TECHNICAL EVALUATION OF ROMDAS ULTRASONIC MEASUREMENT SYSTEM

TPL Technical Memo - ST1

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by

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1. INTRODUCTION

The ROMDAS Transverse Profile Logger (TPL) contains six Ultrasonic Measurement Systems (UMS). These contain five ultrasonic transducers which are fired sequentially to establish the distance to an object.

A series of static tests were conducted to evaluate the performance of the UMS. This technical memorandum outlines the results of these tests. All tests were conducted using the PC based software provided with the sensors and not the ROMDAS system.

2. TIME STABILITY OF READINGS

The system was set up 400 mm from a wall and initialised. The readings were checked over a period of 6 hours on an hourly basis. There were no significant changes to the readings over this time. This indicates that the sensors are stable with respect to time.

3. ACCURACY OF MEASUREMENTS

The accuracy of measurements was tested by operating a UMS array on a bench top. Starting at 100 mm, an object was moved a 5 mm intervals away from the UMS array and the measurements were recorded. The measurements were made with only a single sensor transmitting so as to eliminate any effects of interference from the other sensors. The tests were performed for Sensors 1 to 3.

Figure 3.1 shows the results of the tests for the 3 sensors[1]. It will be observed that there are 3 'zones' for the readings:

- initially, the readings increase with increasing distance, however, the relationship is unstable;
- there is a second zone where the output is not influenced by the object;
- above 200 mm there is a strongly linear relationship between the distance and the readings.

[1] Sensor 3 readings were taken only at sampled intervals below 200 mm to ensure that the discontinuities observed with other sensors were also present.

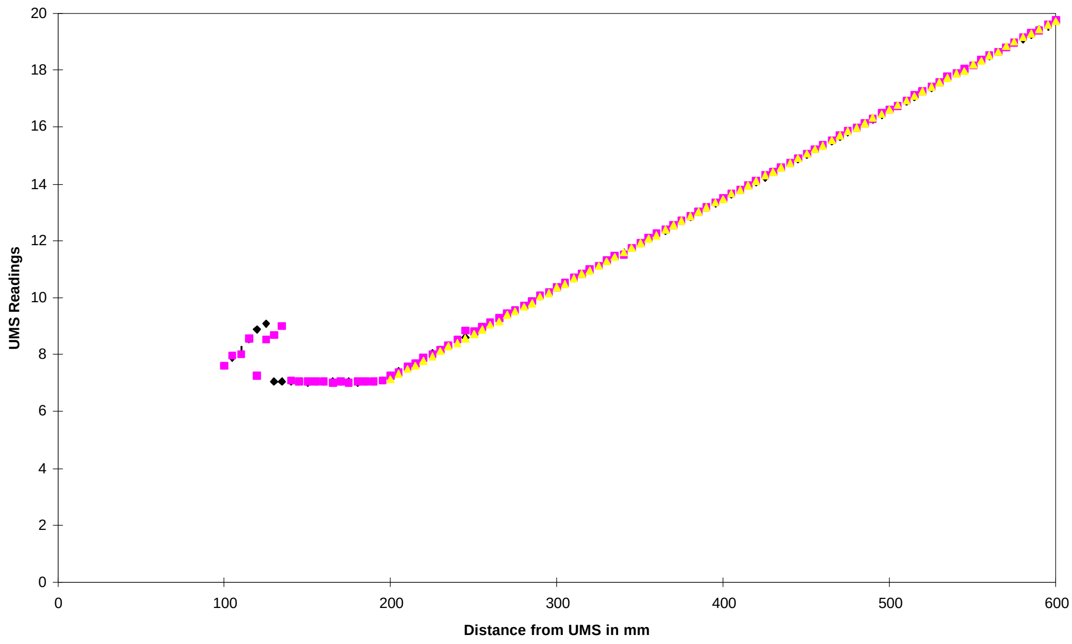

Figure 3.1: Effect of Distance on Measurements

For each sensor, a linear regression equation was fitted to the data above 200 mm. The following are the equations obtained. The 't' statistics for each coefficient are in parentheses. All coefficients are significant and the standard errors of the equations are very low.

