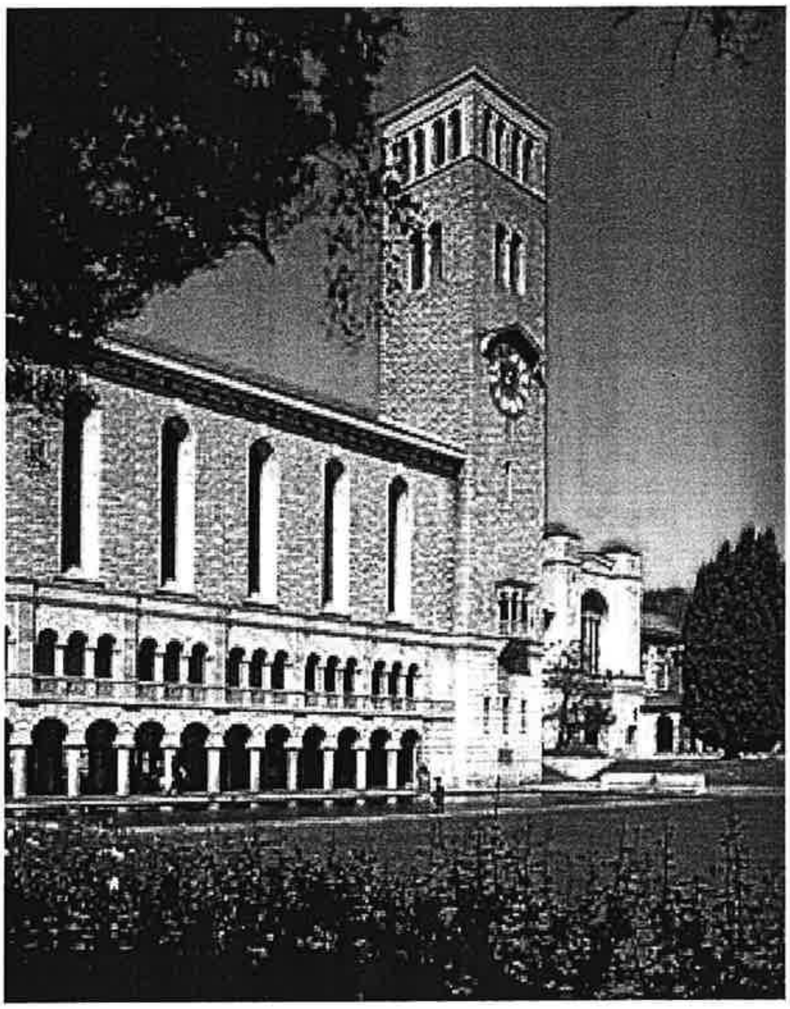
1st international conference on

STRUCTURAL CONDITION ASSESSMENT, MONITORING AND IMPROVEMENT

12 – 14 December, 2005, Perth, W. Australia



The University of Western Australia

Support Organisations:

vil and Resource Engineering, the University of Western

scipline Group, the University of Western Australia

onference Organisation, Singapore

1st Int'l Conference on **Structural Condition Assessment, Monitoring and Improvement**
December 12 – 14, 2005, Perth, W. Australia

MANAGEMENT AND ANALYSIS OF DATA FOR DAMAGE OF LIGHT STRUCTURES ON EXPANSIVE SOIL IN VICTORIA, AUSTRALIA

N. Y. Osman*, Swinburne University of Technology, Melbourne, Australia
K. J. McManus, Swinburne University of Technology, Melbourne, Australia
A. W. M. Ng, Swinburne University of Technology, Melbourne, Australia

