PDCA Driven-Pile Terms and Definitions

This document is available for free download at *piledrivers.org*. Preferred terms are descriptively defined. Potentially synonymous (but not preferred) terms are identified with the nomenclature "same as **Preferred Term**."

Allowable Stress Design ("ASD") – A design method in which stresses caused by design loads are not permitted to exceed a percentage of the elastic limit of the components.

Batter(ed) pile – Same as **Inclined pile**.

Beginning of restrike ("BOR") – The first representative restrike hammer blow.

Blow count – A measure of the effort required to advance a pile, quantified as the number of hammer impacts required for the pile to penetrate a certain distance, having units of blows per length; can be derived from **Set**.

- **Equivalent blow count** – A blow count measured over one penetration length and then converted to another penetration length (e.g., 10 blows per inch converts to an equivalent blow count of 120 blows per foot; 10 blows per 25 mm converts to an equivalent blow count of 120 blows per 300 mm).

Boot plate – Same as **Toe plate**.

Capacity (ASD) – The maximum (ultimate) load capable of being resisted. It is the lesser of the geotechnical or structural capacity. Comparable LRFD term: **Resistance, nominal**.

- **Assigned capacity** – The capacity determined from a load test; it depends on the type of load test, and the method of data interpretation. It is the lesser of the geotechnical or structural capacity.
- **Bearing capacity** – Same as **Compression capacity**.
- **Compression capacity** – The maximum (ultimate) compression (downward) load capable of being resisted. It is the lesser of the geotechnical or structural capacity.
- **Geotechnical capacity** – The maximum (ultimate) load capable of being resisted by soil and/or rock.
- **Initial capacity** – The maximum (ultimate) load capable of being resisted immediately at end of initial drive. It is the lesser of the geotechnical or structural capacity.
- **Lateral capacity** – The maximum (ultimate) lateral (horizontal) load capable of being resisted. It is the lesser of the geotechnical or structural capacity.
- **Long-term capacity** – The maximum (ultimate) load capable of being resisted at some specific time after end of initial drive. It is the lesser of the geotechnical or structural capacity. It may be more (e.g., geotechnical: set-up; structural: concrete fill), or less (e.g., geotechnical: relaxation; structural: corrosion, deterioration) than the initial capacity.
- **Shaft capacity** – The maximum (ultimate) load capable of being resisted by a pile's shaft.
- **Structural capacity** – The maximum (ultimate) load capable of being applied to a pile that does not exceed its nominal material strength or buckling limit.
- **Tension capacity** – The maximum (ultimate) tension (upward) load capable of being resisted. It is the lesser of the geotechnical or structural capacity.

Toe capacity – The maximum (ultimate) load capable of being resisted by a pile's toe.

Ultimate capacity – same as **Capacity**.

Uplift capacity – same as **Tension Capacity**.

Usable geotechnical capacity – The maximum (ultimate) load capable of being continuously resisted (long-term) by soil and/or rock resistance. It may be more (e.g., set-up), or less (e.g., liquefaction, relaxation, scour) than the initial geotechnical capacity.

Usable structural capacity – The maximum (ultimate) load capable of being continuously applied (long-term) to a pile that does not exceed its nominal material strength or buckling limit. It may be more (e.g. concrete fill), or less (e.g. corrosion, deterioration) than the initial structural capacity.

Cushion – Material(s) used to dampen and more-evenly distribute forces due to impact.

Hammer cushion – Material(s) placed in a pile-driving helmet.

Pile cushion – Material(s) placed on a concrete pile head to reduce pile stresses.

Downdrag – 1. Downward movement of soil relative to a pile. 2. Pile settlement due to drag force.

Drag force – Load transferred to a pile at some location above the neutral plane due to downward movement of soil relative to the pile.

Maximum drag force – The cumulative drag force transferred to a pile from the pile head to the neutral plane.

Dragload – same as **Drag force**.

Driving stress, allowable – The maximum stress which is permitted to occur anywhere in the pile during driving, determined as the pile nominal material stress multiplied by a reduction factor.

