ACCURATE MEASUREMENT OF RUNWAY PAVEMENT GEOMETRIES

J. GRANLUND & E. WEDIN
Swedish Road Administration, Consulting Services, Sweden
johan.granlund@vv.se
M. CLAEZON, R. LUNDGREN & N-E NYQVIST
The LFV Group, Swedish Airports and Air Navigation Services, Sweden

ABSTRACT

Pavement unevenness brings safety risks. One example is that excessive Runway roughness impact negatively on winter operations, with increased ice and snow contamination reducing the aircraft's brake friction. When planning a costly pavement geometry repair, large savings can be made by optimal grinding and levelling works. Accurate measurement of the existing pavement geometry is then a condition to relevant design and volume calculation. In a long-term joint project, the LFV Group, Swedish Airports and Swedish Road Administration have developed and evaluated a method for cost-effective high fidelity pavement geometry measurement. The new measurement method provides the demanded accuracy. It also increases the resolution hundredfold; depicting any significant local bumps that might exercise "forced" control on asphalt machines. Design-related discussions with the paving contractor, such as on volumes, are minimized. The on-site measurement time has been cut from several days to some hours, thereby reducing disturbance to traffic operations. These advantages can bring great savings. Busy airports may benefit much from the reduced on-site time.

1 IT IS IMPORTANT TO MEASURE AND REPAIR PAVEMENT UNEVENNESS

UNEVENESS IS HAZARDOUS

Runway unevenness brings several safety risks, such as [1]:

- When the aircraft wheels bounces up, the reduced wheel load will result in less drag load from the braking action.
- When the wheel bounces down, tire deflection can "trick" the antiskid system by a false indication, since the systems speed calculation is based on constant tire diameter.
- The pilot's ability to maintain a constant brake pressure is reduced.

In cold climate, excessive Runway roughness also impact negatively on winter operations. Increased ice and snow contamination then reduce aircraft brake friction.

A photo from a very uneven and thus hazardous Swedish Runway is shown in Figure 1.

Figure 1 – Example of hazardous Runway unevenness

ACCURATE PAVEMENT GEOMETRY MEASUREMENTS IS A CONDITION

A condition for many airfield pavement repair projects is accurate geometry measurements, in order to:

- select a suitable repair method,
- optimize the asphalt works,
- calculate a relevant repair budget,
- control the paving works into a high level of quality.

2 OBJECTIVES

Since asphalt is costly, savings can be made by designing the optimal grinding and levelling works, using the calculated volumes in the enquiry document's bill of quantities and then purchasing the asphalt construction works at fixed price - without adjustment to outcome production volumes. Such a contracting strategy requires the pavement to be accurately measured. No existing measurement method meets relevant accuracy requirements. Therefore a new measurement method had to be implemented.

The new measurement method relates to a pavement repair procedure being patented by SRA Consulting Services [2].

When drafting the method for use on airfields, the objectives included increased accuracy and resolution in measurements, as well as reduced disturbance to aircraft operations.

3 PAVEMENT GEOMETRY MEASUREMENT - TRADITIONAL VS NEW METHOD

TRADITIONAL LAND SURVEY METHOD

Traditionally, the Runway pavement geometry is measured with traditional stationary land survey equipment. An example is the geodetic total station showed in Figure 2. The field survey takes several days and disturbs intensive aircraft traffic.

Figure 2 – Traditional stationary land survey

The measurements are taken in a grid with sides 5 or 10 m long. A 10 * 10 m grid measurement gives the pavement level in (on average) 4 points per 100 m^2. Due to the sparse resolution, local deformations are often not recorded. A 10 m grid can not accurately register unevenness with wavelengths less than 20 m, as per the Sample Theorem.

Local bumps might exercise “forced” control on asphalt machines. Thus, lack of bump information can affect quality and costs in the construction phase, while also being a breeding ground for contract work disputes.

NEW METHOD FOR EXHAUSTIVE PAVEMENT GEOMETRY MEASUREMENT

The new method combines two mobile measurement equipments, The Road Liner and the Profilograph, as described below. All pavement measurements are made from special vans while driving. This cuts the on-site time to a handful of hours.

