B.2.3

ZARAGOZA'89
ENVIRONMENTAL
ACOUSTICS

8º SYMPOSIUM FASE'89
«ACUSTICA AMBIENTAL»
Zaragoza, Abril 1989

RAIN: ITS EFFECT ON SOIL IMPEDANCE AND PROPAGATING SOUND

C. G. Don, A. J. Cramond and D. E. P. Lawrence

Department of Applied Physics,
Chisholm Institute of Technology,
Caulfield East, Melbourne, Australia, 3145.

INTRODUCTION

When sound propagates over soil it is influenced by the ground impedance which, in turn, depends on the amount of moisture in the earth. One method of investigating how rain alters the ground impedance is to reflect acoustic impulses from surfaces with different moisture content and then observe the change to the pulse shape caused by the reflection[1]. An advantage of this technique is that a wide range of frequencies are being investigated at the one instant, which can be important when considering a time-dependent situation such as the behaviour of rain soaking into the surface.

EXPERIMENTAL TECHNIQUES

A two microphone method[1] has been used to capture the direct and the reflected impulse from a source producing 0.5ms duration sound. By Fourier analysing both pulses the plane wave reflection coefficient, R_p, can be calculated over the range 500Hz to 10kHz and the normalized characteristic impedance $Z = R + iX$ deduced from the known geometry.

Moisture readings were obtained by coring a 2cm deep sample, removing any grass root structure, then heating it at about 105°C until the mass remained constant. Generally, three or more samples were taken around the measurement site and the average value of the moisture content calculated.

IMPEDANCE MEASUREMENTS

When the impedance of relatively dry (less than 10% moisture by weight) grassland is measured the values often agree with a single parameter model[2] when an appropriate value of the effective flow resistivity σ_E is chosen. At other sites, the real part of the impedance can exhibit an almost frequency independent behaviour, typical of a layered ground structure, where more sophisticated models[3] are required to fit the data.

Addition of water to the soil causes an overall increase in the impedance. Often relatively narrow "resonances" occur at one or more frequencies, as indicated in Fig.1(a) which was taken over grassland on a day after heavy rain. Fig.1(b) are impedance values obtained at the same site after the addition of further water. While the resonant frequencies in the moderately wet grassland impedance data are associated with large Rp values, Fig.1(c) indicates they are less than unity. With the addition of further water the reflection coefficient can approach and even exceed one, Fig.1(d), a result caused by small differences between the frequency content of the direct and reflected pulses. In reality, at such frequencies the wet ground is effectively acting as a perfect reflector with unity reflection coefficient and an infinite impedance.

Figure 2 presents data obtained over fine sand. When dry, the sand particles are small independent grains giving rise to a low effective flow resistivity, with impedance curves such as the three examples shown in Fig.2(a). Addition of water causes the top layer of grains to agglomerate, which can produce a very pronounced resonance as shown in Fig.2(b). If the surface is now broken, for example by raking, allowing air paths to form between aggregates of wet sand, the impedance drops markedly, Fig.2(c), and falls within the range observed with the dry sand. Similar effects have been found with earth cleared of vegetation. Thus the very high impedance appears to result from a layer formed by the water. Inspection of the ground itself suggests that the layer is one to two centimetres deep.

The impulse measurements are affected by an area at least a metre square around the point of specular reflection. Yet if this point is shifted by only 10cm the position, number and magnitude of the resonances can alter significantly. For this reason a four microphone technique is now being used to observe how adjacent regions vary as the moisture content changes.

Attempts to predict the resonances in terms of thin film interference and using models of soil impedance have thus far been unsuccessful. Considering the layer as a simple thin film, enhancement would occur when $\lambda = 2d \sin\theta$ which, for a 2cm thick layer and a resonance around 5kHz suggests a sound speed in the wet soil of around $100ms^{-1}$. This is assuming θ is about 30^{o} for the geometry involved. If the ground is taken to be locally reacting, as is commonly assumed, then θ would be zero and the speed doubles. Equations are available[2] for estimating the phase speed and attenuation of sound in fibrous absorbent materials of known flow resistivity. Assuming the top layer of the wet soil has an effective flow resistivity of 1,500,000rayl, the predicted speeds vary from 10 to $90ms^{-1}$ for the frequency range involved in these pulses. This has the effect of broadening any resonance far beyond that observed experimentally. Moreover, the predicted attenuation through 4cm of soil reduces reflections from the lower surface so much that no resonances are expected. The lack of precise data on the behaviour of the speed of sound and the phase changes in wet soil has resulted in a program at Chisholm to measure these properties by passing impulses through soils.

PROPAGATION OVER GRASSLAND

Because the resonances are very point dependent, when data from a large number of positions around a field are averaged together the resultant impedance curves are relatively smooth, without resonances, and can generally be fitted by a single effective flow resistivity.

