

## SYSTEM FOR VERTICAL CENTERING AND POSITIONING OF STEEL PLUNGE COLUMN IN TOP-DOWN CONSTRUCTION METHOD

### FIELD OF THE INVENTION

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The present invention relates to a system for vertical centering and positioning of a steel plunge column during deep excavation in the top-down construction method, and more particularly to a hydraulic adjustment unit that has large-area base and pile hole wall supporting and retaining pipe to provide sufficient earth-retaining force to a foundation pile hole, and having a push plate movable by a hydraulic-actuated extendable supporting arm and multiple pivoted arms to push against the steel plunge column for vertical centering and positioning thereof in the foundation pile hole. The present invention also relates to a computerized digital positioning monitoring system for observing, measuring and displaying vertical accuracy and displacement of the steel plunge column to enable precise and real-time adjustment of the steel plunge column's vertical position in the foundation pile hole.

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### BACKGROUND OF THE INVENTION

The top-down construction method has been proven by related construction documents from many countries in the world to have a lot of advantages. It can be performed without being affected by weather conditions and reduces the noise in the basement construction. With the top-down construction method, sub-structure and super-structure floors can be proceeded at the same time to shorten the construction time, the constructed beams or floor slabs can be used as earth-retaining structure to replace the H-beam and provide even higher constructional safety. The top-down construction method also reduces the time needed for deep excavation and the

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possibility of damaging neighboring buildings. The top-down construction method is particularly suitable for urban structures that require deep excavation, including high-rise buildings with deep basements and underground structures, such as subway stations.

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Most of the construction environments having large area, requiring deep excavation or located at urban area would encounter problems in connection with geographical conditions, the disposal of groundwater, uneven and unstable lateral earth pressure after excavation, as well as complicated and unpredictable construction conditions and environmental factors in foundation works. All these problems contribute to the development and use of the top-down construction method in the urban areas. The top-down construction method has become a new indicative and major construction method in the nowadays urban building and civil engineering market. The inventor has devoted to the research, development and experiment of some construction-related new subjects, such as large-diameter and large-depth foundation works in the top-down construction. For example, the steel plunge columns for the top-down construction require increased width and length to match the expanded diameter and increased piling depth of the foundation piles. Under this condition, some technical problems that must be overcome in the top-down construction include the observation, measurement and adjustment of the verticality of the steel plunge columns that are positioned in the ground as deep as several ten meters, as well as the firm vertical positioning of these steel plunge columns in the foundation pile holes.

Therefore, it is tried by the inventor to develop a system for vertical centering and positioning of steel plunge column that is suitable for use with various types of foundation piles in the foundation works using the top-down construction method, so as to satisfy the global requirements for lowered construction cost, low pollution and

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shortened construction time, as well as achieve the targets of upgraded construction quality and transparent data processing.

### SUMMARY OF THE INVENTION

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Embodiments of the present invention seek to provide a system for precise vertical centering and positioning of a steel plunge column in a round or a rectangular foundation pile hole in a top-down construction during column hoisting and positioning process and concrete pouring process at different phases thereof.

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Embodiments of the present invention also seek to provide a system that includes hydraulic adjustment units, which not only enable precise vertical centering and positioning of a steel plunge column in the top-down construction, but also provide earth-retaining function in a foundation pile hole.

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Embodiments of the present invention further seek to provide a system that includes an electronic inclinometer and a computerized digital positioning monitoring system to enables precise and real-time observation, measurement and adjustment of the vertical accuracy and displacement of a steel plunge column positioned in a foundation pile hole according to the top-down construction.