Abstract

Over 20,000 homes owned by the Building Housing Commission (BHC) in Victoria, Australia used as "Social Housing" were reported as damaged over the last decade due to soil movement in expansive soil. The method of reporting the damage was based on the tenant's complaints and site investigation of the properties. The report was not uniform. The series of disparate reports formed the BHC database in this matter. This system is under review and an improvement of the quality of the data would assist in supporting the analysis needed to synthesise a model of the system. The problem of deterioration of the housing stock founded on expansive soils is being assessed through research being conducted jointly by Swinburne University of Technology and the University of Melbourne. A series of studies of the deterioration of the housing stock have been made, some with a view to determine the type and amount of work by the building trades to rehabilitate the property and others with the objective of discovering the problem and finding an engineering solution. The problem addressed in this paper is that of determining the most influential factors in the existing database causing damage and establishing a uniform system of data capture that best describes the factors leading to the deterioration. A link from this to the specifications needed for rehabilitation by the trades would be established. The existing database is described and the factors influencing the deterioration are explained and ranked. On the basis of the analysis, a new template for site data capture is proposed.

Keywords: soil movement, expansive soils, damage to housing, data management, data analysis, data mining, neural network analysis

1. Introduction

The Building Housing Commission (BHC) owned and managed over 73,000 properties across Victoria. Over 30 percent of the properties are over 30 years old and most inner city high-rise and walk-up estates have reached the age at which they require major refurbishments or demolition [1]. Over 200 comprehensive damage reports are conducted annually with annual budget of $1Million. One of the Victorian Government's asset management strategies for 2004 to 2009 is to allocate approximately $150 million each year for physical improvements of their housing stock [1]. It is a major program for the government to redevelop the stocks to meet the needs of current and future housing clients.

One of the ways to assist in the improvement of the housing stock is to manage the database in order for them to be readily available for analysis. These will save time and money in finding housing stocks that needs maintenance, reconstruction or demolition. The problem of deterioration of the housing stock founded on expansive soils is being assessed through research being conducted jointly by Swinburne University of Technology and the University of Melbourne. A series of studies of the deterioration of the housing stock have been made, some with a view to determine the type and amount of work by the building trades to rehabilitate the property and others with the objective of discovering the problem and finding an engineering solution.

The problem addressed in this paper is that of determining the most influential factors in the existing database causing damage and establishing a uniform system of data capture that best describes the most influential factors leading to the deterioration. The existing database is described and the factors influencing the deterioration are explained and ranked. On the basis of the analysis, a new template for site data capture is proposed.

2. Data management

Ideally, a good quality database contains information that is extracted from a combination of quality and uniform reports done on a regular and objective basis by a trained team or experts. However, the reports obtained from BHC were not uniform. The method of reporting the damage for BHC was based on the tenant's complaints and site investigation of the properties. The timing of the damage report was at the discretion of the tenants. The damage was first inspected by internal BHC inspectors who reported on the deterioration in terms of what building trades would be involved in the repair and the extent of the involvement. Then, a thorough diagnosis of the damage and geological site investigation was conducted by consulting engineers using their own version of a paper-based report. More than 600 reports dating back from 1980 to 2003 were reviewed for the purpose of analysing damage to light structure on unsaturated soil due to soil movement. The reports contained information of the damage to properties, which include the following categories:

1. *Consultant's detail*
   The name and address of the consultants who was appointed to inspect the property

2. *Property Information*
   The Local Government Authority (LGA) number and the address of the house

3. *Building Information*
   The type of building, year built or age of the property, year of first inspection and the construction type including type of foundations and walls of the property

4. *Site Information*
   The soil class, presence of trees, height, location in regards to the house, and type of trees

5. *Consultant's Diagnosis*
   The consultant's diagnosis on the condition of the property such as cracks; size, severity and location of cracks in the house, settlement of foundation, other problems with the property and also the damage classification of the property according to AS 2870, 1996[2]

6. *Schedule of the Work*
   The consultant's recommendation of the work that needs to be done to the property and the priority of the repair

7. *Estimated Cost of Repairs*
   An estimated cost of repairs to the property

2.1 Database

The first stage to develop a database is to identify and define the objectives of the analysis. Definition of the objectives involves defining the aims of the analysis. A clear statement of the objective will be an advantage in order to set up the analysis correctly [3]. The selection of data from the report is crucial for the analysis of the database. It provides the fundamental input for the subsequent data analysis [3]. In this paper, the objective of the database is to determine the most influential factors in the existing database causing damage and establishing a uniform system of data capture that best describes the factors leading to the deterioration.

