

# EFFECTS OF TEMPERATURE AND HUMIDITY ON ROMDAS ULTRASONIC MEASUREMENT SYSTEM

## TPL Technical Memo - ST4

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by

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## 1. INTRODUCTION

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The ROMDAS Transverse Profile Logger (TPL) uses ultrasonic measurements to measure the transverse profile. The speed of sound is a function of the air temperature and humidity. A series of experiments were therefore made using one of the ultrasonic measurement systems (UMS) to investigate these effects on the measurements.

The experiments were made using a climate chamber. This allowed both the temperature and relative humidity to be varied over a wide range of conditions. The UMS was installed in the chamber with the cable connected to the PC via an access port to the climate chamber. The UMS was set on the floor of the chamber facing the ceiling. The measurements recorded were therefore the distance from the UMS to the ceiling. Owing to the size of the chamber the UMS was not perfectly flat and the ceiling was also irregular. These two factors led to variations in the final measured distances. The data were recorded using three UMS sensors since the remaining two suffered from interference due to protrusions from the chamber sides.

The chamber had both heating and refrigeration available so the temperature was varied over the range of 4 - 40 °C. The 'dry' temperature was displayed on a thermometer outside of the chamber, graduated in 1 °C intervals. The humidity was supplied via a mister which was provided with water from a beaker tube. A second graduated thermometer was used to monitor the 'wet' temperature. The relative humidity was calculated based on the difference between the dry and wet temperatures using a chart supplied by the manufacturer of the climate chamber.

## 2. EFFECTS OF TEMPERATURE ON MEASUREMENTS

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Finch (1988) gives the following equation for the speed of sound:

$$SSND = \frac{Y P T}{P_0 273}$$

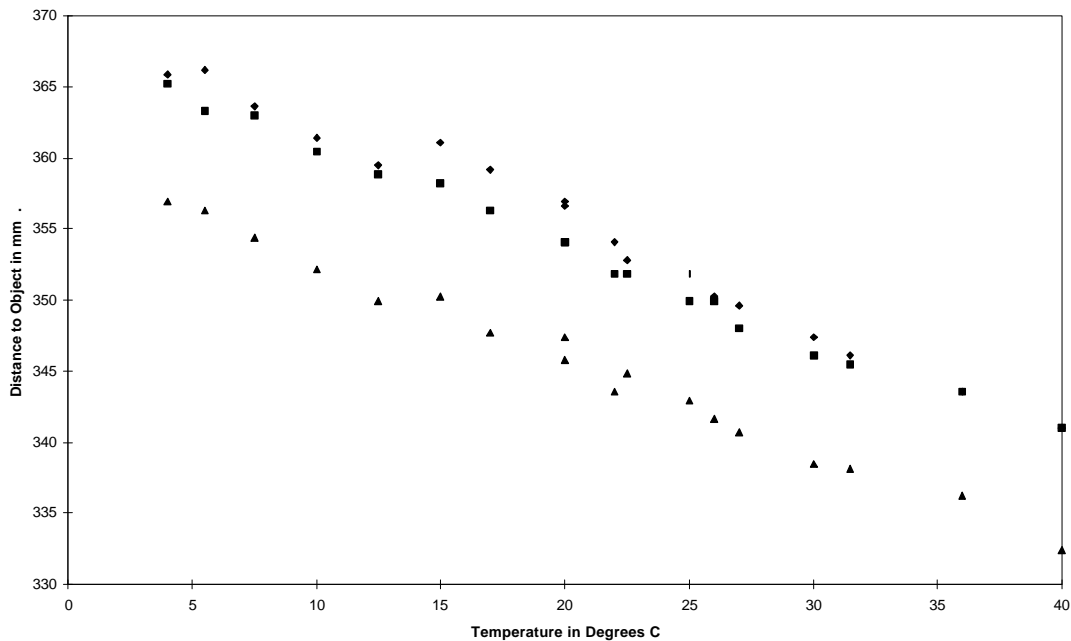
where SSND

is the speed of sound in m/s

Y is the ratio of specific heat capacity at constant pressure and temperature  
 T is the thermodynamic temperature corresponding to t °C  
 P is the density of air at temperature t °C  
 P0 is the density of air at 0 °C

This equation indicates that the effect of temperature on sound is 0.69 m/s/°C (Finch, 1988). It was concluded by Finch (1988) that temperature had a limited effect on the measurements and when evaluating rut depths this was further reduced.