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According to an aspect of the present invention, there is provided a system for vertical centering and positioning of steel plunge column in top-down construction method being applied to piling operation in a rectangular foundation pile hole, comprising a plurality of hydraulic adjustment units, a plurality of pile hole wall supporting and retaining pipes, a two-way electronic inclinometer, and a computerized digital positioning monitoring system; the hydraulic adjustment units being spaced from one another in a space between the rectangular foundation pile hole and a steel plunge column positioned in the rectangular foundation pile hole, and having an earth-retaining function; wherein each of the hydraulic adjustment units includes: a base in the form of a long plate being connected on an outer side to at least one of the pile hole wall supporting and retaining pipes; at least one push plate for closely contacting with an outer surface of the steel plunge column; at least one hydraulic-actuated extendable supporting arm having an end pivotally connected to a lateral side of the base and an opposite extendable end pivotally connected to an end of one corresponding push plate; and at least one set of parallelly spaced pivoted arms respectively having a proximal end pivotally connected to a lateral side of the base and a distal end pivotally connected to a lateral side of one corresponding push plate; whereby when the hydraulic-actuated extendable supporting

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arm is actuated to extend the extendable end thereof, the push plate is moved to push against the outer surface of the steel plunge column while the pivoted arms are moved into an extended position between the base and the push plate, and on the other hand, when the hydraulic-actuated extendable supporting arm is actuated to draw back the extendable end thereof, the push plate is moved away from the outer surface of the steel plunge column while the pivoted arms are moved into a folded position between the base and the push plate, so that the steel plunge column can be adjusted or corrected in position to align with a column centerline in the foundation pile hole and an effective vertical positioning of the steel plunge column in the foundation pile hole during column hoisting and positioning process in the top-down construction can be achieved with the hydraulic adjustment units.

A system for vertical centering and positioning steel plunge column in top-down construction method according to an embodiment of the present invention includes a plurality of hydraulic adjustment units, a plurality of pile hole wall supporting and retaining pipes, a two-way electronic inclinometer, and a computerized digital positioning monitoring system. The hydraulic adjustment units are spaced around a steel plunge column

positioned in a round or a rectangular foundation pile hole. Each hydraulic adjustment unit includes a plate-shaped long base having an outer side for pressing against a wall surface of the foundation pile hole directly or via one or more of the pile hole wall supporting and retaining pipes connected thereto to provide an earth-retaining function, at least one push plate, at least one hydraulic-actuated extendable supporting arm pivotally connected at two ends to the base and the push plate, and at least one set of two pivoted arms respectively pivotally connected at two ends to the push plate and the base, such that the push plate can be supported by the pivoted arm to an inner side of the base and moved by the hydraulic-actuated extendable supporting arm to push against or move away from the steel plunge column for easily adjusting the latter to a vertical position aligned with a column centerline in the foundation pile hole during column hoisting and positioning process. The vertically adjusted steel plunge column can be then connected to an observation column and fixed to a workstation above the foundation piling hole. The two-way electronic inclinometer is mounted on the steel plunge column near an upper end thereof and is electrically connected to the computerized digital positioning monitoring system for measuring any change in the vertical accuracy and displacement of the steel plunge column. Measured results are transmitted to the computerized digital positioning monitoring system for computing and then showing on a monitor and can be printed out for use to ensure precise and perfect vertical centering and positioning of the steel plunge column in the column hoisting and positioning process.

Since the plate-shaped long bases of the hydraulic adjustment units have effectively widened supporting areas, they can provide sufficient earth-retaining strength to the wall surface of the foundation pile hole. The use of the two-way electronic inclinometer and the computerized digital positioning monitoring system avoids the

possible errors in determining the vertical accuracy and displacement of the steel plunge column with the naked eye, and allows the observed and measured data to be transparent and open to the workers for ensuring correct adjustment and positioning of the steel plunge column at different phases in the whole construction process, as well as ensures good construction quality, shortened working time and reduced hazards to the public environment. After the concrete pouring and curing processes, the hydraulic adjustment units can be removed from the foundation pile hole for reuse, which enables lowered construction cost

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

The structure and the technical means adopted by the present invention to achieve the above and other objects can be best understood by referring to the following detailed description of the preferred embodiments and the accompanying drawings, wherein