As stated previously, more than 600 reports from BHC were reviewed and a database was developed according to the information obtained in the reports. The information extracted from the BHC reports had to be edited in order to produce a quality database. Since the report is not uniform, there were some missing factors. Even though the reports were collected from one source, different engineering consultants were appointed to investigate different structures that were reported as damaged. From 1980 to early 1990's, only hard copy reports are available. From the mid 90's, the reports were typed using a computer and some of the reports were stored in both soft and hard copies. Therefore, reading and extracting data from different forms of report is a difficult part of data management. A major source of error at the data gathering stage is the manual entry of the data, which can result in mistyped data or lead to incomplete of missing data [4]. Figure 1 shows the recommended steps of managing and analysing the data using the reports from BHC.

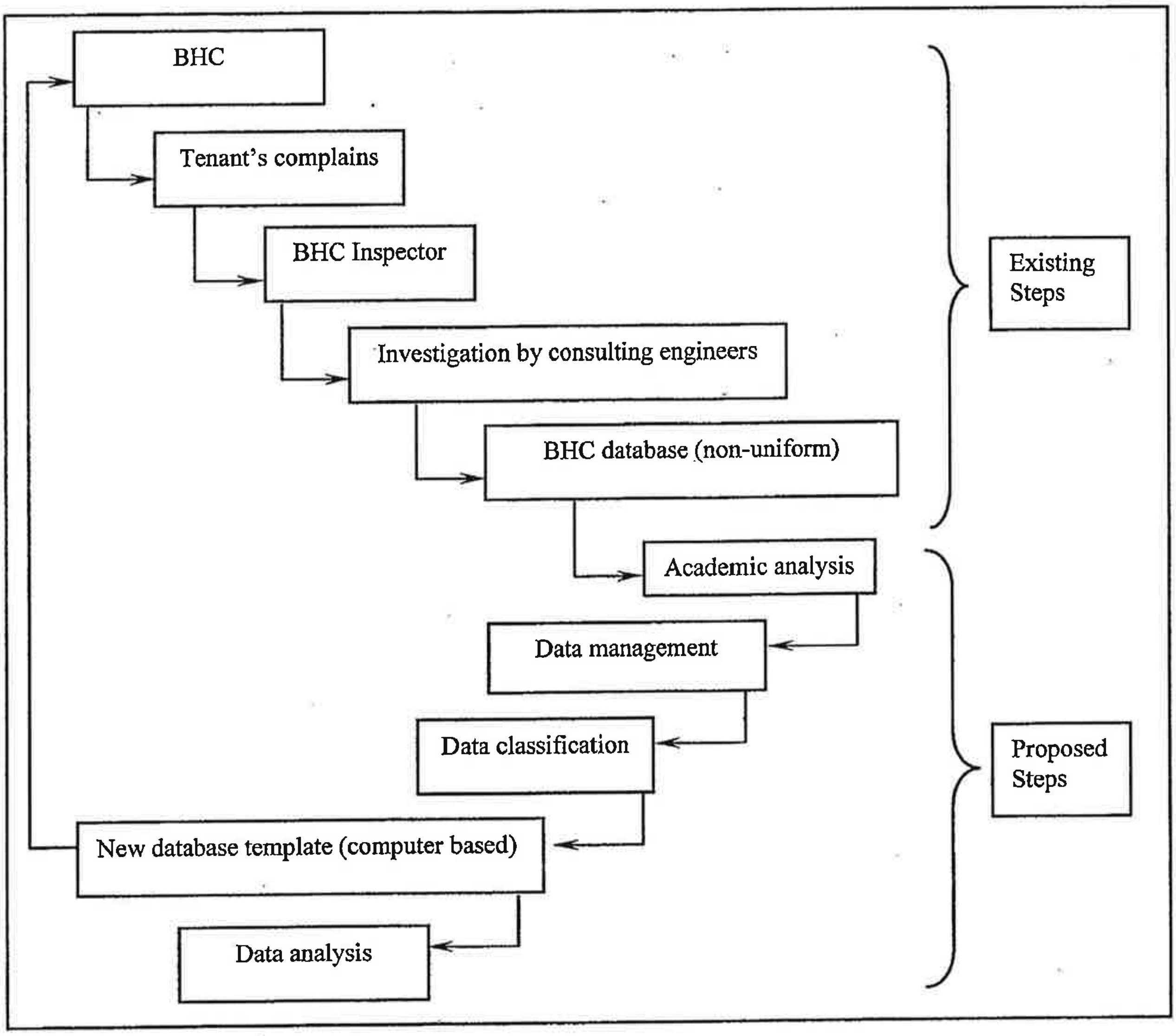


Figure 1 Steps of the management of database

2.1.1 Organisation of data

A unified information system for BHC is recommended in this paper, as it will assist in the organising of the data into a uniform and consistent database. Qualitative and quantitative variables are developed using the selected information from the reports. Qualitative variables are classified into levels, sometimes known as categories while quantitative variables are linked to intrinsically numerical quantities [3]. The approach to dealing with missing values or incomplete data is either to drop them from the analysis or substitute typical values for them [4]. In this paper, the missing or incomplete values are substituted with a numeric value of 999. The reason for this is that the usual zero default value would be confusing for the software used for the analysis since zero is also used for the numbers representing other variables. Approximately 33% of the reports had to be discarded, as there were too many missing attributes in the reports.

A database containing similar categories to the ones in the report with existing and new variables was created. Since the analysis is dealing with damage to light structure founded on expansive soil in regards to soil moisture, the factors influencing the damage are considered. These include climate change, structural stiffness, soil characteristics, vegetation (pre and post construction), site leakage and site drainage. These are the common damage factor potentials (DFP). Of course not all of the factors can be found in the BHC report and some will not be adopted in the analysis. Therefore, some of the factors such as vegetation, climate and geology, not typically included in the BHC reports had to be incorporated into the database and an alternative solution had to be adopted.

Table 1 shows the recommended categories and variables that will be considered in the new database. Existing information from the report are extracted accordingly to accommodate the new category of the database.