Driving stress, maximum – The maximum stress occurring anywhere in the pile during driving. It should be less than or equal to the allowable driving stress.

Dynamic method of analysis – Evaluating capacity, impact force, integrity, transferred energy, etc. by simplified equations using the measured strains and accelerations induced by high-strain impacts on a pile.

Dynamic monitoring – Recording impact-induced strain and acceleration in a pile (e.g., during driving), with the data presented in terms of stress and transferred energy in the pile, as well as capacity estimates.

Elastic shortening – Downward pile movement resulting from compression of the pile material under compression (downward) loading. The head movement will be larger than the toe movement.

Elastic lengthening – Upward pile movement resulting from elongation of the pile material under tension (upward) loading. The head movement will be larger than the toe movement.

Embedment length – The length a pile penetrates into geomaterials.

Estimated embedment length – The length it is estimated a pile will penetrate into geomaterials, generally for bidding purposes only.

Design minimum embedment length – The minimum length into geomaterials a pile must penetrate to satisfy design requirements (e.g., lateral concerns, liquefaction, scour, settlement control, tension) before other termination criterion or criteria are applied.

End of initial drive ("EOID") – The last full blow of pile installation.

Follower – A structural section placed between the hammer and the pile during driving.

Foundation – A structural system which transfers loads to geomaterial.

Foundation unit, deep – A structural unit which transfers the majority of its load or stress to geomaterial at a depth (or depths) considerably larger than the unit's width.

Geomaterial – Material (native or fill) through which a pile penetrates, or on which a pile terminates. Water is not a geomaterial.

Impact force – The force at the time of the first velocity peak, delivered by a pile driving hammer to the pile head; it can be measured by dynamic monitoring.

Inclined pile – A pile driven at an angle to the vertical.

Load – Force applied to a pile.

- **Allowable load** (ASD) – The lesser of the allowable geotechnical load or the allowable structural load.
  - **Allowable geotechnical load** (ASD) – The maximum permissible pile load, generally determined as the usable geotechnical capacity divided by a safety factor. For lateral loads, it is generally determined as the load corresponding to a maximum allowable deflection.
  - **Allowable structural load** (ASD) – The maximum permissible pile load, determined as the usable structural capacity multiplied by a reduction factor.
- **Applied load** – The load actually acting on a pile.
- **Design load** (ASD) – The maximum load calculated to be applied to a pile based on expected loading conditions (dead, live, soil, wind, snow, rain, flood, and earthquake) and foundation geometry; it is not permitted to exceed the allowable geotechnical load or the allowable structural load. Corresponding LRFD term: **Load, nominal**.
- **Factored load** (LRFD) – The sum of nominal loads from different load sources multiplied by their applicable load factors.
- **Nominal load** (LRFD) – The maximum load calculated to be applied to a pile based on expected loading conditions (dead, live, soil, wind, snow, rain, flood, and earthquake) and foundation geometry.
- **Service load** – same as **Load, applied**.
- **Sustained load** – A load whose application duration is longer than the surrounding soil requires to consolidate/settle (e.g., dead load or long-term "live" load such as furnishings or tank contents).
- **Transient load** – A load whose application duration is shorter than the surrounding soil requires to consolidate/settle (e.g., live load such as wind, impact, or traffic).

Load and Resistance Factor Design ("LRFD") – A reliability-based design method in which force effects caused by factored loads are not permitted to exceed the factored resistance of the components.

Load Factor – A multiplier applied to force effects accounting primarily for the variability of loads, analysis inaccuracy, and the probability of simultaneous occurrence of different loads.

Load test – A procedure during which load is applied to the pile.

- **Dynamic load test** – A procedure during which one or more impact loads are applied to a pile, while measuring strain and acceleration, for the purpose of evaluating pile resistance.

Rapid load test – A procedure during which a force pulse (with a duration between 10 and 1000 times the ratio of the length of the pile and the wave speed) is applied to the pile, while measuring load and displacement, for the purpose of evaluating pile resistance.