15 Figs. 1A and 1B show an embodiment of a hydraulic adjustment unit included in the system of the present invention in an extended position and a folded position, respectively;

20 Figs. 2A and 2B are vertical sectional and top plan views, respectively, showing a first embodiment of the present invention, in which multiple hydraulic adjustment units of Fig. 1 are used in a round foundation pile hole;

25 Figs. 3A and 3B are vertical sectional and top plan views, respectively, showing a second embodiment of the present invention, in which multiple hydraulic adjustment units of Fig. 1 are used in a round foundation pile hole;

Figs. 4A and 4B show another embodiment of the hydraulic adjustment unit included in the system of the present invention in an extended position and a folded position, respectively;

- 5 Figs. 5A and 5B show a further embodiment of the hydraulic adjustment unit included in the system of the present invention in an extended position and a folded position, respectively;

10 Figs. 6A and 6B are vertical sectional and top plan views, respectively, showing a third embodiment of the present invention, in which multiple hydraulic adjustment units of Fig. 4 are used in a rectangular foundation pile hole;

15 Figs. 7A and 7B are vertical sectional and top plan views, respectively, showing a fourth embodiment of the present invention, in which multiple hydraulic adjustment units of Fig. 5 are used in a rectangular foundation pile hole;

20 Figs. 8A, 8B, 8C and 8D are diagrams showing the bottom vertical accuracies (%) of a steel plunge column relative to the excavation face observed with the system of the present invention at four different phases of construction; and

Figs. 9A, 9B, 9C and 9D are diagrams showing the bottom displacements (cm) of a steel plunge column relative to the excavation face observed with the system of the present invention at four different phases of construction.

## 25 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described with some preferred embodiments

thereof and with reference to the accompanying drawings. For the purpose of easy to understand, elements that are the same in the preferred embodiments are denoted by the same reference numerals.

- 5 Please refer to Figs. 1, 2 and 3. The present invention relates to a system for vertical centering and positioning of steel plunge column in top-down construction method. As can be seen in Fig. 2, in a first embodiment of the present invention, the system mainly includes multiple hydraulic adjustment units 2 spaced around a steel plunge column 1, which is positioned in a foundation pile hole 6, and a computerized
- 10 digital positioning monitoring system 5. Fig. 1 shows an embodiment of the hydraulic adjustment unit 2 that includes a base 21 in the form of a long plate for pressing against a wall surface 7 of the foundation pile hole 6, a push plate 22 for closely contacting with an outer surface of the steel plunge column 1, a hydraulic-actuated extendable supporting arm 23 having a lower end pivotally
- 15 connected to a lateral side of the base 21 and an extendable upper end pivotally connected to a lower end of the push plate 22, and two pivoted arms 24 respectively having an upper end pivotally connected to the same lateral side of the base 21 and a lower end pivotally connected to a corresponding lateral side of the push plate 22. In Fig. 1A, the hydraulic adjustment unit 2 is in an extended position; and in Fig. 1B,
- 20 the hydraulic adjustment unit 2 is in a folded position. The computerized digital positioning monitoring system 5 is used to monitor a bottom vertical accuracy (%) and a bottom displacement (cm) of the steel plunge column 1 and to make precise correction to any tilt and/or displacement of the steel plunge column 1.
- 25 In practical implementation of the present invention, the hydraulic adjustment units 2 can be manufactured with U-shaped steel, channel steel, H-shaped steel, square steel, half-round steel bar, or round steel. The two pivoted arms 24 are parallelly spaced

from each other with their lower ends connected to and located near an upper end and a lower end of the push plate 22, respectively. As can be seen in Fig. 2B, the hydraulic adjustment units 2 are spaced around the steel plunge column 1 and the bases 21 thereof can function as an earth-retaining structure. Further, the bases 21  
5 of the hydraulic adjustment units 2 can have an earth-retaining length matching a depth of the steel plunge column 1 in the foundation pile hole 6.

