The as-built coordinate data may be used to create a layout of openings in the prefabricated panel.

Abstract: A method of locating anchor bolt openings in a prefabricated panel includes positioning a laser scanner on or near a concrete slab, foundation or other surface. The concrete slab can include a plurality of embedded anchor bolts, pipes, conduits, stubs or other items. As-built coordinate data regarding the concrete slab and the plurality of anchor bolts, pipes, conduits, stubs or other items can be collected using the laser scanner. The as-built coordinate data may be used to create a layout of openings in the prefabricated panel.
Declaration under Rule 4.17:  
— of inventorship (Rule 4.17(iv))  
Published:  
— with international search report  
(88) Date of publication of the international search report:  
31 July 2008  
(48) Date of publication of this corrected version:  
18 September 2008  
Information about Correction:  
see Notice of 18 September 2008
FENTM.OOIVPC

SYSTEM AND METHOD FOR POSITIONING PREFABRICATED PANELS

Cross-Reference to Related Applications

[0001] This application claims the priority benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 60/873,393 filed December 7, 2006, the entirety of which is hereby incorporated by reference herein.

Background of the Inventions

Field of the Inventions

[0002] The present inventions relate to three-dimensional scanning systems and, more particularly, to a laser scanning system and related method utilized in the drilling and positioning of prefabricated panels, structural members and other items used in the construction of a building.

Description of the Related Art

[0003] Prefabricated panels are often used in the construction of certain types of structures. For example, such panels can be used as exterior or interior walls, partitions, flooring, ceilings or other portions that comprise a building or other structure. Typically, prefabricated panels and other similar structural members are secured to a concrete slab using a plurality of anchor bolts. Anchor bolts, appurtenances (e.g., plumbing stubs, pipes, conduits, etc.) and the like can be embedded within the concrete slab before the prefabricated panels are delivered to the construction site. Consequently, even small discrepancies in the positioning of the embedded anchor bolts and other items can complicate the installation of a panel to the slab, another panel and/or any other item.

[0004] For example, if the spacing and pattern of the embedded anchor bolts, pipes or conduits do not match the spacing and pattern of the corresponding openings in the panel, a contractor may have to re-drill holes in the panels on-site and during installation, a process which may be time-consuming and expensive.

Summary of the Inventions

[0005] An aspect of at least one of the embodiments disclosed herein includes the realization that scanners and/or other scanning devices can be used to determine the location of anchor bolts, plumbing stubs, pipes (e.g., water, sewer, etc.), conduits (e.g., electrical,
telecommunications, etc.), pipe supports and other items after they have been installed in a slab. The data from the scanner can then be used for the placement of openings on prefabricated panels for anchor bolts, stubs, pipes, conduits and/or other items. The installation and assembly of such panels can also be further facilitated by generating a three-dimensional model by utilizing such scanner and/or other related technologies. In some embodiments, the scanner, other scanning device or other position detection device comprises a laser scanner.

[0006] Thus, in accordance with at least one of the embodiments disclosed herein, a scanner or other position detection device can be positioned on or near a concrete slab. The concrete slab includes a plurality of anchor bolts, stubs, pipes, conduits and/or other items embedded therein. As-built coordinate data regarding the concrete slab and the anchor bolts can be collected using the scanner. A layout of openings within a construction component for anchor bolts, stubs, pipes, conduits and/or other items can be determined based on the as-built coordinate data. In some embodiments, the scanner or other position detection comprises a laser scanner.

[0007] According to one arrangement of at least one of the embodiments disclosed herein, a system of positioning a prefabricated panel relative to a floor that comprises a plurality of fixed anchor bolts, stubs, pipes, conduits and/or other items includes a scanner or other position detection device configured to scan a surface of the floor and the anchor bolts, and to generate a series of three-dimensional coordinate data. Further, the system can include a processor configured to receive the coordinate data and create a three dimensional surface model. An output device can be configured to visually display a representation of the three-dimensional surface model. The location of the anchor bolts, stubs, pipes, conduits and/or other items relative to each other and to the floor as displayed by the output device is used to create corresponding openings in the prefabricated panel. In some embodiments, the scanner or other position detection device comprises a laser scanner.

[0008] In accordance with a further aspect of at least one of the embodiments disclosed herein, a method of positioning a prefabricated panel can include providing a prefabricated panel and placing one or more positioning markers on a surface of the prefabricated panel. In addition, a laser scanner device can be positioned in visual proximity
with the prefabricated panel. Further, a target set of coordinates can be provided for each positioning marker. The laser scanner device can be configured to visually display, for at least one positioning marker, a laser beam that intersects a point in space having the target set of coordinates. Moreover, the prefabricated panel can be moved to locate at least one laser beam within the corresponding positioning marker.

**Brief Description of the Drawings**

[0009] These and other features, aspects and advantages of the inventions disclosed herein are described below with reference to the drawings of certain preferred embodiments, which are intended to illustrate and not to limit the inventions. The drawings comprise the following figures:

[0010] FIG. 1 illustrates a perspective view of an area defined by a plurality of forms and configured to receive a volume of concrete according to one embodiment.

[0011] FIG. 2 illustrates a perspective view of a plurality of anchor bolts, pipes and conduits embedded within a concrete slab which was poured within the forms of FIG. 1.

[0012] FIG. 3 illustrates a perspective view of an embodiment of a laser scanner positioned on the concrete slab of FIG. 2.

