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(54) **CONCRETE SHEET PILE CLAMP ASSEMBLIES AND METHODS AND PILE DRIVING SYSTEMS FOR CONCRETE SHEET PILES**

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See application file for complete search history.

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(57) **ABSTRACT**

A clamp assembly for a pile driving system for driving a concrete sheet pile, the clamp assembly comprising a clamp body, a first clamp member supported relative to the clamp body, and a second clamp member supported for movement relative to the clamp body, and a bumper member. A clamp region is formed between the first and second clamp members. The bumper member is supported relative to the clamp body above the clamp region. The clamp body is configured such that the concrete sheet pile enters the clamp region from below. The second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region. The bumper member resiliently deforms to inhibit direct transmission of forces between the concrete sheet pile and the clamp body during driving of the concrete sheet pile.

14 Claims, 3 Drawing Sheets

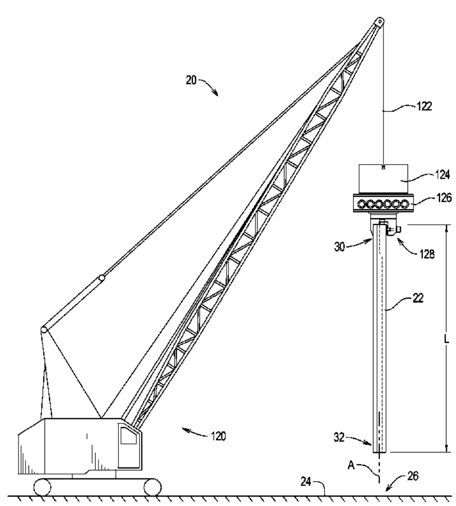

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FIG. 1

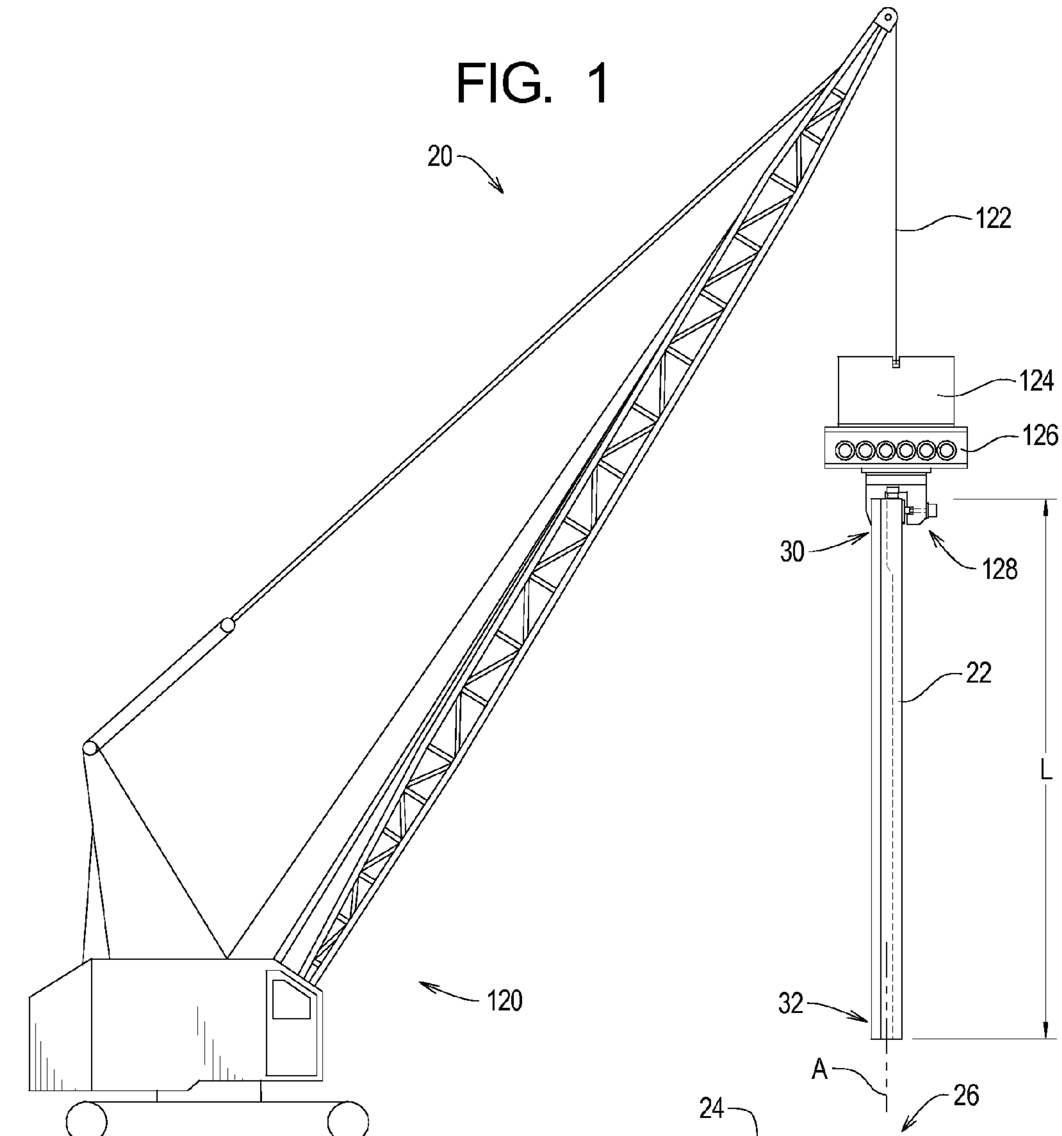

FIG. 2

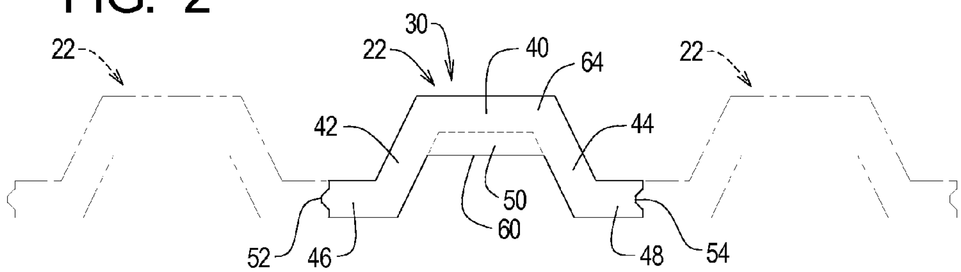

FIG. 3

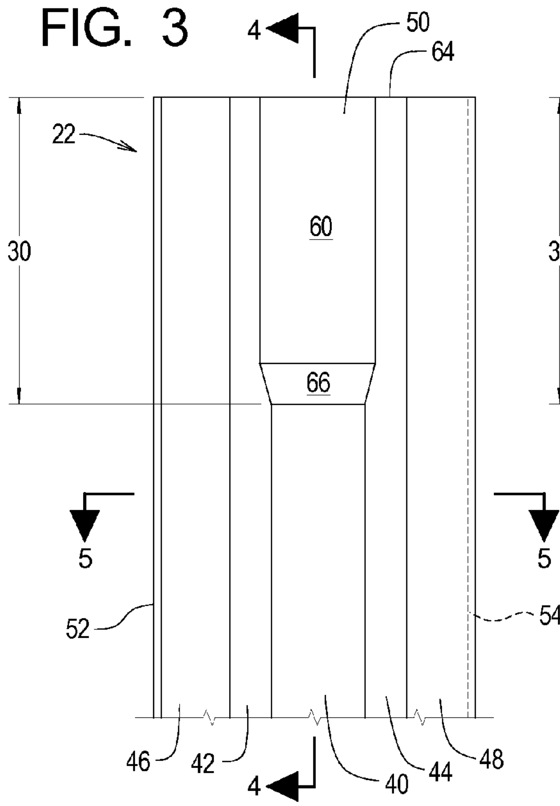

FIG. 4

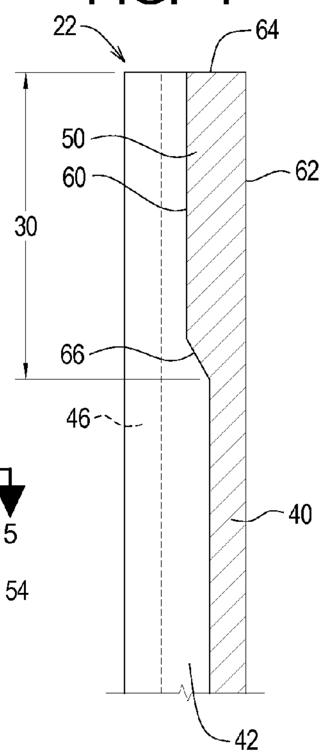

FIG. 5

