INTEGRATION OF MEASUREMENT SYSTEMS BY USING GPS

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Abstract: In the framework of Halftime a research program of HBG and TNO tests were carried out with GPS measurement systems on different machinery. On two building sites in the Netherlands the GPS measurements were performed with a paver and a piling rig. In the horizontal plane the accuracy of RTK GPS was sufficient for both processes. With the use of the same measurement system for different machinery a virtual grid can be laid upon the building site.

Keywords: GPS, Paving, Piling, HALF TIME

1. INTRODUCTION

A research program of TNO and Holland Beton Group (HBG) was founded with the main goal to reduce the production time of building with 50%. This program is called HALF TIME. The program is divided in two major subprograms.

- The research with respect to time reduction in different aspects of building and construction. The topics in this subprogram were organisation of building, technical innovations, IT and extreme solutions.
- The implementation program. In this program the lessons learned from the former subprograms will be implemented in existing building projects.

One of the research topics within the technical innovations is positioning and identification. Members of the research group for this topic came from HBG Woningbouw (house building), NGT (piling), HWG Civiel (paving and earthmoving), HAM (dredging) and TNO Building and Construction Research.

This paper deals with the research on integrating measurement systems of different machines. First the background of the research is discussed. Secondly there is a consideration of test cases. After that the actual tests are presented. A discussion of the results and some concluding remarks will finish this paper.

2. BACKGROUND

On a building site different contractors have to perform several survey operations. For surveying they use their own measuring equipment with different technologies. If it is possible to use one system for the different contractors efficiently and with sufficient accuracy, this will have the following advantages:

- less measuring data conversion,
- reuse of reference points,
- reference points will not be disturbed
- a better understanding of tolerances

These advantages should also lead to reduction of costs and reduction of time due to surveying. Another advantage which is even more important is the reduction of time and costs due to building failures which are the results of measuring problems.

Besides the different measurement systems mentioned above there is a tendency to integrate measurement in the machinery for automatic or partly automatic control. An advantage of this is for instance the possibility for electronic data exchange with CAD systems. It is also possible to exchange data of the ‘as build’ situation. With this information

it is possible to bias the theoretical CAD information with the actual environmental situation created by preceding processes. In figure 1 a schema of this method is shown. The 'as build' situation can be derived from quality control measurements done by a separate survey or measurements performed by the machinery during production itself.

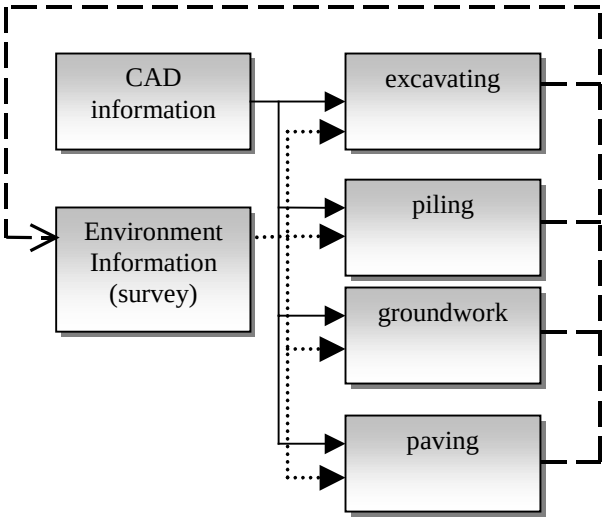

Figure 1. Schema of data exchange.

3 DEFINITION OF TEST CASES

In order to find out if it is profitable to use the same measurement system on different machinery, two totally different machines were chosen. One a piling rig and the other a paver. The reason for choosing these machines was based on two aspects:

- The partners involved in the project use this machinery and have an experienced crew for these machines available.
- These machines are expected to work with a higher accuracy than other equipment like bulldozers and cranes in groundwork and structural work.