By arranging the hydraulic adjustment units 2 around the steel plunge column 1 in the above-described manner during the top-down construction, the hydraulic arrangement  
10 units 2 can provide a vertical earth-retaining function. The bases 21 in the form of long plates provide widened effective earth-retaining areas and accordingly, sufficient supporting strength without the risk of being adversely affected by the soft soil foundation of the pile hole wall surface 7. Thus, accurate vertical positioning of the steel plunge column 1 in the foundation pile hole 6 can be ensured. Further,  
15 after concrete pouring, when the steel plunge column 1 has been correctly embedded and fixed in the set concrete, the hydraulic adjustment units 2 can be removed from the foundation pile hole 6 for reuse.

Fig. 3 shows a second embodiment of the system according to the present invention,  
20 which is different from the first embodiment in having hydraulic adjustment units 2 that respectively have two or more push plates 22, two or more hydraulic-actuated extendable supporting arms 23, and four or more pivoted arms 24.

Both the first and the second embodiment of the system of the present invention are  
25 applied to a round foundation pile hole 6. However, in a third and a fourth embodiment of the present invention, the system is applied to a rectangular foundation pile hole 6, as shown in Figs. 6 and 7, respectively. In the third and

fourth embodiments, the system of the present invention mainly includes multiple hydraulic adjustment units 2, multiple pile hole wall supporting and retaining pipes 3, a two-way electronic inclinometer 4, and a computerized digital positioning monitoring system 5. The hydraulic adjustment units 2 are spaced from one another  
5 in a space between the rectangular foundation pile hole 6 and a steel plunge column 1 positioned therein.

Please refer to Fig. 4, in which there is shown another embodiment of the hydraulic adjustment unit 2 for use in the third embodiment of the system of the present  
10 invention as shown in Fig. 6. In the another embodiment thereof, the hydraulic adjustment unit 2 each includes a base 21 in the form of a long plate having an outer side connected to multiple pile hole wall supporting and retaining pipes 3, multiple push plates 22 for closely contacting with an outer surface of the steel plunge column 1, multiple hydraulic-actuated extendable supporting arms 23 respectively having a  
15 lower end pivotally connected to a lateral side of the base 21 and an extendable upper end pivotally connected to a lower end of one corresponding push plate 22, and multiple sets of two pivoted arms 24 respectively having an upper end pivotally connected to the same lateral side of the base 21 and a lower end pivotally connected to a lateral side of one corresponding push plate 22. In Fig. 4A, the hydraulic  
20 adjustment unit 2 is in an extended position; and in Fig. 4B, the hydraulic adjustment unit 2 is in a folded position. With these arrangements, the upper ends of the hydraulic-actuated extendable supporting arms 23 can be obliquely outward extended to locate the push plates 22 at more suitable positions for pressing against the steel plunger column 1, so that the steel plunger column 1 can be adjusted or corrected in  
25 position to align with a column centerline in the foundation pile hole 6. After it is hoisted and then positioned in the foundation pile hole 6, the steel plunger column 1 is coupled with an observation column 25 via a coupling seat 26, and the system of

the present invention is used to enable easy vertical centering of the steel plunge column 1 to align with the column centerline in the foundation pile hole 6 as well as vertical fixing of the steel plunge column 1 to a workstation over the foundation pile hole 6.

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Fig. 5 shows a further embodiment of the hydraulic adjustment unit 2 for use in the fourth embodiment of the system of the present invention as shown in Fig. 7. The hydraulic adjustment unit 2 in the further embodiment thereof is generally structurally and functionally similar to the another embodiment thereof, except that, in the further embodiment, each hydraulic adjustment unit 2 has only one pile hole wall supporting and retaining pipe 3 connected to a full length of the outer side of the base 21, and can have only one push plate 22, one hydraulic-actuated extendable arm 23 and one set of two pivoted arms 24 connected to the base 21. In Fig. 5A, the hydraulic adjustment unit 2 is in an extended position; and in Fig. 5B, the hydraulic adjustment unit 2 is in a folded position.