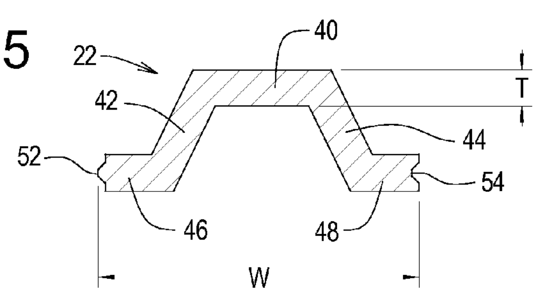

FIG. 6

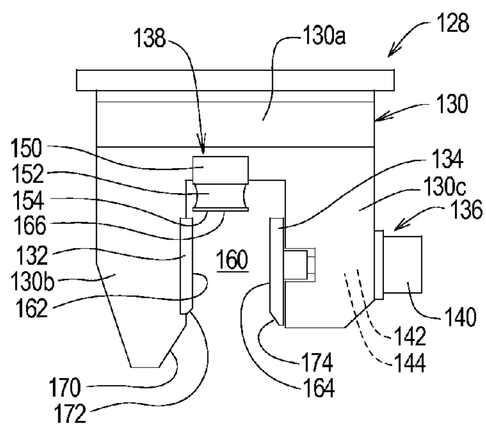
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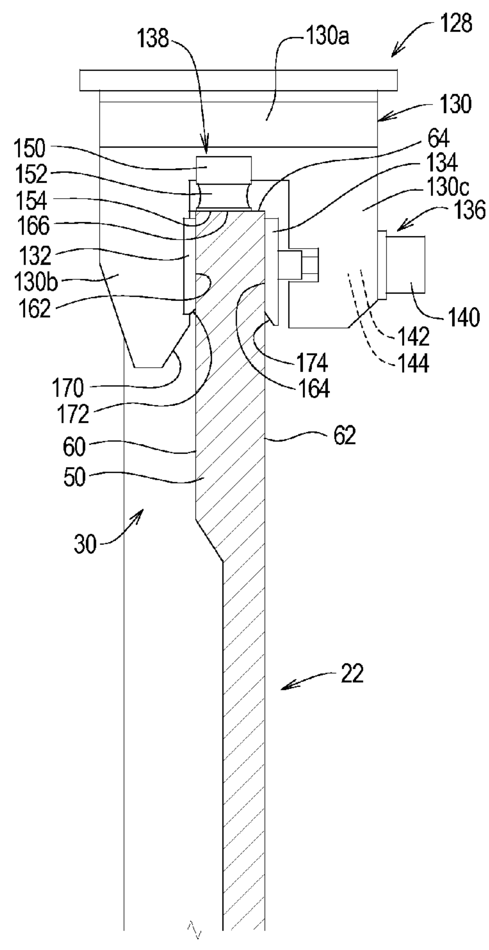
FIG. 7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CONCRETE SHEET PILE CLAMP ASSEMBLIES AND METHODS AND PILE DRIVING SYSTEMS FOR CONCRETE SHEET PILES

RELATED APPLICATIONS

This application, U.S. application Ser. No. 13/794,615 filed Mar. 11, 2013, claims benefit of U.S. Provisional Patent Application Ser. No. 61/732,217 filed Nov. 30, 2012, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to pile driving systems and methods and, more particularly, to clamp systems and methods adapted to apply vibratory driving forces to concrete sheet piles.