Sensor 1

UMS = 0.9737 + 0.031255 DIST (170.4) (2279.0) — R^2 = 1.00 — S.E. = 0.0144

DIST = -31.15 + 32.00 UMS (-158.9) (2279.0) — R^2 = 1.00 — S.E. = 0.46

Sensor 2

UMS = 0.9879 + 0.031274 DIST (82.9) (1093.8) — R^2 = 1.00 — S.E. = 0.0301

DIST = -31.56 + 31.97 UMS (-77.2) (1093.8) — R^2 = 1.00 — S.E. = 0.96

Sensor 3

UMS = 0.8634 + 0.031517 DIST (112.2) (1705.8) — R^2 = 1.00 — S.E. = 0.0194

DIST = -27.38 + 31.73 UMS (-105.4) (1705.8) — R^2 = 1.00 — S.E. = 0.62

where DIST is the distance from the UMS in mm
UMS is the UMS reading

The different constants are probably a reflection that the ultrasonic sensors are recessed from the front plate of the UMS array and are not at a constant distance from the plate.

It will be noted that the slopes of the equations are approximately equal. The mean slope in the distance equation is 31.90. Over the range of UMS data (7 - 20), using this mean slope instead of the actual regressed slope results in an error of less than 1 mm. Given the method of measurement – which was of a similar accuracy – this indicates that a single conversion factor can be used for all sensors to convert the UMS readings to the distance in mm.

4. INTERFERENCE FROM ADJACENT SENSORS

The UMS is designed to fire sensors 1 to 5 sequentially. The delay between each firing is required to eliminate any interference from adjacent sensors on the readings. It is understood that the total firing time is approximately 0.125 ms which means that the delay is 0.025 ms between firings.

To test the effects of interference on adjacent sensors the same series of measurements described in Section 3 were repeated. However, whereas previously only a single sensor was uncovered, in this test all sensors were uncovered.

As illustrated in Figure 4.1 and Figure 4.2, it was found that there was excellent correlations in the measurements with Sensors 1 and 2. However, Sensor 3, which is in the middle of the UMS began to display interference effects starting at a distance of 290 mm. This was manifested by the readings varying continually and not being able to 'fix' on a set value. The variations were as much as 0.25 raw measurements – or up to 8 mm.

