

LASER SCANNING APPLIED TO HYDRAULIC MODELING

A. J. Evans

Topcon Europe Positioning B.V. Essebaan 11, LJ 2908, Capelle a/d IJssel, The Netherlands
Andrew.Evans@topcon.eu

Commission V, WG V/3

KEY WORDS: Laser Scanning, Field procedures, Channel modelling,

ABSTRACT:

It is often stated that: one person's noise is another's signal. This paper explores the exploitation of the laser returns from the perceived nuisance object that is water.

One of the interesting side-effects of laser scanning is the laser's reaction with water. As hardened terrestrial scanner users will know light rain is often not a concern, whereas heavy rain can result in a measured rain-storm, whilst perfectly flat, mirror-like conditions will produce a geometry perfect reflection of the subject. Which on first glance and when not expected can be a little alarming! Usually there is no return from the water; this in itself has many advantages when measuring the water-object interface for certain projects.

Returning to the inconvenient results from working in heavy rain and extending the application of this characteristic, the author has investigated the effects and usefulness of measuring standing waves and turbulent water such as that found on white-water rivers. The results prove to be effective and although noisy it is possible to derive wave shapes and heights, imply pool depths and water levels, all with the advantage of remote non-contact measurement. Consequently if it is possible to take measurements from a scale-model of a channel then we have a tool that can validate at 1:1 the results derived from scaled open channel hydraulic models.

The objective of a scaled hydraulic model is to create a hydraulic similarity between the flows in the model and the flows in the proposed whitewater channel (once completed). This is to say that the behavior of the fluid particles in the model should be similar, but scaled in magnitude to the behaviours in the completed whitewater park. Currently the method of extracting model data is relatively labour intensive, and also limited to the sections designated by the engineers. Hence it may be possible to not measure key information through the choice of section position.

The results from a laser scanner survey could theoretically generate a very accurate and complete model that the engineers are then able to interrogate at any time and through any section position. There are many advantages post event, given the installation requirements for a scale model it is rare that the model can be kept working and available for the duration of the design project, any measurement mistakes need to be identified or corrected post-data collection relying solely on the engineers expertise. A 3D computer model takes up no physical storage space and can be analyzed at any time after measurement. Techniques also exist for the quick and simple extraction of sectional data.

The author was invited to measure a 1:10th scaled white-water course in May 2009 to explore this laser scanning method and see whether a measurement technique could be applied to extract the information required, the physical model was one of the most comprehensive ever built and the measurement results have provided some compelling data that verifies the design.

1. INTRODUCTION

1.1 Aims and Motivation

The motivation for this paper is to prove a working theory and show a method for validating laboratory models. It is the first opportunity that the author has had to work on this type of model before construction in true-scale. Following construction in 2010 of the modelled channel in 1:1 scale it should be possible to prove that measurements at 1:10th scale do scale up and can be measured at 1:1.

This paper will briefly describe the method used to achieve the model measurement and discuss some of the preliminary results derived from the model, including the rapid measurement and recording of parts of the channel that were re-modelled during the testing of the scale model.

1.2 Concept and Rationale

Laser scanning (scanning) is currently redefining the 3d measurement methodology. Time on-site and personnel requirements are reduced yet the amount of data collected is considerably higher. The key element of scanning is a "measure once use many times" mentality that ensures data rich measurement sets. A side effect of this is the requirement to reduce the data set down to usable information. This lends itself to an entire separate study - but a common statement is that data processing is deemed to take at least 10 times the field work time. Lately this time has been reduced thanks to user expertise and significant software improvements but also to intelligent field-operations that work to minimize unnecessary data collection.

One of the key advantages of pulse scanners over phase is the capability to select objects and resolutions to scan versus the 'scan everything' mentality that equates to a similar time on site but ensures that you measure only the data you need.

Whilst it is possible to measure more points than you need with a high accuracy (approaching 4mm distance accuracy and 6" angle accuracy for a point) there are some interesting issues when measuring with scanners.

Water exhibits similar properties to glass when scanned. It is possible to measure through glass or have the laser deflected achieving no return or even getting a perfect reflection that can confuse the data extraction process somewhat. This paper examines an interesting characteristic of laser measurement to water specifically the reaction with "broken" or "white" water.