BACKGROUND

Piles are often used in construction to support structures, roadways, earthworks, and the like. At least a portion of a pile is typically arranged within the ground. While a pile may be placed into an excavated hole, piles are typically driven into the ground by the application of a driving force to the top of the pile. The driving force may be one or more of static forces (e.g., weight of pile and pile driving equipment), impulse forces (e.g., drop hammer, diesel hammer), crowding forces (e.g., hydraulic ram), and vibratory forces (e.g., eccentric vibro). The exact nature of the driving force is typically selected for a particular type of pile and, to some extent, to a particular set of soil conditions.

A pile is typically driven by applying the driving force along a longitudinal axis of the pile being driven. As discussed above, a driving force applied to a pile to be driven often includes a vibratory force component. The vibratory force component results in forces being applied to the pile being driven in both directions along the longitudinal axis of the pile. Depending on the nature of the pile and soil composition, vibratory forces can significantly enhance the speed at which piles are driven. Vibratory forces can also be gentler on a pile structure being driven than, say, impulse forces.

Vibratory forces are highly appropriate for use with certain concrete piles and certain soil conditions. The present invention is of particular relevance in the context of applying a driving force having a vibratory force component to a concrete sheet pile. In general, a sheet pile may be characterized as having a width dimension that is significantly greater than a thickness dimension. Therefore, in comparison to a pile driver for cylindrical piles, at least a portion of a pile driving system for sheet piles is typically adapted to accommodate the wide and thin form factor of sheet piles. The form factor of a concrete sheet pile is also basically wide and thin, but a concrete sheet pile is typically a precast, reinforced, concrete structure.

In the context of concrete sheet piles being driven with a driving force having a vibratory force component, the pile driving system typically comprises a vibratory device and a clamp system. The vibratory device generates the vibratory force component, and the clamp system ensures that the vibratory forces are applied in both directions along the longitudinal axis of the pile being driven. The clamp system is adapted for the particular form factor of the pile being driven.

The need exists for improved pile driving systems and methods for concrete sheet piles and, more specifically, to clamp systems and methods for effectively applying the

vibratory force component of a driving force to a concrete sheet pile with minimal damage to the concrete sheet pile.

SUMMARY

The present invention may be embodied as clamp assembly for a pile driving system for driving a concrete sheet pile. The clamp assembly comprises a clamp body, a first clamp member supported relative to the clamp body, and a second clamp member supported for movement relative to the clamp body, and a bumper member. A clamp region is formed between the first and second clamp members. The bumper member is supported relative to the clamp body above the clamp region. The clamp body is configured such that the concrete sheet pile enters the clamp region from below. The second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region. The bumper member resiliently deforms to inhibit direct transmission of forces between the concrete sheet pile and the clamp body during driving of the concrete sheet pile.

The present invention may also be embodied as method of clamping a concrete sheet pile to a pile driving system, the method comprising the following steps. A first clamp member is supported relative to a clamp body. A second clamp member is movably supported for movement relative to the clamp body such that a clamp region is formed between the first and second clamp members. A bumper member is supported relative to the clamp body above the clamp region. The concrete sheet pile is caused to enter the clamp region from below. The second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region. Direct transmission of forces between the concrete sheet pile and the clamp body is inhibited during driving of the concrete sheet pile by causing the bumper member to resiliently deform.