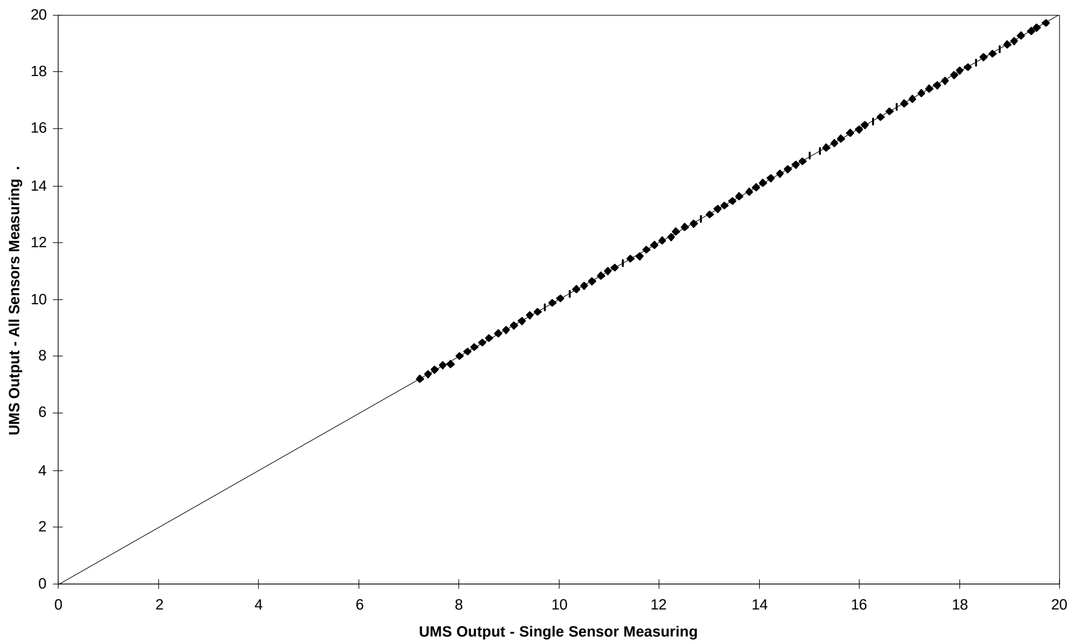

Figure 4.1: Interference Test - Sensor 1

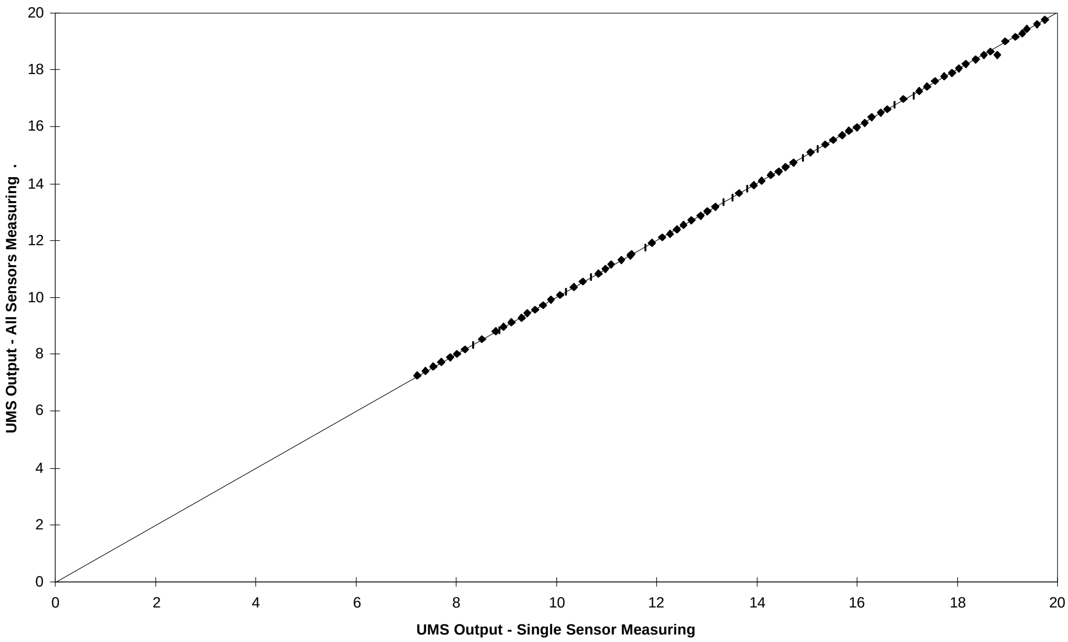

Figure 4.2: Interference Test - Sensor 2

To verify whether these observed effects were due to interference, the four other measurement sensors were blocked so that only Sensor 3 was firing. The measurements were observed to immediately stabilise around a single value which was the same as that observed in the previous single sensor test. Allowing all five sensors to fire resulted in unstable measurements.

As a further test of the interference effects a series of objects were placed at irregular distances from each sensor. It was found that this caused Sensors 2, 3 and 4 to be unstable with their measurements, with Sensor 3 being the most unstable.

It is therefore concluded that the firing timing between sensors is too short and needs to be increased. If it is assumed that the sensors will be mounted 400 mm above the pavement surface, the speed of sound can be used to calculate a sufficient delay. A safety factor should then be built in to allow for a further margin of error.

5. CONCLUSIONS

The main conclusions of the preliminary tests are:

- the UMS sensors are stable with their measurements over an extended period of time;
- the measurements are unstable below a distance of 200 mm, however, exhibit a strongly linear relationship in the zone 200 - 600 mm. It is therefore proposed that the TPL be mounted at a distance of 400 mm above the pavement surface;

- the current delay between firings of adjacent sensors is insufficient to eliminate interference effects and should be lengthened.

As a result of these preliminary results the second stage of static testing will commence. This will consist of monitoring the performance of the sensors in a climate chamber varying temperature and humidity.

The field testing of the TPL will commence once the UMS have been modified to increase the delay.