[0013] FIG. 4 illustrates a plan view of a concrete slab in relation to benchmark and laser scanner locations according to one embodiment.

[0014] FIG. 5 illustrates a side elevation view of an anchor bolt embedded within a concrete slab according to one embodiment.

[0015] FIG. 6A illustrates a plan view of a target configured for placement over an anchor bolt according to one embodiment.

[0016] FIG. 6B illustrates a side elevation view of the target of FIG. 6A.

[0017] FIG. 7A illustrates a perspective view of a target configured for placement over an anchor bolt according to a second embodiment.

[0018] FIG. 7B illustrates a perspective view of a target configured for placement over an anchor bolt according to a third embodiment.

[0019] FIG. 7C illustrates a perspective view of a target configured for placement over an anchor bolt according to a fourth embodiment.
[0020] FIG. 7D illustrates a perspective view of a target configured for placement over an anchor bolt according to a fifth embodiment.

[0021] FIG. 8 illustrates a cross-sectional view of an anchor bolt target comprising an electronic marker according to one embodiment.

[0022] FIG. 9 is a schematic illustration of the collection, transfer and application of field data using various devices and systems disclosed herein according to one embodiment.

[0023] FIG. 10 is a flow chart illustrating an embodiment of the operation of the laser scanner and other system components to locate anchor bolt, piping, conduit or other openings within a prefabricated panel.

[0024] FIG. 11 is a perspective view of a prefabricated panel being positioned over a corresponding set of embedded anchor bolts, pipes and conduits according to one embodiment.

[0025] FIG. 12 is a flow chart illustrating an embodiment of the operation of the laser scanner and other system components to accurately position a prefabricated panel on a concrete slab or other surface.

[0026] FIG. 13 is a perspective view of a laser scanner and a prefabricated panel comprising three positioning markers according to one embodiment.

**Detailed Description of the Preferred Embodiments**

[0027] The laser scanning positioning system and the various methods and features associated with it are described in the context of prefabricated panels of a building because they have particular utility in this context. However, the positioning systems and methods described herein, as well as their various systems and features, can be used in other contexts as well, such as, for example, but without limitation, for devices, systems and methods used in the manufacture of other structures, personal property and the like.

[0028] The positioning system discussed herein can facilitate the installation and/or assembly of buildings and other structures comprising prefabricated panels. For example, by gathering and processing as-built coordinates of already constructed concrete slabs and embedded anchor bolts, pipes, conduits, stubs and/or other items, the positioning system can determine the precise locations of the corresponding openings within the
prefabricated panels. This can permit such openings to be accurately drilled before a panel is delivered to a construction site. Consequently, time consuming and costly efforts to re-drill or otherwise modify a prefabricated panel can be reduced or avoided.

[0029] Moreover, the laser scanner can be configured to provide a relatively simple method of positioning and installing panels, structural members and/or other items which otherwise lack adequate points of reference. This can avoid the complex, tedious and sometimes inaccurate field measurements using tapes, transits and other surveying equipment.

[0030] With reference to FIG. 1, a plurality of forms 20 can be used to create an interior volume 24 into which cement, concrete, grout and/or other mortar can be placed. The forms 20 can be manufactured of wood, steel, plastic or any other material. As shown, the forms can be sized, shaped and otherwise adapted to define an interior volume 24 having a desired shape, width, length, depth and other properties. The forms 20 can be positioned so that the interior volume 24 extends below and/or above grade. In some embodiments, the shape, dimensions and/or other characteristics of the interior volume 24 can depend, at least in part, on the panels and/or other items which may be placed on the concrete slab formed therein. Further, wire mesh, rebar and/or other additives can be included in the concrete mixture, as desired or required by a particular application or use.

[0031] FIG. 2 illustrates one embodiment of a slab 40 created from allowing a volume of concrete to set within the forms 20 of FIG. 1. As illustrated, a lower portion 46 of the slab 40 can be situated below grade, and an upper portion 48 of the slab 40 can be situated above grade. Alternatively, the entire concrete slab 40 can be positioned above or below grade. Concrete slabs 40 can be designed to accommodate one or more items that may be placed or attached thereon. For example, the slab 40 can be sized, shaped, positioned and otherwise configured to receive and secure one or more prefabricated panels (not shown).

[0032] With continued reference to FIG. 2, a plurality of anchor bolts 60 or other fasteners, pipes 70 (e.g., potable water, sewer, natural gas, etc.), conduits 80 (e.g., electrical, telecommunications, etc.), stubs and/or other items can be embedded within the concrete slab 40. As shown, an anchor bolt 60 can be positioned within the interior volume 24 of the forms 20 (FIG. 1) so that its threaded portion extends above the top surface 42 of the concrete
slab 40. In other embodiments, one or more anchor bolts 60, pipes 70, conduits 80, stubs and/or other items can be situated along different portions of the slab 40, such as, for example, one or more vertical (side) walls 44.

[0033] The anchor bolts 60, pipes 70, conduits 80, stubs and/or other items can be positioned within a concrete slab 40 using one or more different methods. For example, an anchor bolt 60, pipe 70 or conduit 80 can be embedded in the concrete by being strategically positioned relative to the forms before a volume of concrete is poured. Alternatively, the anchor bolts 60, pipes 70, conduits 80 and/or other items can be installed into the slab 40 after the concrete has been poured. For instance, an opening can be made in the slab 40 to accommodate an anchor bolt 60, piping stub 70 and/or a conduit 80. In such embodiments, grout or other bonding material can be subsequently placed within an opening to secure the position of the item embedded therein.