The present invention may be embodied as a pile driving system for driving a concrete sheet pile. The example pile driving assembly comprises a vibratory device and a clamp assembly. The clamp assembly comprises a clamp body operatively to the vibratory device, a first clamp member supported relative to the clamp body, a second clamp member supported for movement relative to the clamp body, and a bumper member supported relative to the clamp body above the clamp region. A clamp region is formed between the first and second clamp members. The clamp body is configured such that the concrete sheet pile enters the clamp region from below. The second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region. The vibratory device is operated to apply vibratory forces to the concrete sheet pile through the clamp body and the first and second clamp members. The bumper member resiliently deforms to inhibit direct transmission of forces between the concrete sheet pile and the clamp body during driving of the concrete sheet pile.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view of an example pile driving system and clamp system of the present invention for driving a concrete sheet pile;

FIG. **2** is top plan view highlighting one example concrete sheet pile such as the example concrete sheet pile of FIG. **1** in an overall installation of a plurality of similar concrete sheet piles;

FIG. **3** is a front elevation view of an upper end of the example concrete sheet pile of FIG. **1**;

FIG. **4** is a side elevation section view taken along lines **4-4** in FIG. **3**:

FIG. **5** is a top plan section view taken along lines **5-5** in FIG. **3**;

FIG. **6** is a side elevation view of the example clamp system of FIG. **1** in an open configuration; and

FIG. **7** is a side elevation view similar to FIG. **6** illustrating the example clamp system in a clamped configuration relative to the example concrete pile as depicted in FIG. **1**.

DETAILED DESCRIPTION

Referring initially to FIG. **1** of the drawing, depicted therein is a pile driving system **20** constructed in accordance with, and embodying, the principles of the present invention. The example pile driving system **20** is illustrated in connection with a pile **22** to be driven into the ground **24** at a desired location **26**. The example pile **22** is a concrete sheet pile.

FIGS. **2-5** illustrate certain details of the example pile **22** driven by the example pile driving system **20**. The pile **22** is not per se part of the present invention and may take on configurations other than those depicted in FIGS. **1-5**, but an understanding of the example pile **22** will facilitate an understanding of the example pile driving system **20**.

FIG. **1** illustrates that the example pile **22** is an elongate structure defining a longitudinal axis A extending along a lengthwise dimension L thereof. A first end portion **30** and a second end portion **32** are spaced at opposite ends of the pile **22** along the longitudinal axis A. The first end portion **30** is adapted to be engaged by the pile driving system **20** as will be described in further detail below. FIG. **5** illustrates that a width dimension W of the pile **22** is significantly larger than a thickness dimension T thereof.

FIGS. **2-5** further illustrate that the example pile **22** defines a center portion **40**, first and second arm portions **42** and **44**, and first and second edge portions **46** and **48**. A gripping projection **50** extends from the center portion **40** at the first end portion **30** of the example pile **22**. The gripping projection **50** further extends between the first and second arm portions **42** and **44** at the first end portion **30**. A first edge projection **52** is formed on the first edge portion **46**, and a second edge recess **54** is formed in the second edge portion **48**. First and second engaging surfaces **60** and **62** are formed by the gripping projection **50** and the center portion **40** at the first end portion **30**, respectively. An upper surface **64** is defined by the top of the pile **22**. A transition surface **66** extends between the first engaging surface **60** and the center portion **40** outside of the first end portion **30** of the pile **22**.

The engaging surfaces **60** and **62** are substantially parallel to each other, and the upper surface **64** is substantially orthogonal to the engaging surfaces **60** and **62**. Typically, the engaging surfaces **60** and **62** are substantially vertical and the upper surface **64** is substantially horizontal when the pile **22** is driven into the ground **24**.

With the foregoing discussion of the example concrete sheet pile **22** in mind, the details of construction and operation of the example pile driving system **20** will now be described in further detail with respect to FIGS. **1**, **6**, and **7**.

As shown in FIG. **1**, the example pile driving system **20** comprises a crane **120** from which a crane line **122** extends. A vibration suppressor **124** is connected to the crane line **122**. A vibratory device **126** is connected to the vibration suppressor **124**. A clamp **128** is connected to the vibratory device **126**.