The author noticed the reflection of the laser with water in 2005 and experimented with measurement to moving water in 2007. Follow-up work showed that it was possible to measure very complete models of water surfaces with laser scanners, but hardware and the requirement for pc control made the practical implementation of this technique difficult. Recent advances in hardware design have made site operation much easier and considerably more effective, particularly with the capability to use the scanners as stand-alone units.

Clearly there are many potential applications from the measurement of water surfaces (Milan, 2009; Large & Heritage, 2007), the author has chosen to work on one particular area, the measurement of hydraulic structures and whether laboratory models can be validated in the real-world, this has required proof of concept at a smaller scale.

In May 2009 the author was invited to test the theory on a 1/10th scale model of a white water channel that was created for part of the design process for a channel that will be built during 2010. This offered the opportunity to measure at scale and at real world size at a later date.

The key challenge however was how to measure the water surface at the small scale.

2. METHOD

2.1 Instruments

A Topcon GLS-1000 Laser scanner was used for measurement in the laboratory. Standard laser scanning survey procedure was followed for measuring the channel, three locations were used and three states of flow of the channel were used. The data was coordinated using resection from a set of fixed targets surrounding the facility.

A key advantage of using the GLS-1000 was the capability to work via an ad-hoc WiFi network; this ensured that the author was not subjected to the harsh environment created by the pumps used to create water flow. It was possible to see the scan data measured in real-time from an office environment.

2.2 Field Procedure

Pre-site experimental work was required to select a suitable additive to ensure that it would be possible to measure the "broken" water surface on a small scale. The resulting additive had the following characteristics: it floated "flush" on the surface; was not a material that "clumped" together over short time period and could be easily removed after the measurement was completed.

During the course of the day on-site the channel was measured in three different states: empty; with the design water flow; and with the design water flow including the reflective additive.

Working with the reflective additive proved to be more problematic than expected due to pooling of material in the eddies (reverse currents in the flow). It was necessary to utilise a significant amount of labour to ensure continuous material addition to ensure good coverage in all parts of the water flow.

Fortunately measurement times for the scanner were in the region of a few minutes, so the required physical effort was for short periods of time.

Following completion of the field-work the data was registered using the Topcon ScanMaster software to create a pointcloud of the channel and the water surface.

The registered model was then analysed using Topcon ImageMaster and AutoCAD with the kubit Pointcloud software to check model measurements against the channel design.

3. RESULTS

Whilst we are not able to validate the model results against the actual channel at this stage, it has been possible to compare the model measurements at 1:10th scale to the channel design.

3.1 Model versus Design Wave height

It was possible to take direct measurement in known locations on the course and compare the laser scan data measurement against the expected design size. The most important elements on a white-water channel such as that modelled are the depths of water and also the wave height.

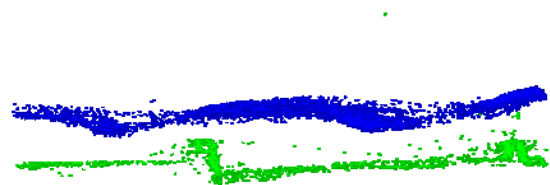


Figure 1 Water Surface and Channel Combined

Figure 1 shows the wave shape and channel long section through one of the pools on the course. The measurements peak-to-trough for the waves matched the design dimensions for the waves, although it is clear that interpretation of this data requires experience of both pointcloud analysis and the character of white-water. The right-hand trough in figure 1 ties to a trough to peak measurement of 50mm. The design height at real-scale for this wave is known to be 0.5m, so at this stage the results are suggesting that the measurement technique should deliver the expected results.

The advantages of working with a 3D pointcloud are illustrated by the Figures 2 & 3. It is very easy to explain how the wave forms are created and see their shape from varying viewpoints. Figure 2 shows the view looking directly upstream.

