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Application of 3-D CAD and 3-D coordinate meter in frame erection

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Abstract

A method for applying 3-D CAD design tool and 3-D measuring device in frame erection is described. The method links together the design data of the building and the as-built measurement data. The Cartesian measurements for each points on the site can thus easily be defined. The preparatory phase of the element assembly takes the advantage of the check measurements by calculating the clearances between different elements in three dimensions and saves them into the memory. In the assembly this assembly data is further corrected with the element dimension data.

1. INTRODUCTION

Position determination in 3-D coordinates, that is the xyz-position, is needed in many stages of the construction process. Therefore, a measurement system frame for construction sites is needed to provide a possibility to link the design data to the construction process. This kind of unified coordinate system can form a grid over the whole site and thus it can also be used for integration of measurements from different measurement devices. Currently, the design of a building can be performed by using a 3-D CAD design tool running in work stations or even in PCs. These CAD design tools are usually based on rectangular and right-hand coordinate systems. After the design of the building the CAD system is used only to plot the drawings of the building on a paper. These drawings are utilised in different measurements during the building process on the construction site /2/.

At present, coordinate measurement are usually based mainly on traditional devices due to high prices of advanced devices. The measurement results are not usually available immediately and not in xyz-coordinates. In recent years advanced theodolite- as well as laser-based coordinate meters have been developed for determining xyz-coordinate points. The development of these devices has made it possible to apply them in the construction process. Their accuracy is also enough for most construction measurement tasks. Although these devices are used to some extend either in the prefabrication plants or on the construction sites, methods for linking the CAD model of the building to the site measurements are underdeveloped.

In this paper a method on the application of 3-D CAD model and 3-D measuring device in frame erection is described. First, an example building has been designed by using a 3-D CAD software tool which is fully three dimensional and is based on the object oriented design. With the aid of this tool all the element related data both the drawings for production and the assembly schemes for their erection can be produced. A 3-D coordinate measuring device can be linked to the 3-D CAD model to give measuring points of the building in the xyz -coordinates of the 3-D device. By taking the advantage of this connection the operator can prepare a list of measurements. After the foundation work has been completed the columns can be erected and the operator can make quality measurements to check the real position and pose of the erected columns. This as-built measurement data on the real position and pose of columns is fed to the erection software together with the design data obtained from the 3-D CAD model. Based on this information the erection software calculates the instructions for the operator to be utilised in the assembly of wall elements. The operator saves these instructions into a hand computer. These instruction are still corrected with the real element data red from the escort memory inside the element to give more exact erection information on line for the operator.

2. UTILISING 3-D CAD IN 3-D MEASUREMENTS ON THE CONSTRUCTION SITE

2.1 Coordinate frames

Coordinate frames play an essential role in three dimensional design tools as well as in three dimensional measurement systems. A building on the site has to situate on a certain location as well as the rooms, corridors, windows, doors and other components have to situate on defined locations in the building. For the location of the building on the site the municipal authorities will define the position on the site in a three dimensional coordinate frame.

The measurer with his 3-D measuring device usually defines a new coordinate system from the geographical one by using special coordinate transformation. He defines the origin such that on this construction site the values of the coordinates are always positive. The directions of x-coordinate axis is along the line of the building and y is perpendicular to x axis. The direction of the y axis depends on the measuring device, and it can be either a left- or a right-hand coordinate system. Further, he can define more than one coordinate system depending on the shape of the building. .

The building has been designed with the aid of a 3-D CAD design tool applying usually a rectangular and right-hand coordinate system where x-coordinate is along the side of the building, y perpendicular to x axis according to the right-hand system and z grows upwards.

2.2 Tool for 3-D CAD modelling

The 3-D CAD software tool used in this work is based on modular thinking. The tool includes a module for making the frame of the building and an other one for the element design. This program package is called GIDES, and it runs under OS/2 in a standard PC environment /5/. The first step in the model design is to define a suitable module grid for the building. This grid is usually based on the colonnade lines of the building skeleton. The grid is three-dimensional and grows upwards from zero level located on the foundation level. After the grid has been completed the designer can start to design columns. GIDES contains a set of basic construction elements in 3D-primitives. There are for instance different types of columns, beams, slabs and wall elements. The user specifies proper dimensions and coordinates for a certain primitive which then becomes a visible element.