The effects of temperature on the measurements was investigated by holding the relative humidity constant at 100 per cent and varying the temperature between 4 and 40 °C. Figure 2.1 shows the distances measured by the UMS over this range. Annex A contains the raw data.



**Figure 2.1: Effect of Temperature on Measurements**

The data exhibit a strong linear relationship, although there is some scatter. This scatter is due in part to the measurement technique wherein it was difficult to (a) hold a constant temperature and humidity and (b) read the dial gauges accurately.

Figure 2.1 is shows that the trend is quite consistent between the different measurement heights. This is more clearly illustrated in Figure 2.2 where the data have been normalised relative to the measurement at 4 °C. A linear regression was fitted to the data from the three sensors which resulted in the following equation:

$$dDIST = 2.84 - 0.6927 \text{ TEMP}$$

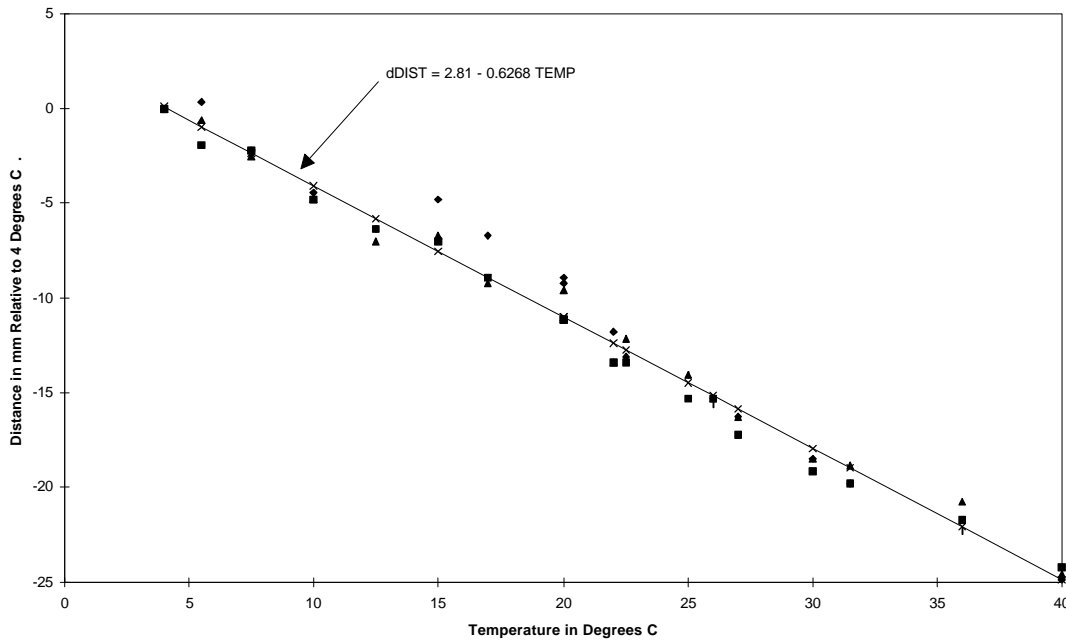
(10.0) (-56.2)

$$R^2 = 0.98 \quad S.E. = 0.89$$

where dDIST is the change in measured distance relative to the distance at 4 °C  
TEMP is the temperature in °C

The ‘t’ statistics are shown under each coefficient. These show that the coefficients are well determined, particularly the temperature coefficient.

The equation shows that there is a variation in height of 0.69 mm/°C. This suggests that it would be desirable to include a temperature monitor with the TPL so that the data can be corrected to a standard temperature.



**Figure 2.2: Effect of Temperature on Relative Distance**

### 3. EFFECT OF HUMIDITY ON MEASUREMENTS

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Finch (1988) indicates that there is limited data available on the effects of humidity on ultrasonic signals. It is reported that the literature considered the effects to be negligible and that at 10 °C the difference between the velocity of sound in saturated and dry air was from 0.6 - 0.9 m/s – a change of about 0.3 per cent. It was therefore concluded by Finch (1988) that humidity would not be significant over the short distances measured by a TPL.

