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Utilization of Artificial Neural Networks to Expand Databases

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1. Abstract

This paper examines the potential use of the artificial neural networks (ANN) technique as a tool for expanding databases. The application presented here targets databases that house mechanistic properties of aggregate materials, commonly used in base and subbase road layers. The research work performed involved the development and utilization of an ANN model to populate a resilient modulus database of granular materials from limited laboratory-generated data. Resilient moduli predicted by the ANN model under a variety of test conditions, including density, stress and moisture content demonstrated consistent trends of known effects that these input parameters have on the resilient response (the output). Results obtained from expanding the original database to include conditions that are not covered in laboratory tests confirmed the ability of the ANN model to produce reliable estimates of the required output.

2. Introduction

Mechanistic–empirical pavement design procedures require the provision of specific material inputs as part of the design process. One such input is the resilient modulus of aggregate materials (M_r) commonly used in base and subbase layers. The M_r parameter is defined as the ratio of the deviator stress (σ_d) to the resilient (recoverable) strain (ε_r):

$$M_r = \frac{\sigma_d}{\varepsilon_r} \qquad (1)$$

The determination of the M_r parameter involves elaborate laboratory testing and special training of technical staff, a capability that the majority of road jurisdictions in Canada lack today. One alternative to circumvent such problem and to provide the needed parameter is to perform limited M_r tests at labs that posess the required testing capability and then use an analytical approach to expand the original database. This paper presents an attempt to utilize the ANN technique to accomplish the stated objective. The laboratory data set used in the current study included M_r entries that were obtained under different conditions of density (89–98% Modified Proctor density), moisture content (3–7%, representing 2.5% dry of optimum to 1.5% wet of optimum) and applied deviator stress (35–85 kPa). These factors are known to afftect the resilient behaviour of aggregate materials [1], [2].

3. Features of ANN Model

The ANN model developed in this study has three input parameters, namely, the compaction density, moisture content and deviator stress, and the output was the M_r parameter. The optimized network, which had a single hidden layer with 12 nodes, was trained using the back propagation technique [3]. The criterion adopted for assessing the network prediction capability was the percentage "Absolute value of the Relative Error" (ARE):

$$|ARE| = \frac{\left|\left(x_{predicted} - x_{actual}\right)\right|}{\left|x_{actual}\right|} 100\% \qquad (2)$$

Using the ARE criterion, the ANN model produced acceptable predictions that deviated by less than 10% from actual laboratory results.

4. Expanding Database

The trained ANN was used to expand the original database, containing 55 test results, to produce more than 1000 data entries covering the ranges of input variables in increments of 1% for compaction density, 0.5% for moisture content and 5 kPa for deviator stress. An example illustrating the population of the database for a fixed moisture content of 5.0% and covering the full range of density (89–98%) under two stress levels (35 and 45 kPa) is displayed in Table 1. The values highlighted in the table are the original laboratory results used in this example.

Predictions made by the ANN model are plotted in Figures 1–3. Figure 1 displays M_r values obtained at different densities for the material compacted at its optimum moisture content (5.3%) and tested using a stress level of 50 kPa. The trend, which shows an increase in M_r as the density increases, agrees with known material behaviour as established in the literature [2]. Figure 2 shows the relationship between predicted M_r values and the material moisture content. A decreasing trend characterizing this relationship is again indicative of known material behaviour. Comparison between M_r values obtained under two different levels of deviator stress is shown in Figure 3. The rate at which the modulus increases with density was found to be higher for the higher stress level, an observation that is reported in the literature. In addition, increase in density beyond 98% causes insignificant changes in the modulus value. Findings from Figures 1–3 demonstrate the ability of the ANN model to effectively capture known relationships that exist in the original database between input and output.