2.3 Instrument for 3-D measuring

The 3-D measurements were carried out with the most advanced optical coordinate meter Acmeter MC, which is especially designed for large scale assembly in shipyards by Prometrics Ltd. Acmeter MC, Fig. 1., measures the coordinates in terms of radial distance with pulsed time-of-light principle and two angles with optical encoders resulting in optimal moving geometry. Being a real one user coordinate meter the measurements are possible to perform without any prism as a target, only the normal diffused surface or cheap diffuse Acman sticker is needed. The accuracy of the coordinate meter is 1 mm (rms) in the measurement range of 3-30 meters and 2 mm (rms) up till 60 meters in xyz-coordinates.

As Acmeter MC is an integrated part of the ACMAN system (Integrated Accuracy Control System) the design data can be used to guide the user during the measurement process. A measurement is an easy task with the automatic focusing of the optical system, which also includes the coaxial red pointing laser for marking and guiding during assembly process. Having efficient methods for calibration to the object coordination, the user gets the difference between the designed and measured coordinate values immediately at the measurement site. The ACMAN system has software with a database and analytical tools for further analysis of the measurement results.

Used Acmeter MC is manually operated system, which limits its use to normal 3-D static measurements. The possibility to use pre-programmed sequences or automatic tracking of the object could extend the feasibility of a 3-D coordinate meter also to dynamic measurements during assembly.

Figure 1. Acmeter MC: An optical coordinate meter.

2.4 Linking 3-D CAD model and 3-D measurement device

CAD-programs are usually designed for right-hand coordinate systems. Some different output formats (DXF, TIFF, IGES) for data transfer between different programs exist, but there is no chance to save specified points in user defined coordinate systems. This saving operation is essential for proper use of different measuring devices. The GIDES 3D-CAD design tool applied in this project contains a function which allows the user to make formatted file of selected points. This function asks for two points in the 3D-model and the corresponding points which have been measured on the construction site. After this have been done the user can digitise all necessary points on the screen with the mouse. The function calculates a conversion matrix from the 3D-model to the user specified coordinate system and uses this matrix to convert digitised points to that system.

3. FRAME ERECTION

3.1 Erection of columns

The measurer defines the exact location and height for the set of bolts of every column in the foundation work phase. After casting the locations for the sets of bolts are checked and corrected if not inside tolerances. Then the columns are erected by lifting them with the aid of a crane to their places. The erectness is set either by using a level, a plumb line or two theodolites. The facade line for the columns is also set as straight as possible. After erecting the whole line of columns the worker uses his eyes for checking the straightness.

3.2 Check measurements

Usually no check measurements are done on the construction site after the worker has erected the columns and they look good for the human eye. However, the columns are never in upright position, but each column is inclined to some direction. Therefore, a check measurement for each column was performed after the erection. Performing the check measurement for high rise columns with ordinary 3-D measurement devices like to prism measuring theodolites is not a simple task especially at the upper end of the column, since someone has to climb to the column to set a measurement point there. In the Acmeter system case, a measuring point, a small piece of paper, can be glued in advance at the upper end of each column. This makes it more easily possible to perform check measurements for the location and erectness of columns. In this way the exact location and pose of columns can be obtained and saved into a file. In checking the location and pose of columns the measurer also measures and saves the height (the z-coordinate) of the foundation for the concrete elements at the points of columns. Hence, all the necessary data except the dimensions of the precast concrete wall elements for preparing the assembly of the elements are at hand.