[0034] With continued reference to FIG. 2, anchor bolts 60, pipes 70, conduits 80, stubs and/or other items can be positioned along a perimeter of a concrete slab 40. As described in greater detail herein, one or more panels (e.g., an exterior wall, an interior wall, a floor panel, etc.) can be subsequently placed over such embedded items and secured to the concrete slab 40. Further, depending on the shape, size and overall design of the structure to be erected thereon, the concrete slab 40 can also comprise anchor bolts 60, pipes 70, conduits 80, stubs and/or other items in one or more interior locations. Thus, the systems and methods described herein can be applied to create openings in both exterior and interior panels.

[0035] In some embodiments, contractors construct concrete slabs 40 with a plurality of anchor bolts 60, pipes 70, conduits 80, stubs and/or other items extending therefrom according to a detailed engineered design or plan. However, there may be discrepancies between an as-built version of the concrete slab/embedded items system and the intended design.

[0036] For example, the dimensions (e.g., length, width, height, etc.) of a constructed slab 40 may vary from the design on which the construction was based. In addition to or in lieu of any dimensional differences, the as-built location and/or spacing of the anchor bolts 60, pipes 70, conduits 80, stubs and/or other items may vary from the intended design. Thus, scanning systems and methods described herein can be used to ensure
that prefabricated panels and the like are accurately and properly customized (e.g., drilled for the required openings) and installed on an already-constructed slab 40.

[0037] With reference to FIG. 3, a laser scanner 100 can be used to collect field data related to a slab 40 (e.g., slab corners, steps, other surface features, etc.), anchor bolts 60, pipes 70, conduits 80, stubs and/or any other feature within its scannable view. As shown, the scanner 100 can be placed directly on top of the slab 40. Alternatively, however, a scanner 100 can be positioned in one or more other locations, such as, for example, the adjacent ground, a platform, another stationary structure or the like.

[0038] Further, the scanner 100 can include legs 120 that securely interface with a bottom support surface. The legs 120 can be adjustable to permit a user to modify their length and/or position. In order to expand its scanning coverage, the laser scanner 100 can be configured to rotate about an axis 110 and/or tilt. A scanner 100 can rotate and/or tilt automatically and/or manually, as desired or required by a particular application or use.

[0039] In some embodiments, it may be necessary to move the laser scanner 100 to another portion of the concrete slab 40 or another location in order to collect field data that are not visible or cannot otherwise be captured from the initial position. Thus, as illustrated in FIG. 4, a laser scanner 100 may need to be moved from a first location 150A to a second location 150B in order to scan the entire targeted area and all the items and features situated therein (e.g., concrete slab 40, anchor bolts 60, pipes 70, conduits 80, etc.).

[0040] With continued reference to FIG. 4, the laser scanner 100 can use two or more known benchmarks 90 to determine its coordinates (e.g., easting, northing, etc.) and elevation. The coordinate data of such benchmarks 90 can be based on one or more standardized spatial coordinate systems, such as, for example, the State Plane Coordinate System (SPCS), the Universal Transverse Mercator (UTM) or the like. In addition to or in lieu of being "tied" to such standardized systems, a benchmark 90 can be based on a local or other non-standardized coordinate system. Alternatively, the benchmarks 90 may not be based on any coordinate system. In some embodiments, a laser scanner or another system component can be configured to convert the collected data from one coordinate system to another.
In some embodiments, a laser scanner 100 is configured to accurately collect field coordinate data pertaining to a slab 40, anchor bolts 60, pipes 70, conduits 80, stubs and/or other features as long as the scanner 100 can determine its own location relative to established benchmarks 90 or other points of reference. Thus, a user may be permitted to selectively reposition a laser scanner 100 without negatively affecting the coordinate data gathering process. Further, the benchmarks 90 can be used to relate the collected coordinate data to one or more other coordinate systems.

As illustrated in FIG. 3, the laser scanner 100 can rotate, tilt or otherwise move to collect field data regarding scanned surface features. For example, the scanner 100 can collect coordinate data related to features (e.g., corners, edges, etc.) of the concrete slab 40, anchor bolts 60, pipes 70, conduits 80, stubs and/or the like. However, depending on its shape, size, exterior features (e.g., threads) and other characteristics, an anchor bolt 60, pipe 70, conduit 80, stub or other item may not be able to provide an adequate surface for laser scanning purposes.

As shown in FIG. 5, an embedded anchor bolt 60 can include a plurality of external threads 62 and a substantially flat upper surface 64. In some embodiments, the anchor bolt 60 comprises a standard outer diameter (e.g., \(\frac{1}{4}\) inch or smaller, \(\frac{3}{8}\) inch, 1 inch, 2 inch, 3 inch or larger, etc.) and a standard thread pattern. Thus, the effective surface area of an anchor bolt 60 which may be detected by a laser scanner can be relatively small. Moreover, the threads 62 can make it additionally difficult to obtain a laser scan of the anchor bolt surface.