To prepare the example pile driving system **20** for use, the clamp **128** is rigidly connected to the vibratory device **126**, and the vibratory device **126** is rigidly connected to the vibration suppressor **124**. The vibration suppressor **124** is suspended from the crane **120** by the crane line **122**. The example crane **120** takes the form of a tracked vehicle capable of moving across the ground **24**. The clamp **128** is adapted to be substantially rigidly connected to the pile **22** as will be described in further detail below.

During use, the clamp **128** is rigidly connected to the pile **22**, and the crane **120** is operated to suspend the pile **22** above the desired location **26** on the ground **24**. The crane **120** is then operated such that the second end portion **32** of the pile is in contact with the ground **24** at the desired location **26**. The vibratory device **126** is then operated such that the vibratory forces created by the vibratory device **126** are transmitted to the clamp **128** and to the pile **22**. The vibratory forces created by the vibratory device **126** and the static forces created by the weight of the pile **22**, clamp **128**, vibratory device **126**, and vibration suppressor **124** create a driving force that drives the pile **22** into the ground **24** at the desired location **26**. The vibration suppressor **124** inhibits transmission of the vibratory forces from the vibratory device **126** to the crane line **122** and thus to the crane **120**.

Referring now to FIGS. **6** and **7**, it can be seen that the example clamp **128** comprises a clamp body **130**, a first clamp member **132**, a second clamp member **134**, an actuator assembly **136**, and a bumper assembly **138**. The example actuator assembly **136** comprises an actuator **140** and an actuator shaft **142**. The example actuator shaft **142** extends through an actuator opening **144** formed in the clamp body **130**. The example actuator **140** is a hydraulically operated device that uses hydraulic pressure to displace the actuator shaft **142** relative to the actuator **140**. The example bumper assembly **138** comprises a bumper base **150**, a bumper member **152**, and a bumper plate **154**. The example clamp body **130** comprises a clamp body base portion **130***a*, a first clamp body arm **130***b*, and a second clamp body arm **130***c*. In the example clamp **128**, the first clamp member **132** is rigidly connected to the first clamp body arm **130***b*, the second clamp member **134** is movably supported relative to the second clamp body arm **130***c*, and the bumper assembly **138** is rigidly connected to the clamp body base portion **130***a*.

The first clamp member **132** is rigidly connected to the clamp body **130** on one side of a clamp region **160**. The actuator shaft **142** extends through the actuator opening **144** to an opposite side of the clamp region **160**. The second clamp member **134** is rigidly connected to the actuator shaft **142** such that the second clamp member **134** is also on the opposite side of the clamp region **160** from the first clamp member **132**. The first clamp member **132** defines first clamp surface **162**, and the second clamp member **134** defines a second clamp surface **164**. The example clamp surfaces **162** and **164** are substantially parallel to each other, and the clamp region **160** lies between these surfaces **162** and **164**. In the example clamp **128**, first, second, and third guide surfaces **170**, **172**, and **174** are formed to guide the pile **22** into the clamp region **160** as will be described in further detail below.

The example bumper member **152** is secured to the example bumper base **150** by any appropriate means such as adhesive, clamp, bolts, and the like. The example bumper member **152** is similarly secured to the example bumper plate **154** by any appropriate means such as adhesive, clamp, bolts, and the like. The example bumper base **150** is in turn secured to the clamp body **130** such that the bumper member **152** is arranged above the clamp region **160**. The example bumper plate **154** defines a bumper surface **166** that is arranged to define an upper end of the clamp region **160**. The example bumper surface **166** is substantially orthogonal to the first and second clamp surfaces **162** and **164**. During driving of the pile

22, the first and second clamp surfaces **162** and **164** are substantially vertical, and the bumper surface **166** is substantially horizontal.