Static load test – A procedure during which measured loads are applied relatively slowly to a pile, while measuring pile movement.

Manufacturer's rated energy – The manufacturer's specified energy of a powered hammer.

Neutral plane – The location where equilibrium exists between the sum of sustained compression load plus drag force and the sum of mobilized positive shaft resistance and mobilized toe resistance. The neutral plane is also where relative movement between the pile and soil is zero.

Pile, driven – A slender column, having a preformed shape and size, that can be inspected prior to and during installation, which is installed by impact hammering, vibrating or pushing into the earth and used to resist axial and/or lateral loads.

Pile head – A pile's uppermost end.

Pile impedance (Z) – A material property of a pile cross section, determined as the product of the Young's modulus (E) and cross-sectional area (A), divided by the wave speed (c): $Z = EA/c$. Can also be determined as the product of the mass density (ρ), wave speed, and cross-sectional area: $Z = \rho cA$.

Pile point – A special type of pile shoe.

Pile shaft – The portion of a pile between the pile head and the pile toe.

Pile shoe – A separate reinforcement attached to the pile toe to facilitate driving, protect a pile's lower end, and/or improve toe resistance.

Pile tip – same as **Pile toe**.

Pile toe – A pile's lowermost end.

Redrive – A substantial number of impacts, or a substantial time of vibration, which significantly deepens the pile's toe elevation.

Refusal – The driving condition evidenced by negligible set, associated with the hammer impact force being insufficient to overcome driving resistance; it is often associated with an equivalent blow count of approximately 10 blows per inch (10 blows per 25 mm). Not to be confused with **Termination criteria**.

Relaxation – A decrease in pile capacity which occurs after driving (associated with decreased capacity at or near the toe).

Replacement pile – A pile installed in another pile's stead (e.g., when the original pile is unsatisfactory).

Resistance – The sum of all mobilized forces (static and dynamic) that oppose a pile load.

Factored resistance (LRFD) – The nominal resistance multiplied by a resistance factor.

Maximum driving resistance – The maximum (ultimate) soil and/or rock resistance during driving (the driving resistance in an upper layer may exceed the driving resistance at end of drive).

Nominal resistance (LRFD) – The maximum (ultimate) load capable of being resisted, governed by the lesser of the geotechnical capacity or material strength limit. Equivalent ASD term: **Capacity**.

Shaft resistance – The load resisted by a pile's shaft; it must be less than, or equal to, the shaft capacity.

Negative shaft resistance – Soil resistance acting downward along a pile shaft because of an applied tension (upward) load; it must be less than, or equal to, shaft capacity.

Positive shaft resistance – Soil resistance acting upward along a pile shaft because of an applied compression (downward) load; it must be less than, or equal to, shaft capacity.

Toe resistance – The load resisted by a pile's toe; it must be less than or equal to the toe capacity.

Resistance Factor – A multiplier applied to nominal resistance accounting primarily for variability of material properties, structural dimensions and workmanship, and resistance prediction uncertainty.

Restrike – An impact, or limited series of impacts, to a previously driven pile to assess its capacity or integrity.

Safety Factor (ASD) – 1. The ratio of usable geotechnical capacity to allowable geotechnical load. 2. The ratio of usable geotechnical capacity to design load. (see Commentary below for difference between allowable load and design load)

Set – The pile penetration per hammer impact; can be derived from **Blow count**.

Set-Up – An increase in a pile's geotechnical capacity which occurs after driving (most-often associated with increased shaft capacity).

Signal matching analysis – A rigorous numerical evaluation of the dynamic monitoring data from an individual hammer blow to estimate static pile capacity, relative soil resistance distribution, pile stresses, and dynamic soil properties, using pile and soil models (more-comprehensive than dynamic method of analysis).

Skin friction – Soil resistance acting along a pile shaft, caused by soil moving relative to the pile shaft; it must be less than, or equal to, the shaft capacity.

Negative skin friction – Soil resistance acting downward along a pile shaft, caused by soil moving downward relative to the pile shaft.