Optionally, as illustrated in FIG. 3, some or all of the anchor bolts 60 or other items (e.g., pipes, conduits, etc.) can include a target 200 which can help a laser scanner 100 to more accurately detect the presence of anchor bolts 60 and determine their coordinates. A target 200 can provide a smoother and larger surface area than the anchor bolt 60 to which it is attached, thereby facilitating the laser scanning process. Targets 200 can be shaped, sized and configured to be received by an anchor bolt 60 or other item that is positioned within the concrete slab 40.

Further, pipes 70, conduits 80, stubs and/or other items embedded within a concrete slab can also include one or more targets 200 to facilitate the detection of their
position. In some embodiments, a target 200 can be positioned on top a pipe 70, conduit 80 or other item. Alternatively, targets 200 can be placed at one or more other locations, such as, for example, at or near the point where the pipe 70, conduit 80 or other item meets the concrete slab or other surface.

[0046] With reference to FIGS. 6A and 6B, a target 200 can include a generally circular outer shape. In the illustrated embodiment, the target 200 comprises a plurality of substantially semi-circular projections 210 along its outer surface. Further, the target 200 can include a central circular opening 204 which is configured to receive an anchor bolt 60, pipe 70, conduit 80, stub and/or other item. However, the target can comprise openings that have a different shape, such as, for example, rectangular, triangular, other polygonal, oval, etc. The central opening 204 can comprise interior threads adapted to match the external threads 62 of an anchor bolt 60. Alternatively, the opening 204 of the target 200 can be generally smooth or have other types of features (e.g., bumps, anti-slip members, etc.). Thus, a target 200 can be screwed on or slipped over an anchor bolt 60, pipe 70, conduit 80, stub and/or other item. In other embodiments, a target 200 can be adapted to snap onto or otherwise grasp the exterior, top surface or other portion of an anchor bolt 60, pipe 70, conduit 80, stub and/or other item.

[0047] Further, the targets 200 can help protect the underlying anchor bolts 60, pipes 70, conduits 80, stubs and/or other items. For example, the targets 200 can reduce the likelihood of damaging contact between objects and the anchor bolts 60, pipes 70, conduits 80, stubs and/or other items. The targets 200 can also prevent or reduce the impact of a tripping hazard created by having anchor bolts 60, pipes 70, conduits 80, stubs and/or other items protruding out of the concrete slab 40. According to some embodiments, targets 200 are painted with or manufactured from bright colors to make them more visible to workers and other individuals present in the vicinity of the concrete slab 40.

[0048] Targets 200 can be manufactured from one or more flexible, rigid or semi-rigid materials, such as, for example, plastic, metal, rubber, wood, fiberglass and/or the like. The targets 200 can be durable so that they can withstand water, sunlight, wind or any other elements to which they may be exposed.
[0049] The size, shape, design, internal opening details, external features, manner of interface with an anchor bolt, pipe 70, conduits 80, stubs and/or other projecting item and other characteristics of a target 200 can vary as desired or required by a particular application. For example, a target 200 can include a generally polygonal, multifaceted or other outer shape. In other embodiments, the target 200 can have a generally smooth outer surface and/or a closed upper portion. In still other arrangements, the shape of the inner opening 204 of the target 200 can be non-circular, such as, for example, triangular, square, multifaceted, other polygonal, oval and the like.

[0050] As illustrated in FIG. 7A, a target 200A can have a hexagonal or other polygonal outer shape. The generally flat outer surface segments 220A can allow a scanner to more accurately collect field data related to the target 200A. Likewise, in FIG. 7B, the illustrated embodiment of a target 200B includes a flat surface 220B. The remaining exterior surface 224B of the target 200B can be generally round. In another embodiment, as shown in FIG. 7C, the target 200C comprises a generally triangular exterior shape. The size of the flat exterior surfaces 220C can be similar or different from each other. The shape, size and/or general configuration of a target can be different than illustrated and discussed herein.

[0051] With reference to FIG. 7D, a target 200D can be shaped to include one or more notched portions 218D along its perimeter. As shown, the notch 218D can comprise two inwardly-oriented flat surfaces 220D which meet to form an internal corner 222D. In some embodiments, the flat surfaces 220D is sized and angled so that the internal corner 222D substantially coincides with the centerline of the center opening 204D when viewed from a frontal position. Thus, such a target 200D can allow a scanner to better locate the center of an anchor bolt 60, pipe 70, conduit 80, stub or other item. In such an embodiment, a user can desirably rotate all targets 200D present within a scanned area so that the internal corners 222D generally face the laser scanner.

[0052] FIG. 8 illustrates another embodiment of a target 200E configured for placement over an anchor bolt, pipe, conduit or other item. The target 200E includes an electronic sensor 230 and a lower opening 204E which is adapted to threadably receive an upper portion of an anchor bolt, pipe, conduit or other item. The lower opening 204E can be differently configured so as to receive a portion of an anchor bolt, pipe, conduit or other item.
using a different connection method (e.g., friction fit, snap connection, etc.). As shown, the opening 204E can be configured to extend only partially through the body of the target 200E. Alternatively, the opening 204E can lack internal threads and/or can extend through the entire depth of the target 200E.

[0053] With continued reference to FIG. 8, the electronic marker 230 can be positioned at or near the center of the target 200E. For example, the electronic marker 230 can be embedded within the body of the target 200E, immediately above the opening 204E. Thus, the position of the electronic marker 230 can closely coincide with the center of the adjacent anchor bolt, pipe, conduit or other item. As a laser scanner may not be capable of detecting the electronic marker 230, one or more other types of detection devices can be used to determine the position of the marker 200E.