1. *Property Information*
   This information is relevant for the purpose of analysis to highlight any repeat damage to an existing structure and the frequency of the damage taking place in a particular region or suburb.
2. *Building Information*
   The type of construction is significant. An examination of the performance of the damaged structures provides an indication of the combinations of footings, walls and types of buildings that suffer more damage due to soil movement. This will act as a guide for future design of damage resistant structures. The information of the sizes of footing are also an advantage. The age of the building or the year of built are also useful as they allow an interpretation of the availability of the types of materials at the time, and also of the site moisture condition (whether it be drought or normal seasonal condition) at the time of construction.
3. *Site Information*
   a. Vegetation
      Only 10% of the reports have mentioned any detailed site information on type and size of vegetation, and distance of vegetation from the structure. However, most of the reports are lacking this information. Therefore, since this factor is one of the damage factor potentials, the data of the vegetation covers were extracted from Vegetation map [5] according to the region instead. This map does not show detailed information for a particular site but gives a general impression of the type of vegetation cover in the region.
   b. Geology
      The regional geology of the site was extracted from Geology of Victoria Map [6] . As the soils are predominantly derived from deep weathering from the parent rock, the geology is an indication of the type of soil in the region.
   c. Climate
      The influence of climate on potential damage to light structures on expansive soils is measured using Thornthwaite moisture Index (TMI). It ranges from –40 to 40 for the driest and the wettest part of Victoria respectively. TMI calculations for the period1940-1960 [7] and for the period 1961 to 1990 [8] were included in the database according to the region. The two TMI's were used to indicate the change in the climate over a period of time. Over the era examined in the database, the change in TMI showed a drying of the climate implying that the depth of unsaturated soil was increasing. This suggested a greater potential for surface movement developing with age of the structures
4. *Consultant's Diagnosis*
   A detailed diagnosis of the damage structure, incorporating extent and severity, is important to quantify the damage to the structure. A detailed measurement showing the size of cracks for instance would be required. The size of movement or settlement of the foundation would also be required, if possible to determine.
5. Costs
   This is an estimate of the cost of repair if it were to be done. However, at this stage, this is not very useful as a DFP as the prices are not constant over the era.