The resolution is enhanced with hundredfold up to 1 000 points per 100 m^2. This is high enough to capture any bump or depression that significantly affects volume calculations or paver’s works. The new method can accurately register unevenness and roughness with wavelengths down to about 2 dm; one hundred times better than the traditional method.

The Road Liner

The Road Liner is a van equipped for road line marking and with land survey equipment.

The first task for the Road Liner is to spray thin broken reference lines along the Runway, later used for relative positioning of the Profilograph. The c/c distance between the lines is 3 m, therefore 15 +1 = 16 lines are marked on a 45 m wide Runway. A marked Runway is showed in the right hand photo in Figure 4.

The second task is to measure the absolute height above sea profile of the reference marked lines. For this task, the Road Liner is equipped with modified state-of-the-art land survey equipment. This includes a high-end global positioning system (GPS) receiver, a computer and also a total station prism mounted on a rod. The rod is mounted on a cycle wheel in front of the van, as seen in Figure 3. The rod is instrumented with inclinometers, to make slope corrections between the prism and the pavement contact point under the cycle wheel. The Road Liner concept also include equipment to be located along the pavement; a handful of tripods and two geodetic total stations that can be moved from tripod to tripod as the van drives in up to 6 km/h along the Runway. The measurement principle is very much like the principle for modern computer aided machine control systems, but in converted order.

Figure 3 – Road Liner

The Profilograph

Cross sectioning is made with a high speed laser/inertial Profilograph, see photos in Figure 4.

Figure 4 - Laser / inertial Profilograph

The Profilograph is designed for highway road surface condition monitoring. In the front rut bar, 17 lasers are measuring a 3.2 m wide cross section as seen in the left hand photo in Figure 4. Each laser makes 16 000 – 64 000 measurements per second. Since the van is driven at up to some 120 km/h (about 33 m/s), this results in over 6 000 samples per m^2.

A 45 m wide Runway is measured in 25 runs, each 3.2 m wide. These runs are then linked with overlap into a pavement geometry model that covers the whole Runway. Relative position of each run is monitored by video recording of the reference lines painted by the Road Liner. The two video cameras can be seen in the rear of the Profilograph at the right hand photo of Figure 4.

Creating the pavement geometry model

The pavement geometry model is created back office. For assessment of absolute level and longitudinal profiles, data from the Road Liner is used. For assessing relative levels within each cross section, data from the Profilograph is used. In sections where the high speed Profilograph may have drifted sideways, due to wind bursts etc, the measured data is laterally adjusted with information from the video cameras. The model is reported with a lateral resolution of 1 dm, while the longitudinal resolution (normally 1 m) can be adjusted to fit Clients request.

4 EXPERIENCED PERFORMANCE WITH THE NEW METHOD

PERFORMANCE ON A RUNWAY

The measurement quality achieved with the new method has been evaluated in a full-scale accuracy experiment at a 2300 m * 45 m = 103 500 m^2 Runway. The analysis was made by the LFV Group, making a comparison with data from traditional geodetic survey in a 5 * 10 m mesh.

Comparison in 3158 common mesh node points

The average deviation in level between data from measurements made with the new method and with the traditional method was +/- 0.7 mm.

The difference in positive volume was 67.6 m^3.
The difference in negative volume was 69.9 m^3.
The difference in net volume was 2.3 m^3.

These small average differences confirm that the method is highly relevant.

Comparison outside the common node points

Beside the mesh node points, the new method found bumps with up to 25 mm height at wavelengths below 20 m. These bumps and similar hollows were not registered by the traditional 5 * 10 m mesh.

When making a thin overlay, such bumps will exercise “forced” control of asphalt pavers unless they are milled away before the paving takes place. So, with only data from a traditional measurement, it is likely that many bumps remain also after the paving works. In addition, the paved asphalt volumes will be unnecessary high.

Obviously, the hundredfold increased resolution brings a large improvement in quality to the paving contract works.