[0054] Once a laser scanner 100 or other location detection device has been positioned on or near a slab 40, foundation or other surface, the field data collection process can be initiated. As discussed, the position of the laser scanner 100 relative to nearby benchmarks 90 can be initially determined to permit a user to later move the laser scanner 100 to a different location during the data collection process. Further, determination of the scanner's position relative to certain benchmarks 90 can permit the system to interpret and correlate the data provided by two or more different spatial coordinate systems.

[0055] As discussed, a laser scanner 100 can be configured to automatically rotate, tilt or otherwise move to capture the field data of a desired area. The laser scanner 100 can be configured to obtain such field data (e.g., coordinates, elevation, etc.) each time the scanner head incrementally moves. Alternatively, only the laser head of the scanner can be permitted to move during the data collection process. In some embodiments, a user can be allowed to adjust the incremental distance at which new coordinate data is collected. Thus, by selectively controlling the number of laser scans or hits per surface area, a user can effective adjust the "resolution" of a surface scan.

[0056] With reference to the data flow diagram schematically illustrated in FIG. 9, field coordinate data collected by the laser scanner 304 can be saved within one or more data storage devices 308. A data storage device 308 can be internally located within laser scanner 304. Alternatively, the data storage device 308 can be a separate unit that is
connected to the laser scanner 304 using one or more hardwired or wireless connections (e.g.,
wire, wireless communication, using an intermediate linking device, etc.).

[0057] With continued reference to FIG. 9, the collected field data can be
transmitted to a central processing unit (CPU) 316, either directly from the laser scanner 304
or from a data storage device 308. The connection from the laser scanner 304 and/or data
storage device 308 to the CPU 316 can be hardwired (e.g., cable) and/or wireless (e.g.,
digital signal, Wi-Fi, infrared, RFID, Bluetooth, etc.). Thus, a laser scanner 304 can be configured
to transmit the coordinate data to a CPU 316 as such data are collected. Alternatively, a data
storage device 308 can save the field data collected during the scanning process. In such
embodiments, all or some of the coordinate data can be transferred from a data storage device
308 to a CPU 316 at different times. For example, the transfer of data can occur after the
scanning process has been completed, according to predetermined time intervals, after a
threshold time has elapsed, when the user so desires and/or as a result of some other event of
occurrence. As described in greater detail herein, field data received by the CPU 316 can be
used to generate a three-dimensional surface model of the scanned area.

[0058] In addition, a surface model of a scanned area, including a concrete slab
and/or a plurality of anchor bolts, pipes, conduits, stubs or any other items embedded therein,
can permit a user to customize one or more prefabricated panels, other structural members or
the like. For example, the surface model information can be used to manufacture
specially-shaped or specially-sized panels or other structural members which are configured
to accurately interconnect, receive and/or cooperate with anchor bolts, pipes, conduits, stubs
or other items and/or each other. The surface model data can be used in conjunction with
detailed information regarding prefabricated panels or other items configured for placement
on or near a concrete slab. In some embodiments, such information can be combined to
precisely pre-drill or otherwise create the openings on one or more panel surfaces that are
configured to receive anchor bolts, pipes, conduits, stubs or any other items embedded within
a slab.

[0059] Therefore, as shown in FIG. 9, a CPU 316 can help generate one or more
outputs 322 that may assist a user in the manufacture, assembly and/or drilling of panels,
such as, for example, printed engineering drawings or specifications, viewable information on a display (e.g., computer screen, handheld, etc.) or the like.

[0060] FIG. 10 illustrates one embodiment 400 of how a scanning and positioning system can be used to customize prefabricated panels. Once it has been determined that one or more prefabricated panels will be positioned on an already formed concrete slab, a laser or other type of scanner can be positioned on or near that concrete slab 404. As discussed, the scanner can be strategically positioned to maximize the scannable surface area.

[0061] Next, the scanner can be configured to determine its location relative to one or more benchmarks or other points of interest 408. In one embodiment, a benchmark or other point of interest can include a target which can be detected by the scanner. Thus, by determining its relative position to such benchmarks or other points of interest, a scanner may be able to determine its own spatial orientation within one or more coordinate systems. In one embodiment, the laser scanner can scan three benchmarks to adequately determine its location within a particular coordinate system. However, in other arrangements, the laser scanner can determine its position using more or fewer benchmarks or points of interest.

[0062] Alternatively, one or more other methods of determining the spatial position of a scanner can be used. For example, the scanner can comprise a global positioning system (GPS) device or some other satellite-based system for determining its coordinates. In other embodiments, the position of the scanner can be determined using traditional surveying methods and equipment, such as, for example, using survey tapes, transits and/or the like.

[0063] Next, the laser scanner can begin to collect surface data 412 of the concrete slab, anchor bolts, pipes, conduits, stubs, other items and surrounding area. Laser pulses emitted by a laser scanner can reflect off targeted surfaces and return to the scanner. One or more detectors positioned within the scanner can receive the pulses and determine how far a particular pulse traveled based on the time that it took for that pulse to reach the detectors. Thus, the elapsed travel times associated with individual pulses can be converted to distances relative to the scanner. These distances can be further correlated to specific three-dimensional coordinates. As laser pulses are sent and received, a rather large series of coordinate data of surrounding surfaces can be accumulated. If a different type of scanner is
used (e.g., non-laser scanner), one or more other ways of determining the position of the targeted surfaces can be employed.