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The hydraulic adjustment units 2 according to the another and the further embodiment thereof and the pile hole wall supporting and retaining pipes 3 are also manufactured with U-shaped steel, channel steel, H-shaped steel, square steel, half-round steel bar, or round steel.

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In on-site tests conducted by the inventor, the hydraulic adjustment units 2 having the above-described structures according to the system of the present invention are proven to be workable in vertical centering and positioning of both top and bottom of the steel plunge column 1 in the top-down construction method. That is, with the hydraulic adjustment units 2 of the present invention, the whole body of the steel plunge column 1 can be effectively supported and adjusted in horizontal directions by

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the push plates 22 and the bases 21. Moreover, the horizontal supporting and adjusting forces applied by the hydraulic adjustment units 2 to the steel plunge column 1 can be transmitted from the vertically extended bases 21 or the pile hole wall supporting and retaining pipes 3 to the pile hole wall surface 7. Therefore, the hydraulic adjustment units 2 of the present invention can provide sufficient supporting strength without the risk of being adversely affected by a soft soil foundation, ensuring that an accurate vertical positioning of the steel plunge column 1 in the foundation pile hole 6 can be more easily achieved with the present invention. In summary, by using multiple hydraulic adjustment units 2 and pile hole wall supporting and retaining pipes 3 according to the present invention, the steel plunge column 1 can indeed be adjusted to align with the column centerline in the foundation pile hole 6 and accordingly be more easily and precisely positioned in a vertical direction. After the concrete grout is poured via tremie pipes 31 to achieve embedding and positioning of the steel plunge column 1 in the foundation pile hole 6 and after completion of concrete curing, the hydraulic adjustment units 2 and the pile hole wall supporting and retaining pipes 3 can be removed from the foundation pipe hole 6 for reuse. Therefore, the construction cost is lowered.

Please refer to Figs. 2, 3 and 6 to 9 at the same time. It is necessary to know the vertical accuracy and displacement of the steel plunge column 1 in the foundation pile hole 6 during the steel plunge column hoisting and positioning process and the concrete pouring process. In one conventional way, a theodolite is used to measure the displacement of a column centerline of the observation column 25 on a surface workstation, so as to determine the direction in which the steel plunge column 1 is displaced. In another conventional way, a bubble level is used to indicate the displacement direction of the steel plunge column 1 via the position of a bubble in the level. Both of the above two conventional displacement observation ways rely

on the naked eye to decide the displacement of the steel plunge column. By using these ways, no real-time reliable readings can be obtained during the steel plunge column hoisting and positioning process and the concrete pouring process for use by workers at the construction site. As a result, it is uneasy for the steel plunge column  
5 1 to meet the required verticality.

To overcome the drawbacks in the conventional displacement observation ways, the system of the present invention includes a set of specially developed computerized high-precision digital measuring equipment, which includes the above-mentioned  
10 two-way electronic inclinometer 4 mounted near an upper end of the steel plunge column 1 and the computerized digital positioning monitoring system 5 electrically connected to the two-way electronic inclinometer 4, so that the operation for the vertical positioning of the steel plunge column 1 is completely transparent and shown in data to avoid possible errors due to observation with the naked eye. With the  
15 present invention, the whole process of hoisting and positioning of the steel plunge column 1 can be well controlled through measurement and observation by the two-way electronic inclinometer 4 and the computerized digital positioning monitoring system 5. More specifically, according to the present invention, during the steel plunge column hoisting and positioning process and the concrete pouring  
20 process, the bottom vertical accuracy (%) and the bottom displacement (cm) of the steel plunge column 1 relative to the excavation face are observed and measured at four different phases of the construction, as shown in Figs. 8 and 9. Herein, the different phases include a first phase, at which the steel plunge column is lowered to a predetermined depth; a second phase, at which concrete grout is poured into the  
25 foundation pile hole; a third phase, at which the concrete pouring is completed; and a fourth phase, at which the tremie pipes are removed from the foundation pile hole and the steel plunge column positioning operation is ended. Results from the

observation and measurement at different construction phases are directly computed and analyzed by professional computer software to dynamically provide high-precision real-time data, which together with images of the steel plunge column 1 are shown on a monitor 51 and can be printed out to provide result reports 52.