Table 1 Enrichment of the BHC template

	Category	Variables
1	**Property Information**	• Street number • Street Address • Postcode
2	**Building Information**	• Type of Building *- Units, Flats, Detached etc* • Type of footing *- Strip footing, Slab footing etc* • Type of Wall *- Brick veneer, Solid brick etc* • Year built • Year of 1st Inspection • Age of building
3	**Site Information**	• Climate *-TMI 1940-1960 and TMI 1961-1990* • Geology *- Volcanic, Tertiary, Jurassic etc* • Vegetation *- Shrubs, Built up area etc*
4	**Consultant's diagnosis**	• Cracks • Damage (extent and severity) • Heave • Settlement • Leakage • Other • Classification of damage
5	**Cost**	• Estimated cost of repairs

The data and variables from Table 1 can undergo a number of transformations before the finalisation of a new and improved database. The information of the property can be transformed into geographical regions where there could be more than one postcode in one region. Thus making the database more general, as some of the postcodes may not contain a lot of reported damage properties. Only the type of footings and walls used in the building in the Building Information category are valuable to predict the potential damage to light structure. Age is another important variable to consider since it indicates the availability of the materials and the change of climate during the construction. All the variables in the site information category are useful in the prediction of DFP. For this paper, only classification of damage will be adopted in the consultant's diagnosis because the purpose of the analysis is to predict the DFP. The other variables in this category will be used later to develop a model which predicts the damage to light structure. Table 2 shows a new template for the BHC.

Table 2 A new template of the database

	Category	Variables and coding
1	**Property Information**	• Geographical region (GR)
2	**Building Information**	• Construction Footing (CF) • Construction Wall (CW) • Age of building (Age)
3	**Site Information**	• Climate (TMIO and TMIN) • Geology (G) • Vegetation Covers (VC)
4	**Consultant's diagnosis**	• Damage Classification (DC)

3 Data Analysis

The modified BHC database was used firstly to rank the factors which influence the damage of the properties due to soil movement. Since the database is noisy with a lot of missing and incomplete data, a

Neural Network model (NNM) was chosen to provide a model. It is a system that is patterned on the operation of the human brain. It can learn and discern patterns in real-world conditions where data is incomplete or where the number of variables is vast. NNM can model dynamic, non-linear phenomena that are too complex to be described by analytical methods or empirical rules. NNM was found to be the most suitable method for the ranking of DFP. A supervised two layer Feedforward Backpropagation NNM was chosen to carry out this analysis. 50% of the dataset in BHC were used as training, 30% for validation and 20% for testing. The ranking was calculated using Connection Weights Analysis (CWA) and Sensitivity Analysis (SA) [9]. The latter is used to compare the results using CWA. CWA was found to be better than SA in terms of calculating the ranking of damage factor influence Figure 2 shows the architecture of the NNM used for this analysis. A detailed analysis and report can be referred to in [9].

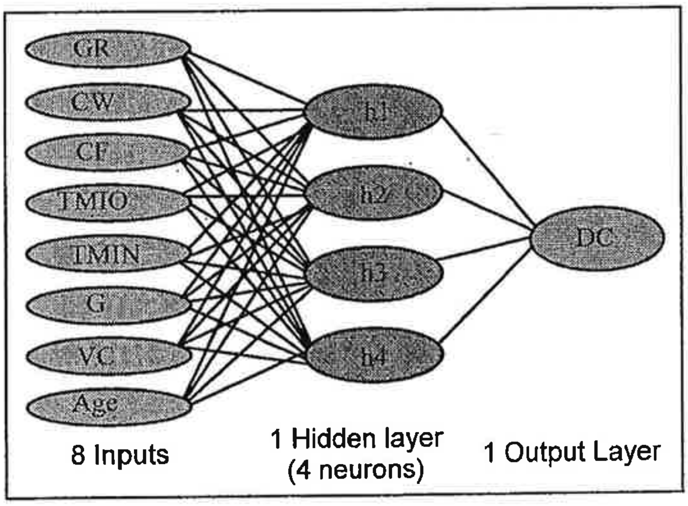


Figure 2 Architecture of NNM for PDI in Victoria [9]