The bumper member **152** is made of a resiliently deformable material that is capable of absorbing at least a portion of shocks from external bodies coming into contact with the bumper member **152**. The example bumper member **152** may be made of any resiliently deformable material capable of meeting the functional requirements as described below without substantial degradation in physical structure of the bumper member **152**. As one example, the bumper member **152** may be made of a rubber-like elastomeric material. In particular, the bumper member **152** may be made of an elastomeric material similar to or the same as the material used in conventional vibration suppression systems for vibrational pile drivers.

In preparing to operate the pile driving system **20**, the actuator **140** is initially operated to retract the actuator shaft **142** as depicted in FIG. **6** such that the clamp **128** is in an open configuration. In this open configuration, the first and second clamp surfaces **162** and **164** are spaced from each other such that the dimensions of the clamp region **160** are greatest. The crane **120** is displaced such that the first end portion **30** of the pile **22** enters the clamp region **160**. Continued displacement of the clamp **128** relative to the pile **22** allows the bumper surface **166** to come into contact with the upper surface **64** of the pile **22**.

The actuator **140** is then operated to displace the second clamp member **134** towards the first clamp member **132** such that the first and second clamp surfaces **162** and **164** come into contact with the first and second engaging surfaces **60** and **62**. The actuator assembly **136** thus applies a clamping force on the center portion **40** and gripping projection **50** of the pile **22** that securely holds the pile **22** relative to the clamp **128**. The pile **22** may then be lifted into position above the desired location **26** and lowered until the second end portion **32** contacts the ground **24** at the desired location **26**.

The crane **120** is then used to suspend the pile **22** at a desired orientation and the vibratory device **126** is operated. The vibratory forces generated by the vibratory device **126** are transmitted to the pile **22** through the clamp **128**. The vibratory forces, along with static force generated by the weight of the pile **22**, vibration suppressor **124**, vibratory device **126**, and clamp **128**, create the driving force that drives the pile **22** into position at the desired location. With the example pile **22**, the desired position is typically next to an adjacent pile **22** as shown in FIG. **2** such that the first edge projection **52** of one of the piles **22** is received by the second edge recess **54** of an adjacent one of the piles **22**.

Further, the first and second clamp surfaces **162** and **164** are sized, dimensioned, and/or configured to minimize slippage between the clamp **128** and the pile **22**. However, if such slippage does occur, which is likely under wet, muddy conditions, the bumper plate **154** comes into contact with the upper surface **64** of the pile **22**. Should slippage occur and the bumper plate **154** come into contact with the upper surface **64**, the bumper member **152** resiliently deforms to absorb shocks that would otherwise be transmitted to the upper surface **64**, possibly damaging the pile **22**.

What is claimed is:

1. A clamp assembly for a pile driving system for driving a concrete sheet pile, the clamp assembly comprising:

a clamp body;

a first clamp member supported relative to the clamp body; and

a second clamp member supported for movement relative to the clamp body, where a clamp region is formed between the first and second clamp members; and

a bumper member is supported relative to the clamp body above the clamp region;

a bumper plate is secured to the bumper member;

the clamp body is configured such that the concrete sheet pile enters the clamp region from below; wherein

the second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region;

the bumper date is arranged to come into contact with the concrete sheet pile during transmission of forces between the concrete sheet pile and the bumper member such that, if slippage occurs between the concrete sheet pile and the clamp assembly when a driving force is being applied through the clamp assembly to the concrete sheet pile, the bumper member resiliently deforms to absorb shocks that would otherwise be transmitted to the upper surface and possibly damage the concrete sheet pile.

2. The clamp assembly as recited in claim **1**, further comprising an actuator member configured to displace the second clamp member towards the first clamp member.

3. The clamp assembly as recited in claim **1**, further comprising a bumper base, wherein:

the bumper member is secured to the bumper base; and

the bumper base is secured to the clamp body.

4. The clamp assembly as recited in claim **1**, in which the clamp body comprises:

a clamp body base;

a first clamp body arm; and

a second clamp body arm; wherein

the first clamp member is rigidly connected to the first clamp body arm;

the second clamp member is movably supported by the second clamp body arm; and

the bumper member is supported by the clamp body base.