[0064] As discussed, one or more targets 200 can be placed around or on top of anchor bolts, pipes, conduits, stubs or any other items protruding from the concrete slab or other surface to provide larger and smoother surfaces for reflecting approaching laser pulses or other the like. Thus, such targets can be used to more accurately determine the position of the corresponding anchor bolts, pipes, conduits, stubs and other items.

[0065] After the laser scanner has scanned a desired area, the three-dimensional coordinate data can be transferred to a CPU for further processing. As discussed herein with reference to FIG. 9, the coordinate data can be transmitted to a CPU as they are collected. Alternatively, the coordinate data can be stored in a local or remote memory device before being transferred to a CPU or other data processor.

[0066] Once the coordinate data have been received by a CPU or other processor, they can be processed and used to generate a three-dimensional model 416 of the scanned area. In some embodiments, the accumulated coordinate data are dumped into a software program, such as, for example, AutoCAD, MicroStation or the like. In turn, such a model can be used to generate dimensioned drawings of the scanned area. Thus, a user can use detailed information regarding the location and spacing of anchor bolts, pipes, conduits, stubs or any other items embedded within a concrete slab to advantageously create corresponding openings in prefabricated panels 420 and/or other components of a structure. In some embodiments, such openings can be drilled or otherwise created by a fabrication shop or other facility by using dimensioned engineering drawings generated using the model. In other embodiments, the as-built orientation of the anchor bolts, pipes, conduits, stubs or other items relative to the concrete slab or other surface can be electronically sent to a facility which will be responsible for creating the corresponding openings in one or more prefabricated panels.

[0067] Once delivered to the jobsite, the prefabricated panels or other building components can be positioned over one or more anchor bolts, pipes, conduits, stubs or any other items extending from or located on the concrete slab. The panel can then be fastened in place using the anchor bolts 424 and/or some other method or device. Thus, the as-built
surface model of the slab, anchor bolts, pipes, conduits, stubs or other items can help prevent installation problems once the panels reach the field. Consequently, as illustrated in FIG. 11, openings 510 in a prefabricated panel 500 can be matched with the corresponding anchor bolts 60, pipes 70 and conduits 80 situated below them.

[0068] The scan system described and illustrated herein can facilitate with the positioning and installation of prefabricated panels in other ways. In some embodiments, a scanner can be used to position panels and other structural components that lack a firm positional relationship to fixed points of reference. For example, it may be difficult to accurately position prefabricated panels and other components that form the interior walls of a structure. Unlike exterior panels that are typically secured relative to a plurality of embedded anchor bolts, pipes, conduits, stubs or other items, such "free-floating" panels that form interior walls and the like may require time-consuming and potentially inaccurate surveying techniques for positioning.

[0069] As illustrated in FIG. 13, a "free-floating" panel 700 can include three positioning markers 710 along one or more of its surfaces. In other embodiments, a prefabricated panel 700 can include more or fewer than three positioning markers 710. Positioning markers 710 can be placed on the surface of the panel 700 when the panel is being manufactured. Alternatively, position markers 710 can be placed on the panel 700 at a subsequent time (e.g., after manufacture or assembly of the panel has been completed). In other embodiments, the markers 710 are shaped or otherwise positioned directly into a panel wall. Alternatively, positioning markers 710 can be separate members that are securely attached to the surface of a panel 700. For example, the positioning markers 710 can be connected to the panel using adhesive materials (e.g., glue), fasteners, welds, rivets or any other method or device.

[0070] In the embodiment illustrated in FIG. 13, the positioning markers 710 have a generally circular shape. However, in other embodiments, the general shape, size and/or other characteristics of the positioning markers 710 can be different, such as, for example, rectangular, triangular, oval and the like. In some arrangements, the positioning markers 710 comprise an interior image (e.g., "X," cross, crosshair, etc.) that can be used to fine-tune the position of the panel.
FIG. 12 illustrates one embodiment of how a scanning and positioning system can be used to locate one or more "free-floating" panels on a concrete slab or other surface 600. As discussed, positioning markers can be situated on one or more surfaces of a prefabricated panel 604.

Using engineering plans or other detailed drawings, the ideal or targeted three-dimensional coordinates of each positioning marker can first be determined 608. Thus, the location of all the positioning markers can be accurately shown in the design drawings for a particular structure. For additional clarity, each positioning marker can be given a unique identifier, which, as discussed herein, can be subsequently entered into the scanner to assist in the positioning procedure.

Next, the three-dimensional coordinates of all the positioning markers can be provided to the laser scanner 612. This can be accomplished by downloading the desired coordinates of each of the positioning markers, along with their unique identifier where available, from a CPU to the scanner. In some embodiments, the scanner can be updated via a hardwired or a wireless connection. The laser scanner can be updated either instantaneously (e.g., real-time) or intermittently, as desired or required by a particular application or use. For example, once the exact three-dimensional coordinates of the positioning markers have been determined (e.g., based on engineered models or drawings), the targeted coordinate and other data can be wirelessly or otherwise transmitted to a laser scanner.

A laser scanner can then be positioned within an unobstructed scanning range of the positioning markers of the target prefabricated panel 616. The panel can be generally positioned in the approximate vicinity of where it is shown according to the engineered model or drawings. In the embodiment illustrated in FIG. 13, the laser scanner 100 is positioned immediately in front of the panel 700 so that it faces the three positioning markers 710.

