**Reviewers: Use this BSP whenever wave equation analysis of piles (WEAP) is specified on plans as pile driving verification method.**

* **WEAP should be the verification method on the plans anytime we exceed 600 kips as minimum nominal axial compressive resistance (MNACR) for end bearing piles and dynamic pile testing (PDA) is not recommended in the Geotechnical Report (FIGR).**
* **For piles tipped in shale or sandstone at any loading where the likelihood of pile damage is increased, the FIGR should give a recommendation for PDA or no PDA. For piles tipped in shale, sandstone, or rock of uncertain strength where PDA is not recommended, WEAP should be considered for the verification method.**
* **Under special circumstances when rock limits or conditions are nonuniform, WEAP can be used solely as verification method in order to limit pile damage because it will require outside expertise to review conditions under which pile is driven to rock with consideration of hammer verification included.**

**The BSP for Dynamic Pile Testing shall also be used per section 5.0. Change the Method of Measurement and Basis of Payment sections in the Dynamic Pile Testing BSP to state no measurement will be made and payment will be covered by Pile Wave Analysis.**

**For piles tipped in hard rock with MNACR less than 600 kips, FHWA-modified Gates Dynamic Pile Formula should be used as verification method, and practical refusal criterion should control end of driving criteria. Consideration should be given to using additional piles to reduce the MNACR below 600 kips.**

**In friction pile conditions, PDA (Dynamic Pile Testing) should be used.**

 PILE WAVE ANALYSIS 2/7/24

**1.0 General.**

**1.1 Scope of Work.** Scope of work shall include furnishing a wave equation analysis of piles (WEAP) as specified in this special provision.

**1.2 Performance and Design Requirements.** Performance and design conditions for WEAP shall be in accordance with section 4.0 of this special provision.

**1.3 Qualifications.** The contractor shall perform wave equation analysis utilizing the services of an independent dynamic pile testing consultant and qualified personnel. An engineer with a minimum of 5 years WEAP experience shall perform the analysis.

**2.0 Execution.**

**2.1 Pile Driving Modeling.** The contractor shall perform preconstruction wave equation analyses and prepare a summary report of the results. The wave equation analyses shall be used to assess the ability of all proposed pile driving systems to install piles to the required capacity and the desired penetration depth within allowable driving stresses. The report shall include a drivability graph relating pile capacity, blow count and driving stresses to depth. The report shall include a bearing graph relating the pile capacity to the pile driving resistance. The bearing graph shall indicate blow count versus capacity and stroke. The report shall also contain a constant capacity analysis or inspector’s chart to assist the engineer in determining the required driving resistance at other field observed strokes. The contractor shall perform wave equation analyses in accordance with section 4.0 of this special provision. Acceptability of the wave equation report and the adequacy of analyses will be determined by the engineer.

**2.1.1** WEAP shall provide driving criteria for driving piling to rock. WEAP shall give pile solution for driving piling through hard material to rock or through soft material to rock. WEAP shall provide an inspector’s chart to be used for end of driving criteria in soft rock. If hard rock is encountered during driving, then Sec 702.4.11.1 Pile Driving to Hard Rock shall be used as the end of driving criteria. When driving to rock of uncertain strength, the WEAP shall be used as the pile driving verification method up until pile refusal on rock occurs. When pile refusal on rock occurs, as approved by the engineer, the minimum nominal axial compressive resistance is verified and no additional pile driving verification method is required.

**2.1.2** Approval by the engineer of the proposed pile driving system will be based upon the wave equation analyses indicating that the proposed system can develop the specified pile capacity at a maximum equivalent pile driving rate of 10 blows per inch in soil and 20 blows per inch at the end of driving to seat pile in soft rock or penetrate to refusal on hard rock, and within allowable driving stresses per *AASHTO LRFD Bridge Construction Specifications*, Section 4.4.1. With approval of the engineer, a pile driving rate greater than 20 blows per inch may be acceptable if a smaller hammer or shorter stroke is needed to keep pile driving stresses within the allowable range when seating pile in rock. The contractor shall provide preliminary pile driving criteria based on wave equation analyses and any anticipated capacity changes after driving, set-up or relaxation, subject to revision based upon field measurements.

**2.1.3** If any changes or modifications are made to the approved pile driving system, additional wave equation analyses in accordance with section 2.1 of this special provision shall be required.

**3.0 Schedule of Contract Submittals.** Proposed independent dynamic pile testing consultant, and a list of assigned personnel and their experience and qualifications shall be submitted to the engineer. All documents shall be submitted 45 calendar days before pile driving starts.

**4.0** **Wave Equation Analysis.** A minimum of one and sufficient additional analyses as needed are required to define performance for all combinations of piles, driving systems and subsurface conditions anticipated. Multiple pile driving systems shall be analyzed as required to find an acceptable system that is capable of driving the piles in accordance with section 2.0 of this special provision. A smaller hammer, shorter stroke, increased cushion, or a combination thereof shall be considered to prevent pile damage when encountering rock.

**5.0 Dynamic Pile Testing.** The contractor has the option to add Dynamic Pile Testing to assist in pile installation. Dynamic Pile Testing shall be in accordance with the Dynamic Pile Testing job special provision and at the contractor’s expense. No additional payment will be made for Dynamic Pile Testing.

**6.0 Method of Measurement.** Pile wave analysis will be measured per each bent.

**7.0 Basis of Payment.** Payment for the above described work will be considered completely covered by the contract unit price for Pile Wave Analysis.