5. The clamp assembly as recited in claim **4**, further comprising an actuator member mounted on the second clamp body arm, where the actuator member is configured to displace the second clamp member towards the first clamp member.

6. A method of clamping a concrete sheet pile to a pile driving system, the method comprising the steps of:

providing a clamp body;

supporting a first clamp member relative to the clamp body; and

movably supporting a second clamp member for movement relative to the clamp body such that a clamp region is formed between the first and second clamp members;

supporting a bumper member relative to the clamp body above the clamp region;

causing the concrete sheet pile to enter the clamp region from below;

displacing the second clamp member towards the first clamp member to engage the concrete sheet pile in the clamp region; and if slippage occurs between the concrete sheet pile and the clamp assembly when a driving force is being applied through the clamp assembly to the concrete sheet pile, the bumper member resiliently deforms to absorb shocks that would otherwise be transmitted to the upper surface and possibly damage the concrete sheet pile; and

securing a bumper late to the bumper member such that the bumper plate comes into contact with the concrete sheet pile during transmission of forces between the concrete sheet pile and the bumper member.

7. The method as recited in claim **6**, further comprising the step of arranging an actuator member displace the second clamp member towards the first clamp member.

8. The method as recited in claim **6**, further comprising the steps of:

securing the bumper member to a bumper base; and

securing the bumper base to the clamp body.

9. The method as recited in claim **6**, in which the step of supporting a bumper member relative to the clamp body comprises the steps of

rigidly connecting the first clamp member is rigidly to a first clamp body arm of the clamp body;

movably supporting the second clamp member on a second clamp body arm of the clamp body;

securing the bumper member to a bumper base; and

the bumper member is supported by securing the bumper base to the clamp body.

10. The method as recited in claim **9**, further comprising the steps of:

mounting an actuator member on the second clamp body arm; and

configuring the actuator member to displace the second clamp member towards the first clamp member.

11. A pile driving system for driving a concrete sheet pile, the pile driving assembly comprising:

a vibratory device;

a clamp assembly comprising

a clamp body operatively to the vibratory device;

a first clamp member supported relative to the clamp body;

a second clamp member supported for movement relative to the clamp body, where a clamp region is formed between the first and second clamp members;

a bumper member supported relative to the clamp body above the clamp region; and

a bumper plate is secured to the bumper member; wherein

the clamp body is configured such that the concrete sheet pile enters the clamp region from below;

the second clamp member is displaced towards the first clamp member to engage the concrete sheet pile in the clamp region;

the vibratory device is operated to apply vibratory forces to the concrete sheet pile through the clamp body and the first and second clamp members; and

the bumper plate is arranged to come into contact with the concrete sheet pile during transmission of forces between the concrete sheet pile and the bumper member such that, if slippage occurs between the concrete sheet pile and the clamp assembly when a driving force is being applied through the clamp assembly to the concrete sheet pile, the bumper member resiliently deforms to absorb shocks that would otherwise be transmitted to the upper surface and possibly damage the concrete sheet pile.

12. The pile driving system as recited in claim **11**, further comprising:

a vibratory suppression assembly operatively connected to the vibratory device; and

a crane operatively connected to the vibratory suppression assembly; where

the crane supports the vibratory suppression assembly, the vibratory device, the clamp assembly, and concrete sheet pile during driving of the concrete sheet pile.

13. The pile driving system as recited in claim **11**, in which the clamp assembly further comprises a bumper base, wherein:

the bumper member is secured to the bumper base; and

the bumper base is secured to the clamp body.

14. The pile driving system as recited in claim **11**, in which the clamp body comprises:

a clamp body base;

a first clamp body arm; and

a second clamp body arm; wherein

the vibratory device is rigidly connected to the clamp body base;

the first clamp member is rigidly connected to the first clamp body arm;

the second clamp member is movably supported by the second clamp body arm; and

the bumper member is supported by the clamp body base.

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