Thus the localised resonances are unlikely to effect propagation results over distances of many meters. The experimental variation of the effective flow resistivity with average moisture content is presented as Fig.3 for the case of grassland and sand.

The effect that rain can have on the propagation of impulse sound is demonstrated in Fig.4, which shows the excess attenuation as a function of distance from a point source mounted 0.8m above grassland. The excess attenuation is the decrease in the peak value above that expected because of inverse square law spreading. The meteorological conditions were similar on both measurement days, with the direction of propagation into the wind producing a shadow boundary about 25m from the source. The two sets of measurements were taken over the same field about a week apart, during which time very heavy rain had changed the ground impedance from that corresponding to an effective flow resistivity of 170,000rayl to 500,000rayl. It is apparent that changes of about 5dB can occur in the shadow zone because of alteration of the ground impedance.

CONCLUSION

Rainwater can significantly alter the level of propagating sound through its influence on the ground impedance. While an effective flow resistivity can be determined experimentally for a field, when detailed measurements are made of a relatively small area it is found that marked resonances can occur in the impedance at some frequencies. No quantitative theoretical explanation has yet been achieved to explain these very narrow resonances.

ACKNOWLEDGEMENTS

The authors thank the Australian Research Grants Scheme for their support of this work.

REFERENCES

(1) CRAMOND A.J. and DON C.G., "Effects of Moisture Content on Soil Impedance", J. Acoust. Soc. Am. 82, 293-301 (1987)

(2) DELANY M.E. and BAZLEY E.N., "Acoustical Properties of Fibrous Absorbent Materials", App. Acoust. 3, 105-116 (1970)

(3) ATTENBOROUGH K., Acoustical Impedance Models for Outdoor Sound Surfaces", J. Sound Vib. 99, 521-545 (1985).

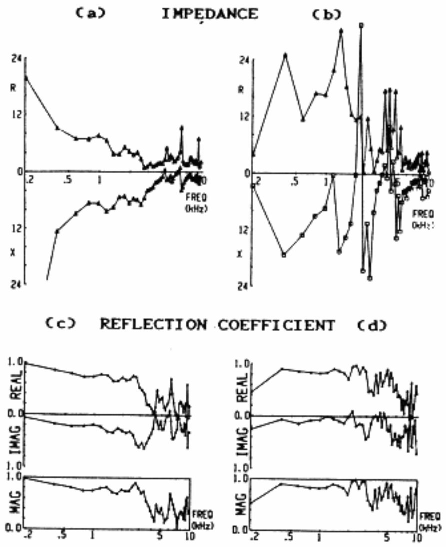

Fig.1 Measurements over wet grassland (a) 30% (b) 40% moisture.

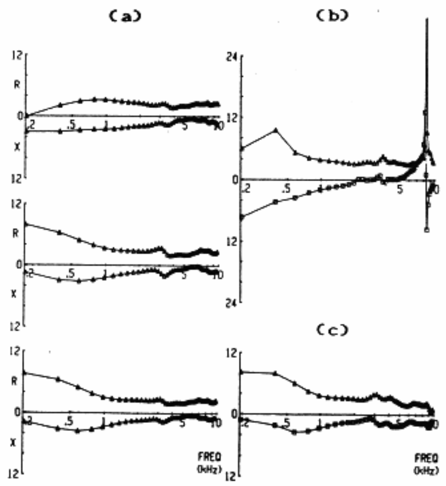

Fig.2 Impedance of sand (a) dry, 1.5% moisture (b) 10% (c) 10%, raked.

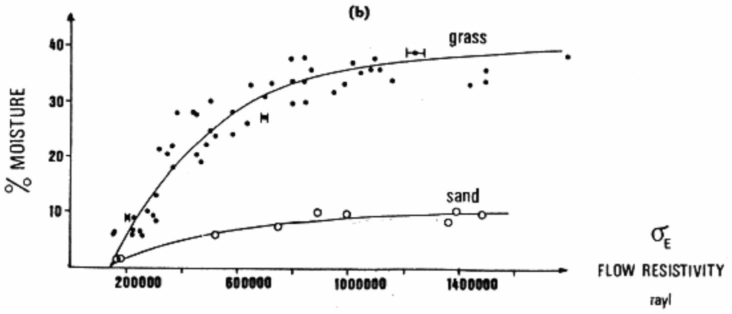

Fig.3 Variation of the effective flow resistivity of soil with moisture content.

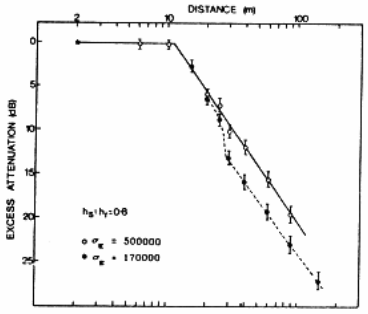

Fig.4 Impulse propagation measurements taken when the grassland had different effective flow resistivities.