EXPERIENCES OF THE NEW METHOD AFTER PAVING A VERY ROUGH RUNWAY

Up until the day of writing, 31 Aug. 2007, the method has been used on a handful of Swedish airfields. The Client, the Paving Contractor and an Aircraft Pilot were interviewed after paving a very rough Runway (see Figure 1) at a municipal airfield in Northern Sweden.

The Clients experience of the new method
The new pavement became smoother than we expected.
We were also happily surprised when the budget for the paving contract work proved to cover the real costs.

The Paving Contractors experience of the new method
We made a substantial amount of control measurements, but found no errors in the drawings of the existing pavement geometry.

An Aircraft Pilots experience of the new pavement
After landing on and taking off from the new pavement, it is impossible to believe that this smooth Runway previously was as rough as we knew it.

PERFORMANCE ON A VERY ROUGH APRON

The new method was used on a very rough Apron. A plan drawing from the resulting pavement geometry model is given in Figure 5.

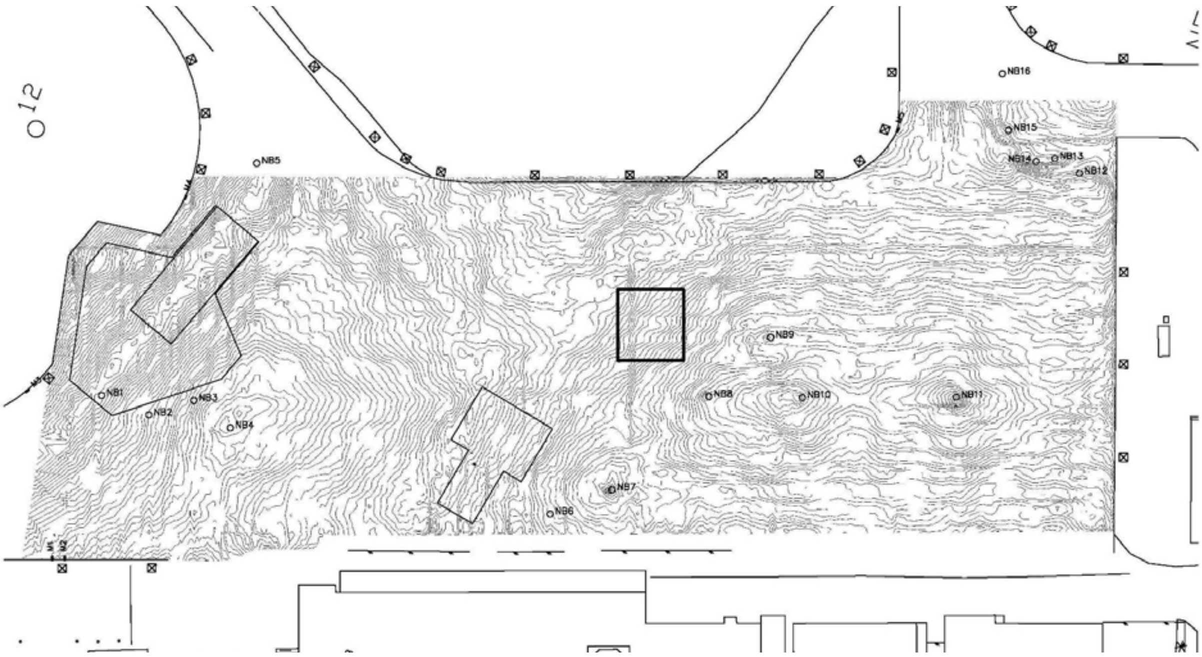

Figure 5 – The Apron seen in a bird's perspective

In the centre of the drawing in Figure 5, a 20 * 20 m control square is marked with a bold line. For this control square, interpolated elevation data has been plotted with data from traditional 10 m mesh survey, as well as from measurements with the new method. The two resulting plots are given in Figure 6.