As discussed herein with respect to other embodiments, a laser scanner can be configured to calculate the coordinates associated with its own position. This can be accomplished by comparing its location to that of known benchmarks or other reference points. Preferably, the scanner can be further adapted to correlate the coordinates of its own
position to the spatial coordinate system of the engineered model or drawings. Alternatively, the coordinate data corresponding to the positioning markers uploaded to the scanner can be correlated to the spatial coordinate system used by the scanner. Regardless, such cross-correlation of data can ensure that the coordinates measured by the scanner and the target coordinates provided to the scanner from the engineered model or drawings are based on a single, identical spatial coordinate system 620.

[0076] In some embodiments, a user can instruct a laser scanner to display laser beams towards one or more positioning markers 624. This can be accomplished by entering the unique identifiers associated with each desired positioning marker. Thus, a user can modify the position and/or orientation (e.g., horizontal position, tilt angle, etc.) of a prefabricated panel until the laser beam emitted by the scanner falls within the target positioning marker.

[0077] For example, a user can move the panel horizontally relative to the ground surface. In addition, a user can tilt or rotate a panel. As discussed, the position of the panel can be fine-tuned by ensuring that the beam falls directly within certain crosshairs or other fine-tuning target. In one embodiment, in order to ensure that the panel has been properly positioned relative to all three dimensions, beams emitted from the scanner can hit their corresponding targets in at least three positioning markers. However, in other embodiments, more or fewer positioning markers can be used to position a particular panel.

[0078] After a panel has been properly positioned, it can be secured to the slab or other surface 628. The panel can be secured to a ground surface (e.g., concrete slab), to other adjacent panels (e.g., floor panels, vertically-oriented panels, roof panels, etc.) and/or any other member or surface, as desired or required. The panel positioning process can be repeated for additional panels, depending on the complexity of the building or other structure being constructed. In some embodiments, depending on the design of a particular structure, it may be desirable or necessary to move the laser scanner in order to position other panels.

[0079] In some embodiments, the positioning markers and the laser scanner positioning system described herein can be used to position one or more items or features on the surface of a panel. For example, the scanner can be configured to indicate the position of openings along a vertical surface of a panel. In other embodiments, the markers and scanner
can be used to indicate the exact location of attachment of certain fasteners, tabs, latches, supports, aesthetic or ornamental features, other structural members (e.g., cross-bracing, plates, etc.) or the like.

[0080] The methods and systems disclosed herein can be used to accurately locate and create openings within one or more panel surfaces. As discussed, such openings can be configured to receive anchor bolts, pipes, conduits, stubs or any other items whose position is fixed relative to a concrete slab or other surface. Although interior and other "free floating" panels may not require anchor bolt openings, openings can be located and created for any pipes, conduits, stubs or any other items extending from a corresponding area of the concrete slab. As illustrated in FIG. 13, an interior panel 700 can include one or more openings 730 that will receive pipes, conduits and any other items positioned on or within the concrete slab.

[0081] Although the embodiments disclosed herein are discussed with reference to a laser scanner, it will be appreciated that any other type of device capable of determining a spatial position can be used, such as, for example, infrared scanners, other optical scanners and/or the like.

[0082] Although these inventions have been disclosed in the context of a certain preferred embodiment and examples, it will be understood by those skilled in the art that the present inventions extend beyond the specifically disclosed embodiment to other alternative embodiments and/or uses of the inventions and obvious modifications and equivalents thereof. In addition, while several variations of the inventions have been shown and described in detail, other modifications, which are within the scope of this invention, will be readily apparent to those of skill in the art based upon this disclosure. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments or variations can be made and still fall within the scope of the invention. It should be understood that various features and aspects of the disclosed embodiment can be combined with or substituted for one another in order to form varying modes of the disclosed invention. Thus, it is intended that the scope of the present inventions herein-disclosed should not be limited by the particular disclosed embodiments described above.
What Is Claimed Is:

1. A method of locating at least one opening in a construction component, the method comprising:
   - positioning a scanner on or near a concrete slab, the concrete slab comprising a plurality of members embedded therein and extending upwardly therefrom;
   - collecting as-built coordinate data regarding the concrete slab and the plurality of members using the scanner; and
   - determining a layout of openings in a construction component based on the as-built coordinate data.

2. The method of Claim 1, wherein the scanner comprises a laser scanner.

3. The method of Claim 1, wherein the construction component comprises a prefabricated panel.

4. The method of Claim 1 additionally comprising the steps of transferring the as-built coordinate data to a processor and generating a surface model of the scanned concrete slab and members.

5. The method of Claim 4 additionally comprising the step of generating a printout that indicates the layout of openings for the members in a construction component.

6. The method of Claim 1 additionally comprising the step of creating openings in the construction component according to the layout.

7. The method of Claim 6, wherein the step of creating openings comprises drilling.

8. The method of Claim 1 additionally comprising the step of positioning a target member on at least one of the members.

9. The method of Claim 8, wherein the target member comprises a cap configured to threadably engage an anchor bolt.

10. A system of positioning a prefabricated panel relative to a floor comprising a plurality of fixed members extending upwardly from an upper surface of the floor, the system comprising:
    - a scanner configured to scan a surface of the floor and the members, and to generate a series of three-dimensional coordinate data;
a processor configured to receive the coordinate data and create a three-dimensional surface model; and

an output device configured to visually display a representation of the three-dimensional surface model;

wherein the location of the members relative to each other and to the floor as displayed by the output device is used to create corresponding openings in the prefabricated panel.