Table 1. Expanding original database using ANN

Stress level (kPa)	Compaction Density (% of MMPD*)	Resilient modulus (MPa)
35	90	140
35	91	146
	92	151
	93	156
	94	159
	95	163
	96	167
	97	173
	98	178
	99	180
	100	180
45	90	136
	91	138
	92	145
	93	156
	94	170
	95	184
	96	199
	97	212
45	98	222
45	99	224
	100	226

*MMPD: Maximum modified Proctor density

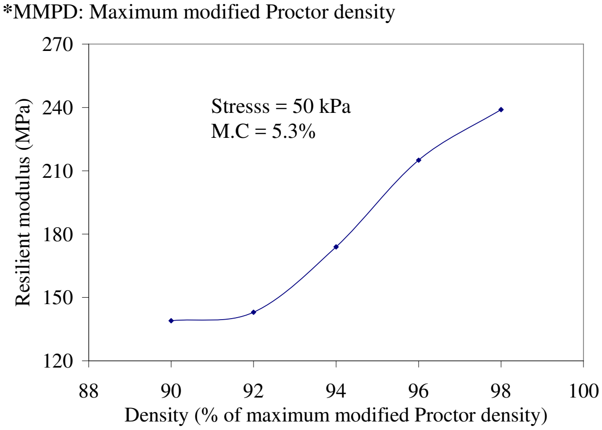

Figure 1. Variation of M_r with density

5. Summary and Conclusions

Mechanistic-empirical pavement design methods require the provision of the resilient modulus as an input to characterize aggregate materials used in road construction. However, due to the elaborate nature of the test procedure used to determine this parameter, an alternative approach is required. This paper presented the use of ANN technique as a tool to expand M_r databases that were created from limited laboratory tests. Findings from the research study demonstrated the ability of the developed ANN model to generate reliable estimates of the resilient modulus parameter and to effectively populate the original database.

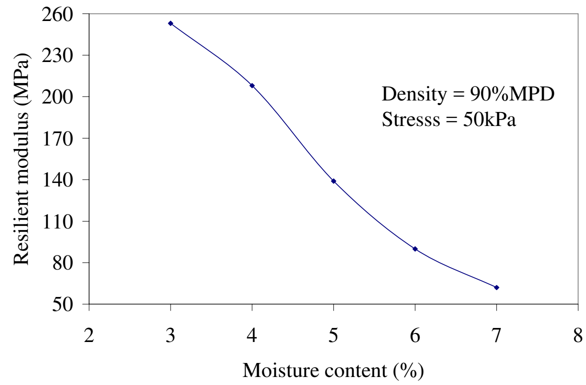

Figure 2. Variation of M_r with moisture content

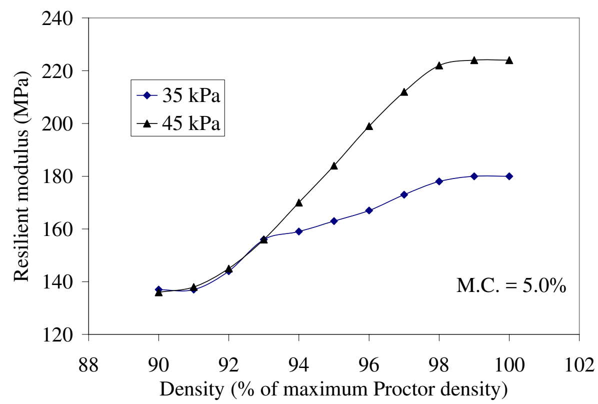

Figure 3. Variation of M_r with density and stress

References

[1] A.R. Dawson, N.H. Thom and J.L. Paute, *Mechanical Characteristics of Unbound Granular Materials as a Function of Condition*, Flexible Pavements, Proc. Euro. Symp. Euroflex. 199, A. G. Correia, ed., Balkema, Rotterdam, The Netherlands, 35-44, (1996).

[2] W.E.I. Khogali and ElHussein H. Mohamed, *Novel Approach for Characterization of Unbound Materials,* In Transportation Research Record No. 1874, pp. 38 – 46, Journal of the Transportation Research Board, (2004). AASHTO (1986). "Guide for Design of Pavement Structures." American Association of State Highway and Transportation Officials.

[3] I.A. Basheer and M. Hajmeer, *Artificial Neural Networks: Fundamentals, Computing, Design, and Application*, Journal of Microbiological Methods, No. 43, pp. 3–31 (2000).