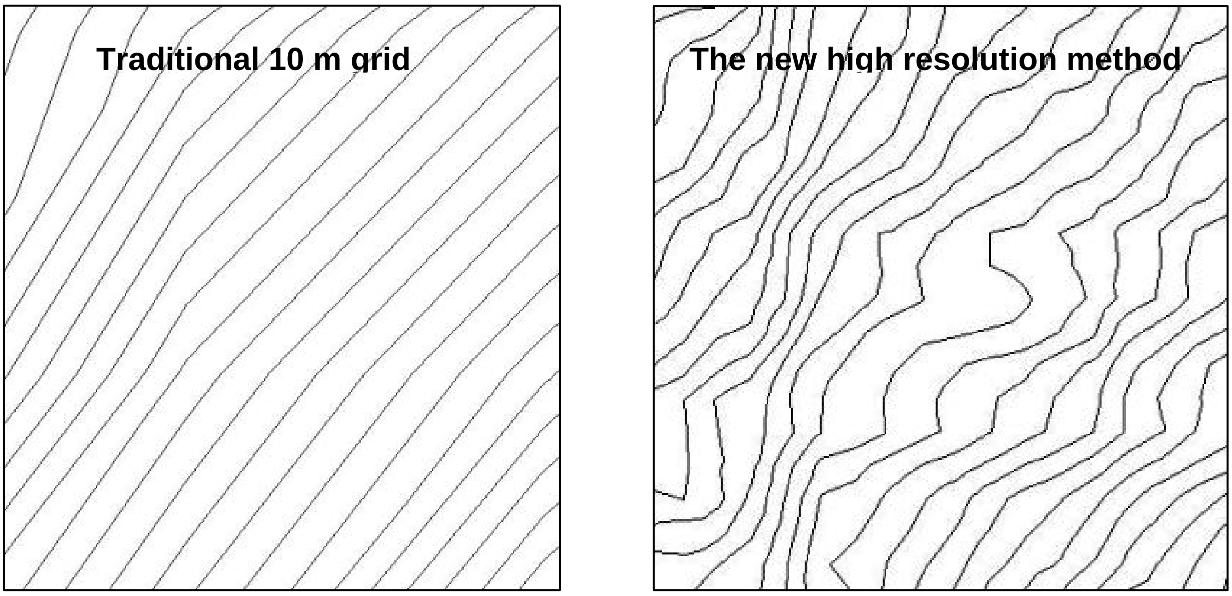

Figure 6 – Elevation plots in the 20 * 20 m Control Square

Each line in Figure 6 corresponds to a 10 mm elevation difference. The left plot presents a nice planar slope. The right plot, produced with data from the new method, reveals a wave pattern with 10 – 20 mm high amplitudes and wavelengths of about 5 m. When driving in North-South direction on the East side of the Apron, this wave pattern excited a powerful pitch motion in cars as well as aircrafts.

Without the hundredfold increased resolution provided by the new measurement method, the pavement repair designer (at an office some 700 km away) would not have been aware about the high-amplitude waves. This would likely have resulted in an erroneous repair design, not sufficient for repair of the severe roughness.

5 CONCLUSIONS

A condition for many airfield pavement repair projects is accurate geometry measurements.

The new method for exhaustive pavement geometry measurement has a number of advantages:

- Decreased on-site time – reducing disturbance to aircraft operations
- Improved accuracy and resolution
- Improved budget control
- Improved repair project net economy

It is reasonable to claim that the improved accuracy and resolution increase quality in the paving works.

Experiences from paving contract works using measurements taken with the new method show that

- The pavement became smoother than expected (Client)
- The budget for the paving contract work proved to cover the real costs (Client)
- The drawings were free from errors (Contractor).

6 FURTHER WORK

It is important to formalize a standard for the new measurement method. This is an on-going task for the LFV - SRA CS joint development team.

ACKNOWLEDGEMENTS

The development of the new method is a fruit of many people's joint competence and energy; Profilograph operators, Road Liner operators, development staff, back-office staff, airfield pavement engineers, etc. Without our long term cooperation, the challenge would have been impossible to meet.

Several of the presented photos are taken by Mr V. Perez, a good friend, skilled pavement engineer and formerly a SCR CS employee.

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