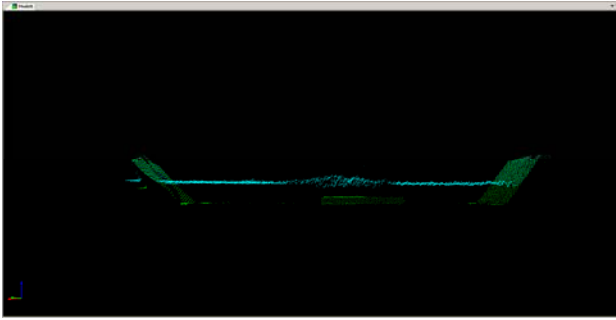


Figure 2 Looking Upstream

Figure 3 shows the same part of the model, surface in blue and channel in green, but from a more descriptive angle.



Figure 3 Wave View

3.2 Channel Model

During the testing phase, the course testers highlighted a flaw in the original design that it was envisaged would cause problems when built at real-world scale. Dimensions were taken on site, but the derived 3D model proved to be the best record of the change. The required 4 minute scan time collected more than adequate data to extract the basic course shape as shown in figure 4.



Figure 4 Modified Section drafted in CAD

This “sketch” was used to record the modifications and apply them to the original design.

3.3 Modelling

The most effective way of displaying the data was to create surfaces from the point cloud. Figure 5 shows part of the channel that has been triangulated but not rendered.

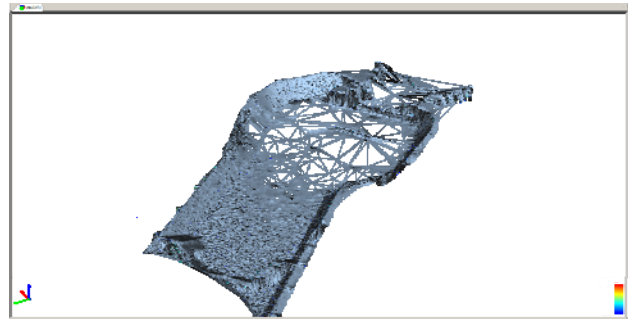


Figure 5 Triangulated Channel model

Figure 6 shows the same part of the channel with the water surface rendered and multiple sections extracted to give emphasis to the wave shape. The centre part of the channel clearly shows the waves caused by the channel features

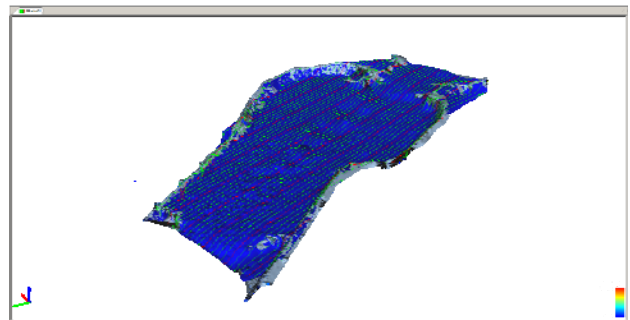


Figure 6 Multiple sections through the water surface

4. CONCLUSION

This paper has described and shown results of applying laser scanning to the measurement of scaled water channels. The findings show that the model design could be measured and that the expected wave heights could be validated using terrestrial laser scanning.

The use of a suitable reflective additive has given the desired result and it is now time to validate the measurement method at the real word scale.

The channel will be built during 2010 and it will be measured on completion with the same configuration of channel obstacles as found in the scaled model. This is a one time opportunity as the obstacles in the water have been designed to be re-configurable, it is expected that the real-scale validation will match to the modelled version and the results will be presented in a later paper on this subject.

ACKNOWLEDGEMENTS

The author wishes to thank Topcon Europe, Andrew Laird of EPDUK and Scott Shipley of S2O Design for their continued support of this project.

REFERENCES

Large ARG, Heritage GL. 2007. Terrestrial laser scanner based instream habitat quantification using a random field approach. *Proceedings of the 2007 Annual Conference of the Remote Sensing & Photogrammetry Society*, Mills J, Williams, M (eds), The Remote Sensing and Photogrammetry Society, CD-ROM.

Milan, D.J. 2009. Terrestrial laser scan-derived topographic and roughness data for hydraulic modelling of gravel-bed rivers. In Heritage, G.L., Large, A.R.G. *Laser Scanning for the Environment Sciences*. Wiley-Blackwell. ISBN 978-1-4051-5717-9, p133-146.