dyn}	Driving criteria established by successful static load test of at least one pile per site condition and dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.80
	Driving criteria established by successful static load test of at least one pile per site condition without dynamic testing	0.75
	Driving criteria established by dynamic testing* conducted on 100% of production piles	0.75
	Driving criteria established by dynamic testing*, quality control by dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.65
	Wave equation analysis, without pile dynamic measurements or load test but with field confirmation of hammer performance	0.50
	FHWA-modified Gates dynamic pile formula (End of Drive condition only)	0.40
	Engineering News (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only)	0.10
Nominal Bearing Resistance of Single Pile—Static Analysis Methods, φ_{stat}	Side Resistance and End Bearing: Clay and Mixed Soils	
	α-method (Tomlinson, 1987; Skempton, 1951)	0.35
	β-method (Esrig & Kirby, 1979; Skempton, 1951)	0.25
	λ-method (Vijayvergiya & Focht, 1972; Skempton, 1951)	0.40
	Side Resistance and End Bearing: Sand	
	Nordlund/Thurman Method (Hannigan et al., 2005)	0.45
	SPT-method (Meyerhof)	0.30
	CPT-method (Schmertmann)	0.50
	End bearing in rock (Canadian Geotech. Society, 1985)	0.45
Block Failure, φ_{b1}	Clay	0.60
Uplift Resistance of Single Piles, φ_{up}	Nordlund Method	0.35
	α-method	0.25
	β-method	0.20
	λ-method	0.30
	SPT-method	0.25
	CPT-method	0.40
	Static load test	0.60
	Dynamic test with signal matching	0.50
Group Uplift Resistance, φ_{ug}	All soils	0.50
Lateral Geotechnical Resistance of Single Pile or Pile Group	All soils and rock	1.0
Structural Limit State	Steel piles	See the provisions of Article 6.5.4.2
	Concrete piles	See the provisions of Article 5.5.4.2
	Timber piles	See the provisions of Articles 8.5.2.2 and 8.5.2.3
Pile Drivability Analysis, φ_{da}	Steel piles	See the provisions of Article 6.5.4.2
	Concrete piles	See the provisions of Article 5.5.4.2
	Timber piles	See the provisions of Article 8.5.2.2
	In all three Articles identified above, use φ identified as "resistance during pile driving"	

*Dynamic testing requires signal matching, and best estimates of nominal resistance are made from a restrike. Dynamic tests are calibrated to the static load test, when available.

Table 10.5.5.2.4-1—Resistance Factors for Geotechnical Resistance of Drilled Shafts

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (Brown et al., 2010)	0.45
	Tip resistance in clay	Total Stress (Brown et al., 2010)	0.40
	Side resistance in sand	β-method (Brown et al., 2010)	0.55
	Tip resistance in sand	Brown et al. (2010)	0.50
	Side resistance in cohesive IGMs	Brown et al. (2010)	0.60
	Tip resistance in cohesive IGMs	Brown et al. (2010)	0.55
	Side resistance in rock	Kulhawy et al. (2005) Brown et al. (2010)	0.55
	Side resistance in rock	Carter and Kulhawy (1988)	0.50
	Tip resistance in rock	Canadian Geotechnical Society (1985) Pressuremeter Method (Canadian Geotechnical Society, 1985) Brown et al. (2010)	0.50
Block Failure, φ_{b1}	Clay		0.55
Uplift Resistance of Single-Drilled Shafts, φ_{up}	Clay	α-method (Brown et al., 2010)	0.35
	Sand	β-method (Brown et al., 2010)	0.45
	Rock	Kulhawy et al. (2005) Brown et al. (2010)	0.40
Group Uplift Resistance, φ_{ug}	Sand and clay		0.45
Horizontal Geotechnical Resistance of Single Shaft or Shaft Group	All materials		1.0
Static Load Test (compression), φ_{load}	All Materials		0.70
Static Load Test (uplift), φ_{upload}	All Materials		0.60