5 With these arrangements, it is able to monitor in real time any change in the displacement and the vertical accuracy of the steel plunge column 1 during the hoisting and positioning process and the concrete pouring process and to perform real-time correction and adjustment operations. That is, in the whole process of top-down construction, all the steel plunge column positioning-related data are

10 transparent, the vertical accuracy of the steel plunge column 1 is clear and definite, and the correction operations can be timely and precisely performed to enable upgraded construction quality.

From the above descriptions, it can be found the system for vertical centering and positioning of steel plunge column in top-down construction method according to the

15 present invention is novel and practical for use, and is functionally superior to the prior art.

The present invention has been described with some preferred embodiments thereof

20 and it is understood that many changes and modifications in the described embodiments can be carried out without departing from the scope and the spirit of the invention that is intended to be limited only by the appended claims.

What is claimed is:

1. A system for vertical centering and positioning of steel plunge column in top-down construction method being applied to piling operation in a rectangular foundation pile hole, comprising a plurality of hydraulic adjustment units, a plurality of pile hole wall supporting and retaining pipes, a two-way electronic inclinometer, and a computerized digital positioning monitoring system;

the hydraulic adjustment units being spaced from one another in a space between the rectangular foundation pile hole and a steel plunge column positioned in the rectangular foundation pile hole, and having an earth-retaining function; wherein each of the hydraulic adjustment units includes:

a base in the form of a long plate being connected on an outer side to at least one of the pile hole wall supporting and retaining pipes;

at least one push plate for closely contacting with an outer surface of the steel plunge column;

at least one hydraulic-actuated extendable supporting arm having an end pivotally connected to a lateral side of the base and an opposite extendable end pivotally connected to an end of one corresponding push plate; and

at least one set of parallelly spaced pivoted arms respectively having a proximal end pivotally connected to a lateral side of the base and a distal end pivotally connected to a lateral side of one corresponding push plate;

whereby when the hydraulic-actuated extendable supporting arm is actuated to extend the extendable end thereof, the push plate is moved to push against the

outer surface of the steel plunge column while the pivoted arms are moved into an extended position between the base and the push plate, and on the other hand, when the hydraulic-actuated extendable supporting arm is actuated to draw back the extendable end thereof, the push plate is moved away from the outer surface of the steel plunge column while the pivoted arms are moved into a folded position between the base and the push plate, so that the steel plunge column can be adjusted or corrected in position to align with a column centerline in the foundation pile hole and an effective vertical positioning of the steel plunge column in the foundation pile hole during column hoisting and positioning process in the top-down construction can be achieved with the hydraulic adjustment units.

2. The system for vertical centering and positioning of steel plunge column in top-down construction method as claimed in claim 1, wherein the hydraulic adjustment units and the pile hole wall supporting and retaining pipes are made of a steel material selected from the group consisting of U-shaped steel, channel steel, H-shaped steel, square steel, half-round steel bar and round steel.
3. The system for vertical centering and positioning of steel plunge column in top-down construction method as claimed in claim 1, wherein the two-way electronic inclinometer is mounted to a fixed point near an upper end of the steel plunge column and is electrically connected to the computerized digital positioning monitoring system; whereby data and image reflecting any change in the vertical accuracy and the displacement of the steel plunge column in the foundation pile hole as observed and measured via the two-way electronic inclinometer during column hoisting and positioning process and concrete pouring process in the top-down construction at different phases thereof can be shown on

a monitor of the computerized digital positioning monitoring system and printed out for reviewing, enabling high-precision adjustment of the vertical accuracy of the steel plunge column and accordingly upgraded construction quality.