Figure 3 shows the results obtained after NNM has been trained. The ranking in descending order of influence is Age, Geology (G), Construction Footing (CF), Vegetation cover (VC), Construction Wall (CW), Thornthwaite Moisture Index (1940-1960) (TMIO), Geographical Region (GR) and Thornthwaite Moisture Index (1961-1990) (TMIN) respectively.

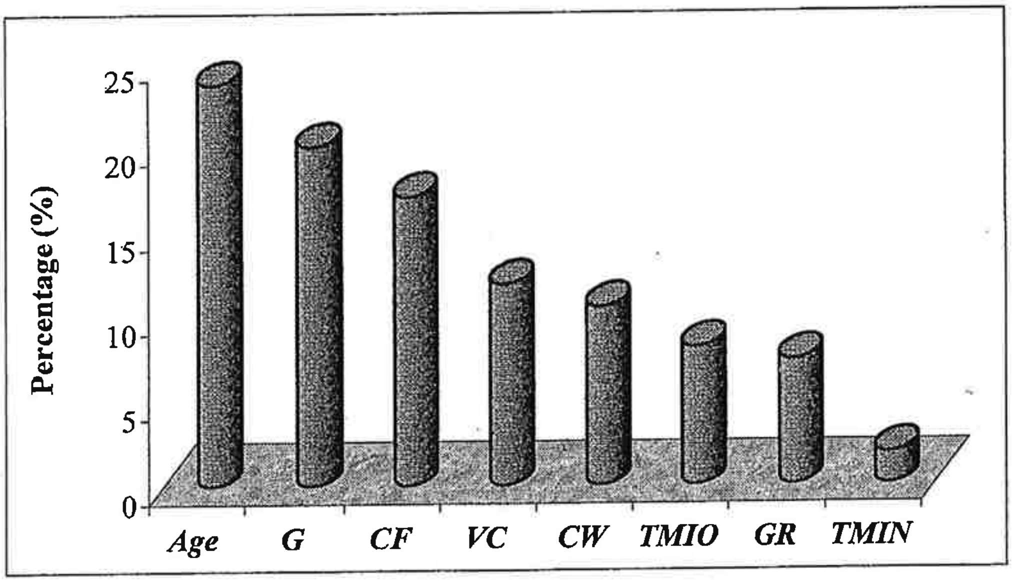


Figure 3 Potential Damage Ranking (PDI) [9]

From the established ranking, the individual factors can be analysed again using another method. Here, a One-way ANOVA mean method was used. Two examples that will be described in this paper are "Type of Footing" (CF) and "Geology" (G) to give a view of the detail of the analysis. Figure 4 represents the type of footing in regards to the effect it has on the damage to the structure. From the column chart of damage category for a range of Footing types, It is obvious that the Raft slab footing falls in the damage category 4 which indicates the most severe category. Bluestone, Stump, stiffened slab fall in the same damage category which is 2 while Concrete slab and strip footing fall in damage category 3. Raft foundations have the advantage of reducing differential settlements and are often used on soft or loose soils with low bearing capacity as they can spread the loads over a larger area.. Although the foundation is suitable for the unsaturated soil, it falls in the most severe case scenario of the damage category in the BHC database. The reason proposed for this is that the size of the foundation was designed for a static climatic zone and did not cater for the drying change in the climate in the region over the life of the structure. This resulted in increased soil movement beyond that anticipated over the life of the structure. The Australian Standard AS2870 [2] which has not commented on the potential effect of possible climate change, implies that no change would occur in anticipated surface movement of the soil and does not lead the designer to look for such change in movement