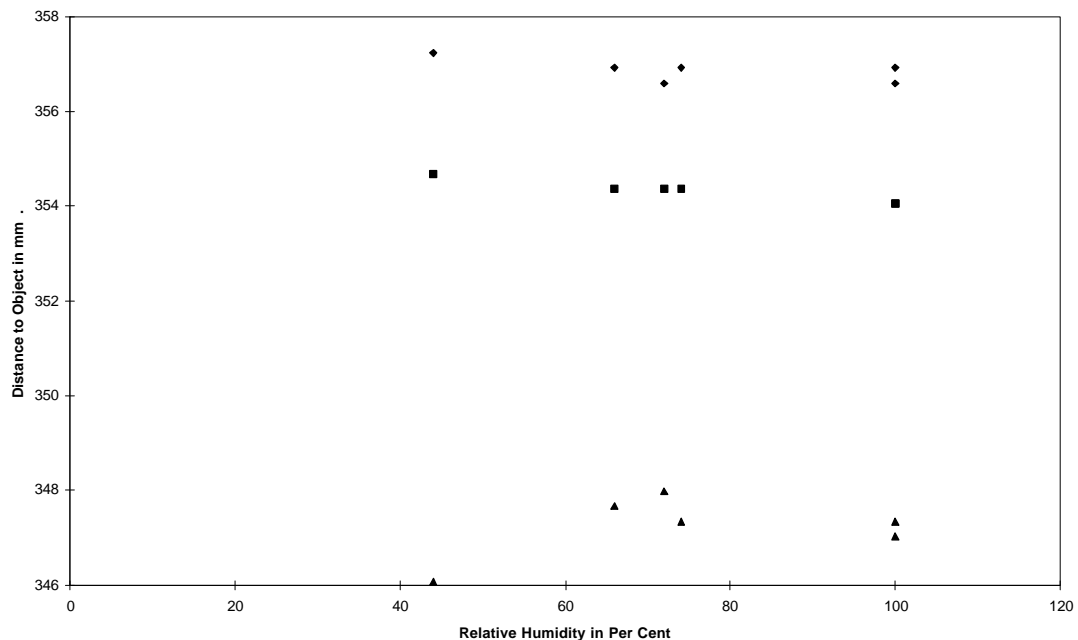
To test this conclusion, a series of measurements were taken at a constant temperature with varying humidity. It proved difficult to hold a constant temperature and vary the humidity with the climate chamber. However, a number of readings

were made at a temperature of 20°C and these are illustrated in Figure 4.3. It can be observed that the distance is effectively independent of the relative humidity. The variation in distance in the range of 44 - 100 per cent relative humidity was between 0.09 - 0.28 per cent. This supports the conclusion by Finch (1988) that it is not necessary to consider humidity with the TPL.

## 4. CONCLUSIONS

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The experiments have shown that it is not necessary to account for humidity in the TPL measurements. It is desirable to account for temperature since the effect is a change in height of 0.69 mm/°C. Changes of this magnitude could lead to errors when comparing rutting on different sections measured at different temperatures. The viability of incorporating temperature measurements into the TPL will therefore be investigated.



**Figure 4.3: Effect of Humidity on Measured Distance at 20° C**

## 5. REFERENCES

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Finch, R.F. (1988). Development of a Rut Depth Measurement Device for Developing Countries. M.Phil. Thesis, Department of Civil Engineering, University of Birmingham.

# ANNEX A

## TEST DATA

Temp °C	Relative Humidity %	Distance in mm			Temp °C	Relative Humidity %	Distance in mm		
		Sensor 5	Sensor 4	Sensor 3			Sensor 5	Sensor 4	Sensor 3
4.0	100	366	365	357	11	88	362	359	352
5.5	100	366	363	356	13	69	359	357	350
7.5	100	364	363	354	15	71	359	357	348
10.0	100	361	360	352	17	64	359	357	348
12.5	100	359	359	350	17	90	357	355	347
15.0	100	361	358	350	18	81	357	355	347
17.0	100	359	356	348	19	58	359	357	348
20.0	100	357	354	347	19	74	357	355	348
20.0	100	357	354	346	20	44	357	355	346
22.0	100	354	352	344	20	66	357	354	348
22.5	100	353	352	345	20	72	357	356	348
25.0	100	352	350	343	20	74	357	354	347
26.0	100	350	350	342	22	60	355	353	345
27.0	100	350	348	341	22	83	353	352	344
30.0	100	347	346	338	45	83	341	341	332
31.5	100	346	345	338					
36.0	100	344	344	336					
40.0	100	341	341	332					