After choosing the equipment the desired accuracy of the processes involved had to be determined. For piling the accuracy has was based on the common house building practice in the Netherlands. This accuracy is +/- 50 mm in the horizontal plane.
The accuracy for paving was a little bit more complicated. In today's practice the accuracy is based on comfort so there is no direct measurement accuracy for a location. In practice a grid of 5 to 10 meter on the road is used in the horizontal plane to determine the height. The height is measured with an accuracy of approximately 5mm but the horizontal position of this location is probably not better than 100mm.
Given that there was only a precision defined in the horizontal plane for piling, the research was limited to horizontal positioning of the machinery.
Considering the accuracy needed for both processes there were several possibilities for measurement systems. One of the systems was real time kinematic GPS, the measurement system chosen.

A concept of using GPS on a building site

In figure 2 a possible approach of RTK GPS on a building site is shown. In this picture a paver and a pilling rig can be seen. Both machines are equipped with two RTK GPS rovers in order to find out the position and the heading of the machines. On a high stable point on the construction site the RTK GPS base station is situated. Both the rovers on the paver and on the piling rig receive the corrections sent by the base station. The baseline that can be used with RTK GPS without loosing accuracy is in the range of 1.5 km. This is enough for the most building sites in the Netherlands.

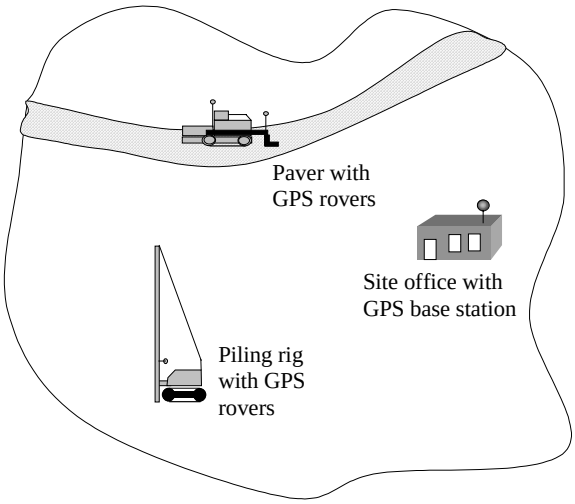

Figure 2. Overview of the building site

4 THE TESTS

Although it was desired to test on one location with the different machines this was not possible. Therefore the test have were done on different locations.

4.1. Test with piling

Equipment

In figure 4 there is a photograph of the piling rig. In this picture the two antennas of the GPS system can be seen. The GPS system that was used consisted out 3 Ashtech GG24 GPS /Glonass receivers. Two of the receivers were used as rovers and one was used as a base station. The GPS stations were connected by a radio link. The software used for the test was a

modified version of navigation and survey software of HAM dredging.

Figure 3. Overview of the building site in Delft.

The location

The location used for the test was a normal house building location in Delft. There were no extra facilities or adjustments made to the building ground for the tests. An overview of the building site is shown in figure 3.

Figure 4 Equipment on the piling rig

The test

During the normal preparation of the building site, pickets were placed on the location for pilling. The position of the pickets was checked with total station measurements. Where placing of the pickets had not been correctly, this was repaired. The RTK GPS base station was mounted on one of the high positions available on the building site.
During the first tests the crew placed the pile with the currently used method. After placing the pile the middle of the pile was determined by total station measurements. The middle of the pile was also calculated from the GPS data. During piling the GPS data were recorded. The other tests carried out were placing the piles by the driver of the rig with help of information on the screen. The locations of all the piles of the building site were available in the software in RD co-ordinates (Dutch datum). Here all GPS data were logged during piling too.

