MODELING MEASUREMENTS AND MEASURING MODELS – PROBLEMS AND SOLUTIONS OF 3-D GEOMETRICAL CONTROL IN CONCRETE BRIDGE ENGINEERING

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Abstract: The paper introduces a model and procedure of 3-D geometric process for concrete bridge engineering. New 3-D CAD design tools and 3-D measurement methods were developed and tested in the several real bridge construction projects in Finland during 2001-2004. The paper describes these observations and suggests the first conclusions for future developments as well as more expansive utilization especially in bridge construction in Finland.

Keywords: concrete bridge design, 3-D CAD, 3-D measurements

1. INTRODUCTION

One of the key problems in concrete bridge engineering is the information break between design office and site measurements. Another key problem is the use of 2-D design methods and drawing CAD tools for design instead of advanced 3-D modeling possibilities. In the paper this problem and its development possibilities are considered based on the results of an R & D project "Intelligent Bridge" carried out in Finland 2001-2004.

2. MODELLING THE DESIGN AND MEASUREMENT PROCESS OF BRIDGE ENGINEERING

In the project MicroStation was used as a software environment for the application development. New 3-D modeling methods were developed and tested. The determined new CAD tools were programmed by utilizing the newest 3-D modeling features of MicroStation. The most essential working applications are different extrusion tools, with which most of the different types of bridge parts can be modeled. The functionality of the 3-D design and measurement systems was tested through several real bridge projects in Finland during 2001-2004. The tests are further continuing.

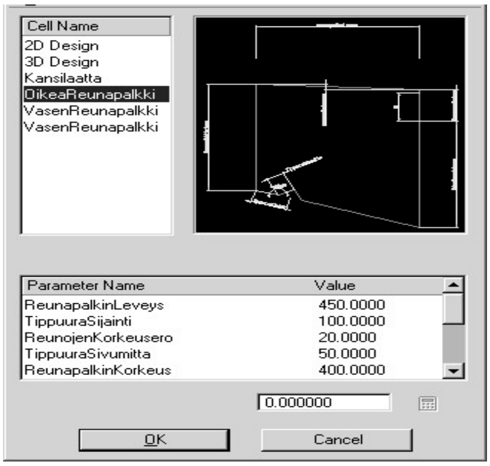

Figure 1. User interface of the 3-D bridge design application: each of different profiles of total bridge structure are separately modeled using 3-D road lines as well as digital terrain model as initial data. The needed dimensions for objects were entered by the aid of parameterized variables.

In the later phase of the process, the designed solid models were directly utilized in site measurements, where robot tachymeters as well as 3-D laser scanners were used. Dimension measurements were tested by using a real-time connection with the design model. The deformations of concrete structures as well as mould ones were anticipated. First tests were executed by transferring the anticipated coordinates directly to the tachymeters used.

In addition two different methods to generate a superimposed surface or solid structure of bridge were studied. In the control measurements also laser scanners were used. The observed 3-D points and point clouds were transferred and connected to the design model using the same CAD analysis software. Also real-time connection between the site measurements and the design model was used. Finally the measured points and point clouds were analyzed by modeling them, if necessary, into 3-D geometric elements and comparing them to the design models. The 3-D deviations were calculated according to the principles of the bridge tolerances.

3. RESULTS

One of the most essential changes will be happened in concrete bridge design. The change from earlier 2-D drawing-oriented design methods to new 3-D modeling methods with new tools seems however to be quite fluently for designers. On account of the first design cases clear benefit was evaluated to be obtained with the 3-D method already just in the design office.

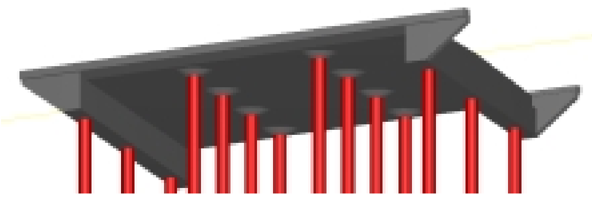

Figure 2. An accurate 3-D solid model of concrete bridge for the next drawing generation and site measurement phases.

Different bridge modeling tools to help bridge designer to work more effective were developed. On account of these tools the most typical concrete bridges having not demanding geometries can be modeled. The cases having complicated variable geometries set always more demands for design. Therefore also more design time will be needed. However, in such cases the benefits of 3-D modeling methods can be more and more utilized.

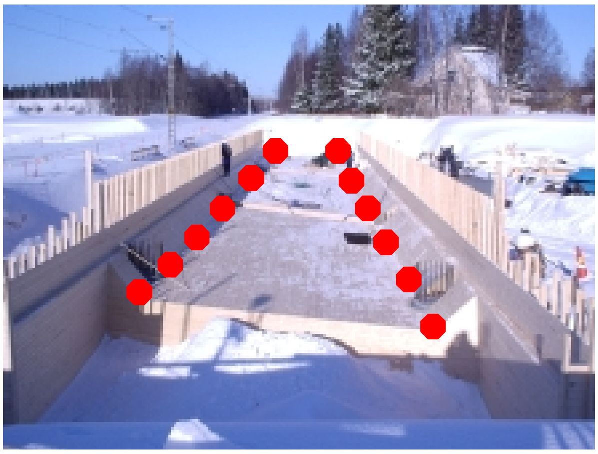

Figure 3. An example of the points needed in practice for mould construction: the angle lines of mould surfaces by the aid of 3-D points with 2 m intervals.