Layer	Thickness	γ_{sat} (pcf)	γ' (pcf)	N	$(N_1)_{60}$	E_s (ksf)	ϕ'	s_u (psf)	k_c (lb/in³)	ε_{50}
1. Loose Silty Fine Sand (SM)	5 ft 15 ft 10 ft	105	42.6	6	9	126	33	--	25 20	--
2. Medium Dense Coarse Sand Little Silt (SP)	25 ft	112	49.6	14	17	340	36	--	60	--
3. Dense Gravel with Sand (GW) (Occasional Cobbles)	47 ft	125	62.6	66	59	1416	40*	--	125	--
4. Limestone Bedrock		REC: 83% RQD: 81%								



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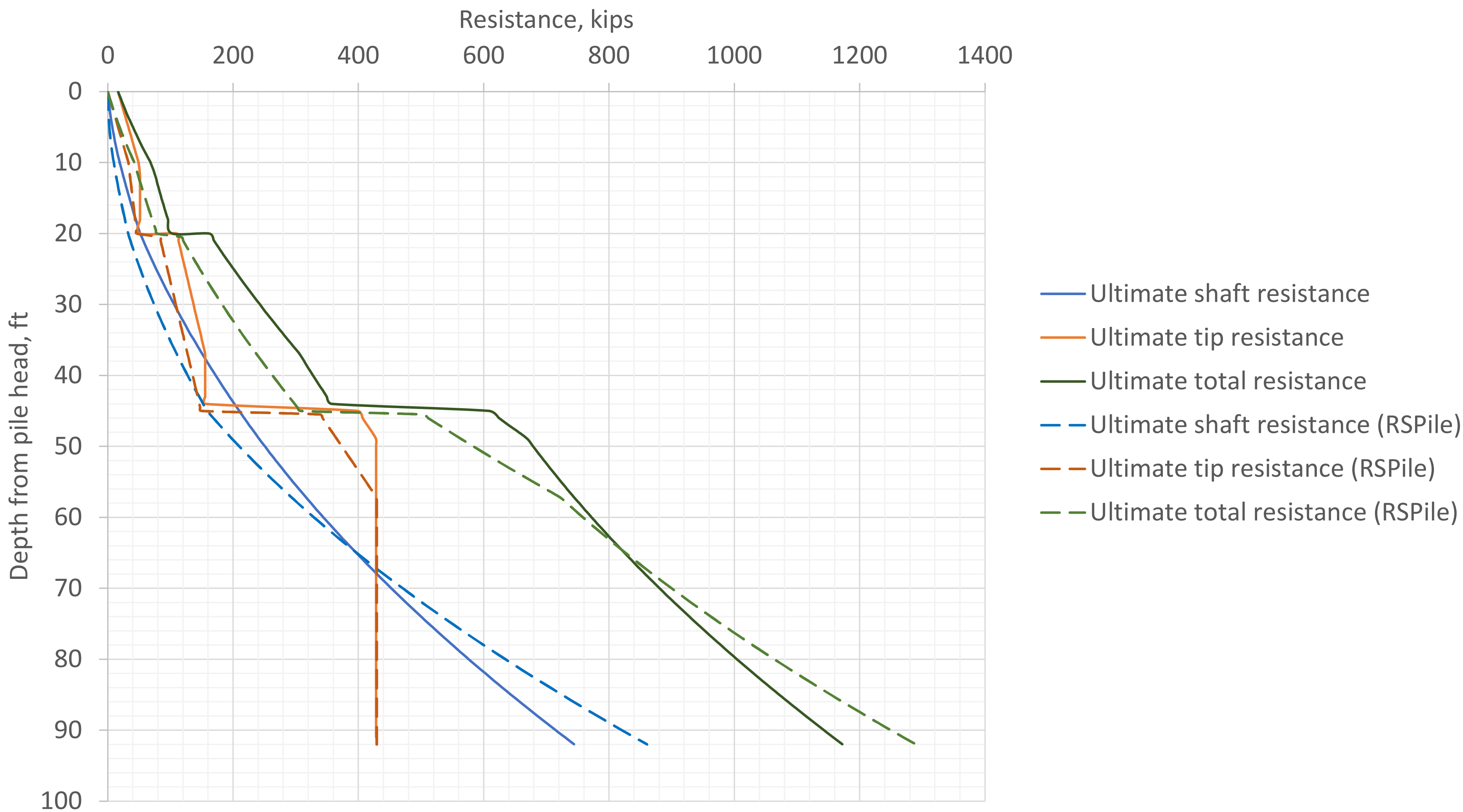
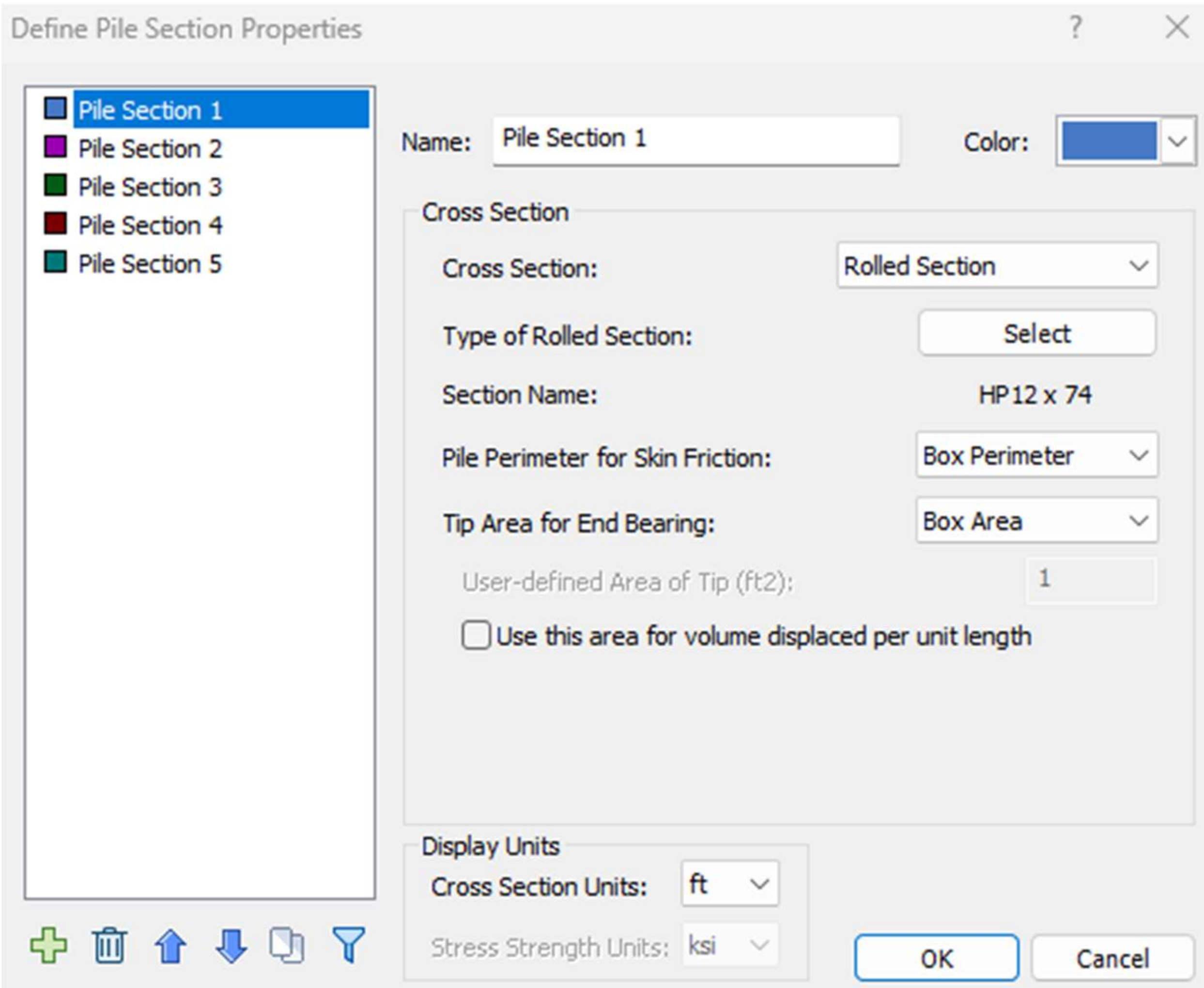
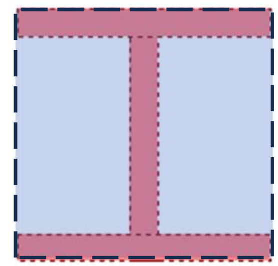