Positive skin friction – Soil resistance acting upward along a pile shaft, caused by soil moving upward relative to the pile shaft.

Termination criterion or **criteria** – Conditions which must be satisfied to allow field construction control to stop driving a pile (e.g., usually achieving a minimum equivalent blow count, evidencing a minimum dynamic monitoring estimated capacity, and sometimes achieving a design minimum embedment length due to lateral concerns, liquefaction, scour, settlement control, tension – there is a difference between estimated embedment length and design minimum embedment length).

Toe elevation – The elevation of a pile's toe.

Estimated toe elevation – The toe elevation at which it is estimated a pile will terminate.

Maximum toe elevation– The highest toe elevation at which a pile can terminate and satisfy a certain design requirement (e.g., lateral concerns, liquefaction, settlement control, scour, tension).

Toe plate – A plate attached to a pipe pile's toe, making it a closed-end pile.

Toe resistance – Same as **Capacity, Toe**.

Transferred energy – Energy transferred to the pile head; it can be determined as the integral over time of the product of force and velocity.

Wave speed – The speed of strain propagation in a pile due to impact.

Wave trace – A graphic representation against time of strain, acceleration, force or velocity in a pile due to impact.

Commentary

Allowable load versus **Design load** – Although these terms are commonly used interchangeably, they have different meanings. "Allowable load" is the lesser of the geotechnical capacity divided by a safety factor, or the structural capacity multiplied by a reduction factor. It is the resistance to load permitted to be provided by a pile, and is consistent among all similarly installed piles on a project. "Design load" is the load required to be resisted by a specific pile, and can be location-specific.

For example, if a design column load divided by the piles' allowable load calculates that 4.3 piles are required to support that column, 5 piles will be installed, and the piles' design load will be less than their allowable load (i.e., 4.3÷5=86% of their allowable load). A pile's design load can also depend on its location within a pile group; piles nearer the group perimeter may have higher design loads owing to overturning moments, even though all piles in the group have the same allowable load.

Inclined pile versus **Battered** or **Batter pile** versus **Raker pile** versus **Raking pile** – "Battered pile" can literally mean, or at least connote, damage, especially to lay people (courts of law). "Batter pile" is likely a colloquial shortening of "battered pile." "Inclined pile" is therefore preferred.

Load test versus **Loading test** – A "load test" would determine the load in a pile, as a load cell or strain gage might do to measure service load. A "loading test" applies load to the pile.

Minimum embedment length versus **Maximum toe elevation** versus **Minimum toe elevation** – "Minimum toe elevation," when literally interpreted, means the lowest elevation at which the pile toe can terminate, which means the pile can terminate at any higher toe elevation (at any shallower embedment length): exactly the opposite of what it is intended to mean. "Maximum toe elevation" is correct using similar nomenclature; "minimum embedment length" is preferred (see **Termination criteria**). A minimum embedment length, or a maximum toe elevation, should only be specified if required to satisfy a certain design requirement (e.g., lateral concerns, liquefaction, settlement control, scour, tension).

Static load test failure – Static load tests, or static load test piles, are sometimes said to have "failed." At times, this refers to a pile which geotechnically plunged, but did not exhibit requisite capacity. However, if one of the static load test's objectives was to plunge the pile, and the pile did not plunge, the test failed in that regard, even if the pile exhibited requisite capacity. If a static load test's intent was to plunge the pile, and the pile did plunge, and in doing so exhibited at least requisite capacity, it was a successful test in two regards (plunging and required capacity), but the test or the pile might be still be referred to as having "failed."

The negative connotation attached to designating a static load test pile which geotechnically plunged as having "failed" may inappropriately preclude a design-team member from incorporating that pile into the permanent structure, potentially adversely affecting the project in a number of ways. It should be recognized that the static load test pile's plunging "failure" mode (permanent toe displacement under load) occurs with every hammer blow which advances a pile during installation.

Additionally, when a pile geotechnically plunges, it might be said that the "pile failed," when in fact the soil failed.