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# Transport infrastructure monitoring: Testing of the NIODIM optical displacement monitoring system at the Sihlhochstrasse bridge in Zürich, Switzerland.

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A gound based optical displacement monitoring system, "NIODIM", is being developed by Norsk Elektro Optikk in the framework of the activities of the European project "Integrated System for Transport Infrastructure surveillance and Monitoring by Electromagnetic Sensing" (ISTIMES), funded in the 7th Framework Programme (FP7/2007-2013). The optical displacement monitoring system has now participated in two real life field campaigns one in Switzerland and one in Italy. The test campaign in Switzerland during a week in May 2011 will be presented below.

The NIODIM system is based on a camera part mounted on firm ground and this camera is imaging a reference point, normally a light emitting diode (LED) which is supposed to be mounted on an object susceptible to move or oscillate. A microprocessor based unit is processing the acquired images and is calculating the displacement.

The Sihlhochstrasse bridge is placed on concrete pillars in the river Sihl in Zürich and the motorway is one of the entrance routes to the city. A site visit had been performed in advance and it had been decided to mount the camera part as well as the processing unit at the lower part of the pillar above the relatively dry riverbed. The reference point in form of a light emitting diode was to be mounted below the bridge deck. However, due to practical access limitations it was not possible to place the reference LED in the middle between pillar pairs, but the LED had to be placed closer to next pair of the pillars downstream the river thus increasing the distance and possibly reducing the potential displacement. A lower signal due to reduced sensitivity (length) and due to lower deflection (better support from the pillar) had to be expected. The system would be powered by a generator placed on the riverbed.

Arriving at the river front the fist day of the field trials was a surprise to most the campaign members. Due to heavy rain the week before, and in particular up in the mountains, the water level in the river was about one metre higher than expected not to mention the strong current. To be on the safe side I had brought my waders with me, but it was hardly possibly to walk in the river. Problems are to be solved and a trip to the nearest shopping centre buying climbing ropes in the sports department and a children's paddling pool in the toys department expanded our toolbox significantly. The paddling pool was used as a barge for transporting the equipment out in the river to the pillar. We were able to install the equipment as planned, but somewhat delayed due to all the water in the river. A climbing rope was attached to the pillar with one end and the other end attached to the riverbank. Power and network cables were attached to this rope.

Tests started the second day saving raw data from the camera to allow for later re-processing. Raw data storage was in the form of small images, one image for each frame i.e. one raw image file for each frame and at a rate of 64 Hz. The tests went on as expected for a while until the system performance dropped unexpectedly from 64 Hz to around 1 Hz. After some help from our main office we found out that our problem was due to the file creation performance of the file system NTFS when many files were present in one catalogue. By automatically sending commands to the processing unit to save files to new catalogues approximately every 10000 frames the system performance was back at the expected 64 Hz. After these initial problems with performance related to the NTFS file system the optical displacement monitoring system behaved as wanted for the remainder of tests.

Based on the look of the bridge i.e. it looks robust and stable, we would not expect large oscillations due to the traffic on top of it. The mount point for the reference LED was also not ideal for observing potential oscillations. Due to the use of standalone generators for power generation measurements were only performed during the day and not during the night. The results with regards to short duration peaks is in line with the expectations namely within 1 mm displacement. However, a larger, long time constant displacement was registered during a certain time frame before noon on sunny days. A displacement of more than 10 mm was registered for a time interval in the order of one hour or more. This larger displacement decreased and the displacement was back on an even slower time-of-day, periodic looking displacement variation. If we disregards the larger “before noon” displacement the long time constant displacement is in the order of 2-3 mm one sunny day and in the order of 5 mm the second sunny day.

The above results have been analysed with regards to different contributions to the long time constant displacement and three candidate causes have been targeted; thermal effects in the mounting brackets, thermal effects related to the pillar and thermal effects in the bridge deck. The time-of-day periodic displacements (2-5 mm) is most likely due to thermal effects in the bridge as a whole or the bridge deck. On the other hand the larger displacements (>10mm), around 1 hour duration before noon, could be caused by the mounting brackets or possibly the pillar. Both the pillar and the camera with mounting brackets of a temporary nature were exposed to direct sunlight in the affected time interval. However, we have not been able to fully explain the displacement seen based on the pillar and the mounting brackets, but we doubt it could be caused by bridge movement alone.

From a development project point of view the tests have been successful; we have both learned some new lessons and demonstrated that the system works not to mention that we have demonstrated for the general public passing by in Zürich that scientists are also able to solve practical problems and cross rivers when required.

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