4.2 Test GPS with paving

Equipment

The paver was equipped with the same type of GPS system as the piling rig. (These were Astech GG24 GPS/Glonass receivers). On the paver 2 GPS receivers were placed with a radio link as rovers. A GPS base station was placed on the roof of a site office. Besides the GPS system the paver was equipped with a laser guiding system for height measurement and a wheel for distance measurement. The equipment is partly shown in figure 5. In this figure the PC's used can be seen. One was for logging the GPS information with navigation software the other for the ASCOS program that was used for calculating position height information for the automatic machine guidance on the paver.

Figure 5 Equipment on the paver

The location

The location for the paving test was a road in a housing development project. It was an open field adjacent to the town of Enkhuizen (The Netherlands). The preparations for paving on the location existed of a prepared sand bed with holes with a max depth of approximately 10 mm, pickets and a chalk line as information for travel direction.

The test

For the test the paver operated with automatic machine guidance with data from ASCOS. The height for pavement was derived from the laser guidance system and the measuring wheel gave the travelling distance. During this normal operation the RTK GPS measuring system was used to log the whole operation. In addition surveys of the paver during standstill were made with a total station.

5 RESULTS AND DISCUSSION

5.1 Results of the piling experiment

The results of the piling experiments show that there was a time period (27% of total experiment time) that the GPS information was not locked. During that period the signal was not good enough for positioning. This problem was most likely caused by 'multipath' due to the low positions of the GPS antennas. By placing the antennas on top of the rig this 'multipath' could be eliminated but then there is the need for accurate sensors to determine the exact point on the ground. Another way to eliminate 'multipath' is to make the GPS receivers deaf for the reflected satellites in the shadow of the rig. At the moment this option is not available on the receivers.

The horizontal position of the pile determined with GPS was within an accuracy of 3 cm with the position determined by total station measurements.

During the period of driving the pile into the ground there was time enough to determine the location of the pile with the GPS equipment. These measurements can be used for automatic quality control and can also be used to record the as build situation.

The two GPS antennas on the piling rig were not only used to determine the heading of the rig. The distance between de antennas was used as an integrity check of the signals. This internal quality check worked very well.

The fine positioning with the present working method using a picket took approximately 7 seconds for the experienced crew of the piling rig. This positioning time will not be shortened with the GPS configuration that was used during the experiments because of the fact that the refresh rate of the position was 1Hz.

5.2 Results of the paving experiment

During 99% off the paving operation there was a locked RTK GPS signal.

The measurements of the laser measurement system were affected during operation by trespassing equipment from other contractors on the building site. Also the compactor had influence on the integrity of the laser measurement set-up.

The measurement wheel had a distance measurement fault of 6 cm on 10 meters. The horizontal GPS position had an accuracy of +/- 1cm. The height accuracy of the laser configuration had an accuracy of approximately 5 mm.

5.3 Discussion

The accuracy in horizontal plane of the GPS systems used is sufficient, for both processes tested. Therefore the theoretical information available for piling and paving can be coupled. The machines can use the same GPS base station, which prevents a mismatch of the measurements for both operations. Also other machinery with the same particulars, as piling and paving machinery, on speed and accuracy of process can be equipped with GPS systems.

By using a real time measuring system it is possible to monitor the position of processes. This information can be used for quality assurance and for recording the as build situation. The registered as build situation can be used to correct the theoretical starting point for the following processes without extra surveying.

In the processes itself there are no possibilities for time reduction by the use of quicker position measuring systems. The time reduction must be achieved by the integration of survey in the process and by reduction building failures due to measurement problems.

6 CONCLUSIONS

For both tested machines GPS can be used for measurements in the horizontal plane with sufficient accuracy.

For relatively slow movements GPS can be used for automatic or semi-automatic machine guidance.

The placements of the GPS antennas should be carefully chosen. The maximum reliability for receiving the signal should be taken into account and the way to determine the working point of the machine too.

In an environment with sufficiently open skies GPS can be used as a measurement system for different machines. With this approach a virtual grid can be laid upon the building site.

A virtual grid upon the building site can be filled with theoretical data from CAD systems and completed and updated with actual measured data from process logs.

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