3.3 Element assembly

Before starting to assemble wall elements into their places, the advantage of the 3-D CAD - and 3-D check measured data was taken. The elements have their designed locations in the building they should also be assembled as accurately as possible to their nominal places. By combining the design data and the as-built data obtained from check measurements, Fig. 2., the gaps between the foundation and the bottom of the element at the point of each column can be calculated giving thus the thickness of wedges to be set on the foundation before assembling the element on the foundation with the aid of the crane. In the same way the gap between the column and the element can be calculated to give the amount of wedges. Correspondingly, before assembling the first element the starting line can be marked to define the third coordinate. Thus, the assembly information for each element can be prepared beforehand by taking the full advantage of the 3-D data. In this way the check measured data is used as a feedback information in the erection process. The prefabrication of concrete elements takes also the advantage of the Acmeter-System. The planning of elements is performed in a CAD system, and this planned data is fed to the Acmeter-System to guide the part fabrication and mould assembly, and after casting for quality control /4/. In this project escort memories were put into the concrete element while pouring the concrete mass into the moulds. After concrete curing a quality control including element check measurements will be performed. The dimension data of the elements obtained in quality control was written into the escort memories inside each element. for late use in the erection process. Thus, the assembly information obtained by combining the 3-D CAD data and the 3-D check measurement data can further be corrected by reading the element dimensions from the escort memory inside the element and correcting the erection data by the element data. In this way the 3D- CAD design data and the real as-built data can be exploited in the frame erection process.

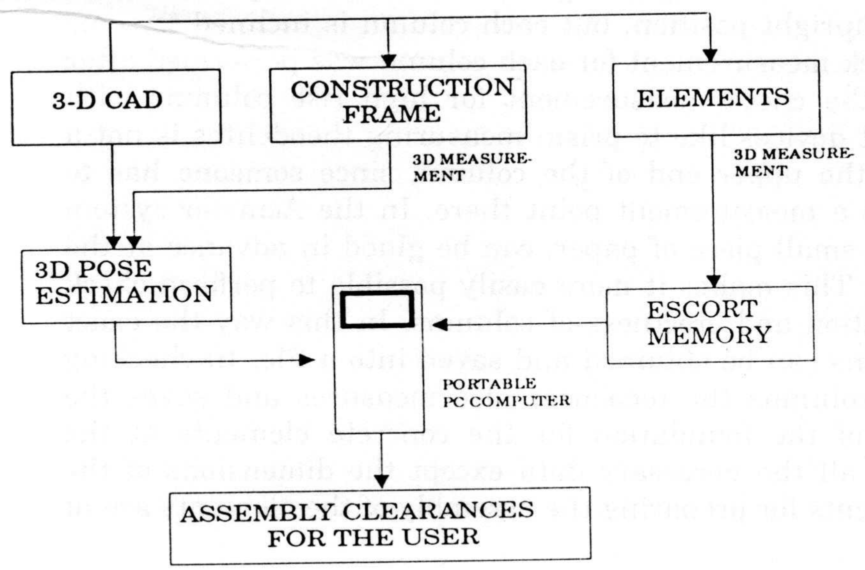

Figure 2. Information flow in assembly.

4. EXPERIMENTATION OF THE ERECTION

4.1 Example building

For testing the method to apply 3-D CAD and 3-D measuring device in the frame erection an example building project was set up. The test environment contains a floor element of concrete, three steel columns and three concrete wall elements. The columns are standing on the floor element and the wall elements are attached to the columns. The 3-D model of the building is seen in Fig. 3. and it was designed by using the GIDES 3-D CAD design tool /5/.