The next challenge is to transfer 3-D bridge model to control site operations. The Fig. 3 describes a group of the points needed for mould construction. In addition the 3-D lines of the edge beams were needed also with suitable intervals. it is essential that the model of super imposed structure is needed in this working phase. This means that the points must include the anticipations of estimated structure deformations as well as mould deformations during concrete processing. In practice this can be done by changing *z* coordinates of the points. The dimension measurements were executed with a tachymetry.

Figure 4. Controlling the accuracy of bridge mould by Cyrax laser scanner - Varkaus.

The accuracy control of complete mould was executed by Cyrax laser scanner (Fig. 4). The 3-

D point cloud must be compared to the model of super imposed structure.

Figure 5. Controlling the accuracy of concrete bridge structure - Suonenjoki.

The accuracy of complete concrete structure was controlled by Cyrax laser scanner (Fig. 5). In the bridge measurements done in the project, the average work consumption has been about 4 hours per a bridge. In addition, one hour was needed for point clouds registration and if wanted, 2 hours for 3-D modeling of the point clouds with Cyclone tool of the Cyrax system.

Figure 6. Measurement of an old bridge - Tampere.

On interesting test was a measurement of an old bridge, which was decided to be continued (Fig. 6). The surfaces of the bridges were measured by a Cyrax laser scanner. The point clouds were registered together and further modeled by Cyclone. The next phases are the calculation of 3-D deviations of the bridge comparing the point cloud to the bridge design model. This means that the model must be first designed on account of the old 2-D drawings. The next step is then to design the 3-D model of the continued bridge. This will be done during the autumn 2004.

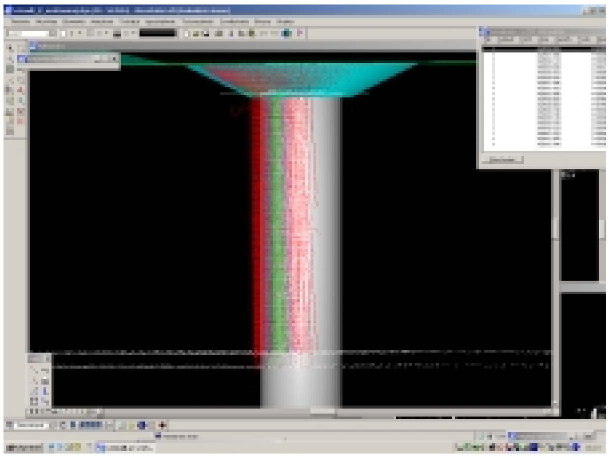

Figure 7. An example of the comparison of point cloud to the solid model of the bridge: the deviations are automatically calculated point by point and further clarified graphically by the aid of different colors. The deviations are the shortest distances from points to the solid.

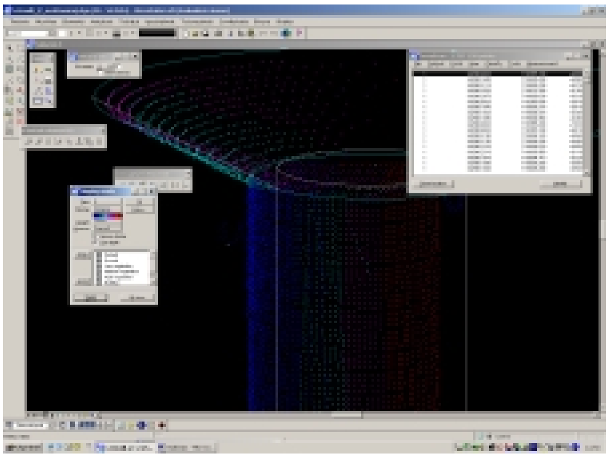

Figure 8. Comparing point cloud to the solid model of column.

4. CONCLUSION

According to the test results this new 3-D concept seems to be very efficient in the domain of concrete bridge engineering. Working in 3-D space was evaluated to decrease design errors. The labor productivity of design work was evaluated to be improved. Still more important was proven to be the possibility to connect models directly to 3-D site measurements. This eliminates transfer errors due to human factors and format conversions.

According to the test the real-time connection between CAD and measurement devices is useful. Its is possible to dimension arbitrary 3-D points to the bridge site and structures. In future it will be also possible to develop more intelligent into real-time measurements. For example, it would be possible to automatically identify the designed coordinates from the solid model on account of the measured coordinates and then calculate the deviations. Also laser scanners with possibility to measure the 3-D forms and dimensions with point clouds seem also to have a very great utilization in bridge engineering. On of the next challenges is the regeneration of the bridge tolerance determinations (SYL specifications) in Finland.

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