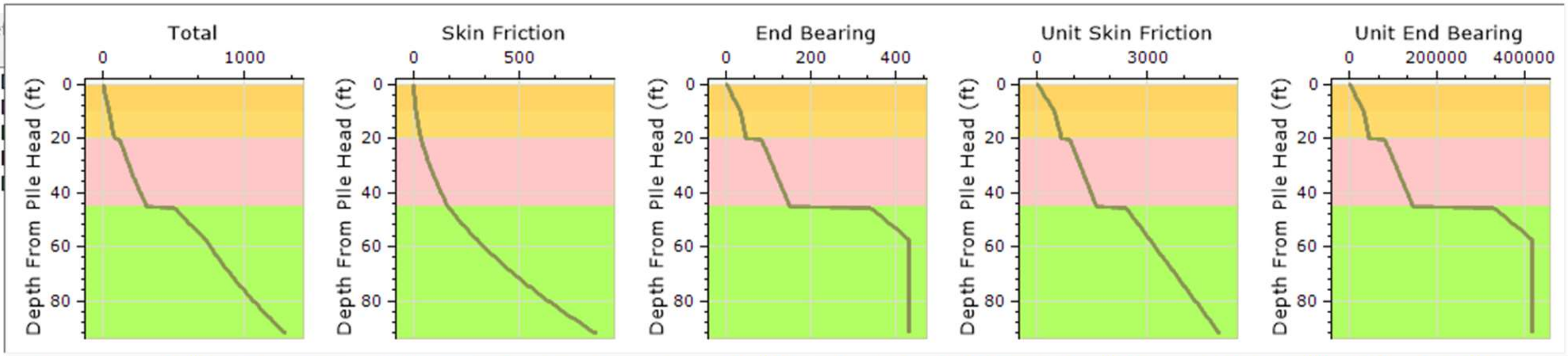
Resistance, kips
0
200
400
600
800
1000
1200
1400
Depth from pile head, ft
0
10
20
30
40
50
60
70
80
90
100
Ultimate shaft resistance
Ultimate tip resistance
Ultimate total resistance
Ultimate shaft resistance (RSPile)
Ultimate tip resistance (RSPile)
Ultimate total resistance (RSPile)



Area?



Perimeter?



Ultimate (Total) (kips)	(Skin Friction)	Driving (Skin Friction) (kips)	(Skin Friction)	(End Bearing)	Driving (End Bearing) (kips)	(End Bearing)	(Unit Skin Friction)	Skin Friction)	(Unit Skin Friction)	(Unit End Bearing)	End Bearing)	(Unit End Bearing)
1230.194	801.010	801.010	801.010	429.184	429.184	429.184	4811.759	4811.759	4811.759	417600.251	417600.251	417600.251
1239.978	810.794	810.794	810.794	429.184	429.184	429.184	4839.291	4839.291	4839.291	417600.251	417600.251	417600.251
1249.818	820.634	820.634	820.634	429.184	429.184	429.184	4866.822	4866.822	4866.822	417600.251	417600.251	417600.251
1259.714	830.529	830.529	830.529	429.184	429.184	429.184	4894.354	4894.354	4894.354	417600.251	417600.251	417600.251
1269.666	840.481	840.481	840.481	429.184	429.184	429.184	4921.885	4921.885	4921.885	417600.251	417600.251	417600.251
1279.673	850.489	850.489	850.489	429.184	429.184	429.184	4949.417	4949.417	4949.417	417600.251	417600.251	417600.251
1289.736	860.552	860.552	860.552	429.184	429.184	429.184	4976.948	4976.948	4976.948	417600.251	417600.251	417600.251

Total | Skin Friction | End Bearing | Unit Skin Friction | Unit End Bearing | **Combined Driven Results** | +

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*Dynamic testing requires signal matching, and best estimates of nominal resistance are made from a restrike. Dynamic tests are calibrated to the static load test, when available.

1/0.45= 2.22= old FS

$$\varphi R = 0.45 * 1289.74 = 580.4 \text{ kips to be compared with} \sum \gamma_i Q_{ni} \leq \varphi R$$

Thank You