4.2 Frame erection

The columns were erected to their places with the aid of the crane and set to their upright positions by ordinary means with the aid of the level. After erection of the columns their real location and pose were measured together with the height of the element foundation with the 3-D measuring device. Then the design information was combined with the as-built measured data to give the clearances (joints) between the element and the foundation as well as the element and the column for wedge settings. This data was input to the PC for later use in the element assembly. When the elements to be assembled with the aid of the crane come, the element dimension data was read from the escort memory to the PC, and the assembly data was further updated with the element dimension data to give corrected gaps for wedge settings. Then the wedges were set first on the foundation to define the height of the element and after that the element was put down onto the wedges taking at the same time care of the location of the end of the element to the point of the side line. When the element was put down on the

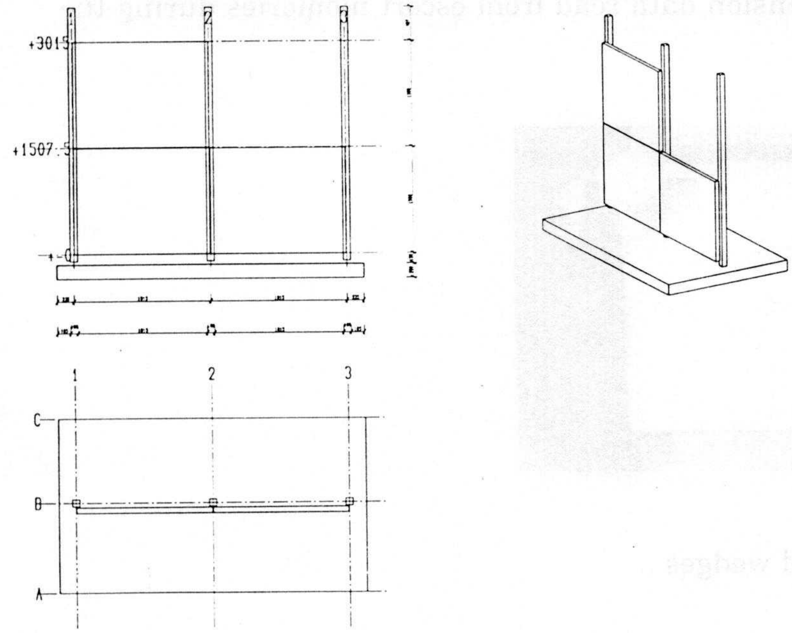

Figure 3. The 3-D CAD design of the example building.

wedges on the foundation the wedges between the columns was set to define final location of the element before fixing it to the columns, Fig. 4. In the assembly of the next element on top of the former assembled one the clearance between the elements is corrected with the element dimension data to give the amount of wedges between elements.

4.3 Evaluation of the assembly

After the element assembly a check measurement was curried out to evaluate the quality of the erection. The location of each corner of the elements was measured with the 3-D measuring device, and compared to the locations designed in the 3-D CAD tool. A tool for checking the Cartesian positions for the corners of the elements was designed and implemented, Fig. 4., to easily curry out the check measurements. The results were then combined to those obtained from the CAD model. In the example erections the assembly accuracy of the elements was within 2 mm.

5. CONCLUSIONS

A method for taking the advantage of the 3-D CAD model and 3-D coordinate meter in the frame erection has been described. The building was modelled by an existing 3-D CAD tool. For on site 3-D measurements a software module was integrated into this tool to make it possible for the measurer to easily prepare a list of measurements and save them into the memory. A method for combining as-built measurement and CAD model data was developed for the preparation of the installation work. This installation data was further corrected by taking into consideration the element dimension data read from escort memories during the installation process.

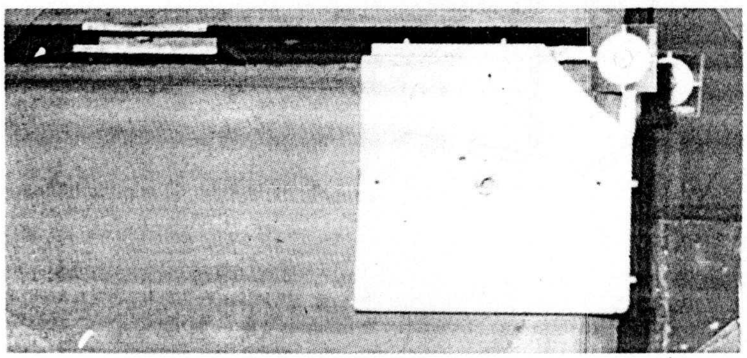

Figure 4. Measurement tool and wedges .

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