11. The system of Claim 10, wherein the scanner comprises a laser scanner.

12. The system of Claim 10, wherein the floor comprises a concrete slab.

13. The system of Claim 10, wherein the output device is an electronic display screen.

14. The system of Claim 10, wherein the output device is a paper printer or a plotter.

15. The system of Claim 10 additionally comprising at least one target member, the target member configured for placement in contact with an anchor bolt embedded in and extending upwardly from the upper surface of the floor.

16. The system of Claim 15, wherein at least a portion of the exterior surface of the target member is substantially smooth.

17. The system of Claim 15, wherein the target member is configured to threadably engage the anchor bolt.

18. The system of Claim 15, wherein the target member comprises at least one flat surface.

19. A method of positioning a prefabricated panel, the method comprising:

   providing a prefabricated panel;

   placing at least one positioning marker on a surface of the prefabricated panel;

   positioning a laser scanner device in visual proximity with the prefabricated panel;

   providing a target set of coordinates for each positioning marker, the laser scanner device being configured to visually display, for at least one positioning
marker, a laser beam that intersects a point in space having the target set of coordinates; and

moving the prefabricated panel to locate at least one laser beam within the corresponding positioning marker.

20. The method of Claim 19, wherein at least one positioning marker is attached to a surface of the prefabricated panel using an adhesive.

21. The method of Claim 19, wherein at least one positioning marker is formed within the prefabricated panel.

22. The method of Claim 19, wherein the prefabricated panel includes at least three positioning markers.

23. The method of Claim 22 additionally comprising moving of the prefabricated panel until a laser beam is located in each of the three positioning markers.

24. The method of Claim 23 additionally comprising securing the prefabricated panel to the floor with an anchor bolt.
FIG. 8
POSITION A LASER SCANNER ON OR NEAR A CONCRETE SLAB TO BE SCANNED

DETERMINE THE LOCATION OF THE LASER SCANNER RELATIVE TO ESTABLISHED BENCHMARKS

COLLECT AS-BUILT FIELD DATA REGARDING THE SCANNED AREA, INCLUDING THE COORDINATES AND ELEVATIONS FOR THE CONCRETE SLAB, ANCHOR BOLTS,PIPES, CONDUITS, STUBS, ETC

GENERATE A 3D AS-BUILT MODEL OF THE SCANNED SURFACES AND ITEMS

DETERMINE A MODIFIED PATTERN FOR OPENINGS LOCATED ON A PREFABRICATED PANEL TO BE POSITIONED ON THE CONCRETE SLAB

INSTALL THE PREFABRICATED PANEL ON APPROPRIATE PORTION OF CONCRETE SLAB AND FASTEN THE CORRESPONDING ANCHOR BOLTS

FIG. 10
ATTACH POSITIONING MARKERS ON A SURFACE OF A PREFABRICATED PANEL

USING THE DETAILED DESIGN DRAWINGS, OBTAIN THE 3-DIM COORDINATES OF EACH POSITIONING MARKER TO A MARKER ACCORDING TO A SPATIAL COORDINATE SYSTEM (ASSIGN A UNIQUE IDENTIFIER TO EACH POSITIONING MARKER)

INDICATE THE 3-DIM COORDINATES OF THE POSITIONING MARKERS TO A LASER SCANNER

POSITION THE LASER SCANNER WITHIN SCANNING RANGE OF THE PANEL'S POSITIONING MARKERS

INSTRUCT THE LASER SCANNER TO DETERMINE ITS POSITION RELATIVE TO THE SAME SPATIAL COORDINATE SYSTEM USED IN THE DETAILED DESIGN DRAWINGS

INSTRUCT THE LASER SCANNER TO PROJECT A LASER BEAM AT ONE OR MORE POSITIONING MARKERS OF THE PANEL BY ENTERING THE CORRESPONDING UNIQUE IDENTIFIERS FOR THOSE MARKERS

POSITION AND INSTALL THE PREFABRICATED PANELS

FIG. 12

SUBSTITUTE SHEET (RULE 26)
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 07/86826

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G01C 15/00 (2008.04)
USPC - 33/286

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
USPC - 33/286

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 33/286; 52/745.1, 782 1 ? text word limited ? see below

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST (PGPB.USPT.EPAB.JPAB); Google Scholar
Search Terms: laser scanner, dimension, coordinate, marker, concrete, panel, anchor, bolt

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 20060193688 A1 (Albritton) 31 August 2006 (31.08.2006) see entire doc, esp figure 23</td>
<td>1-24</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C

1. Special categories of cited documents
   "A" document defining the general state of the art which is not considered to be of particular relevance
   "B" earlier application or patent but published on or after the international filing date
   "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
   "O" document referring to an oral disclosure, use, exhibition or other means
   "P" document published prior to the international filing date but later than the priority date claimed

2. "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
   "X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
   "Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
   "K" document member of the same patent family

Date of the actual completion of the international search
28 May 2008 (28.05.2008)

Date of mailing of the international search report
09 JUN 2008

Name and mailing address of the ISA/JS
Mail Stop PGT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No 571-273-3201

Authorized officer. Lee W. Young

Form PCT/ISA/210 (second sheet) (April 2007)