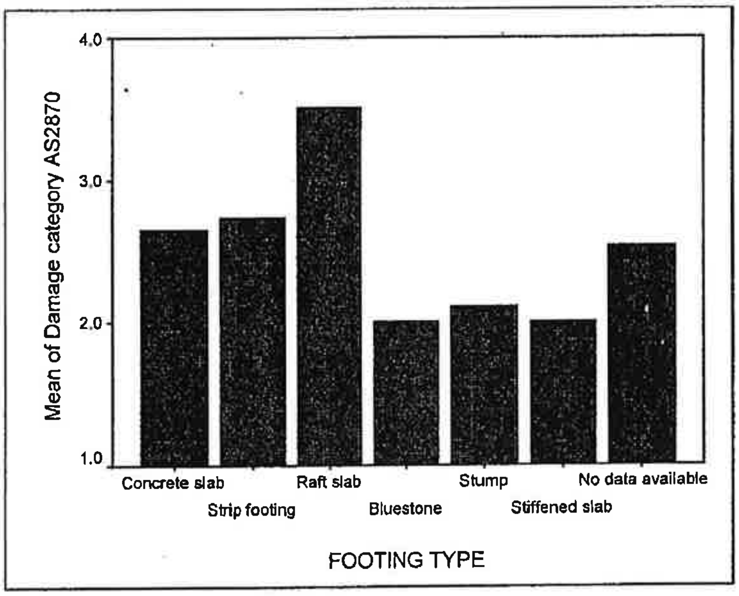


Figure 4 Effect of footing types in regards to damage

Another example of the data is Geology (G) which is ranked second most influential after Age in [9]. Figure 5 represents the effect of different geology in regards to damage to the structure. About half of the surface area in Victoria is covered by moderate to highly expansive residual soils [8], derived from weathering of the basement rocks (Quaternary and Tertiary Basalts and Silurian Mudstones). Most of the geological sites are between Damage Category 2 and Damage Category 3. Since most of them are above Damage Category 2 and approaching Damage Category 3, Damage Category 3 is considered. Damage category 3 are structures that have wide cracks, (5mm to 15mm) with obvious changes in level.

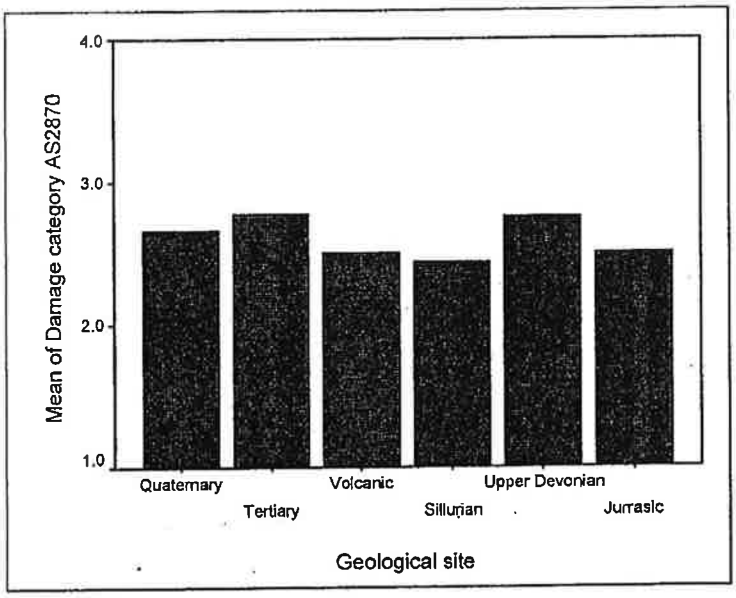


Figure 5 Effect of type of geology in regards to damage

4. Conclusion

A good database and analysis usually depend on the quality of data obtained. This work was developed from the examination of an imperfect database that nevertheless contained useful information A new approach to mining and interpreting the data has been developed using a Neural Network Analysis technique. This has lead to a better understanding of the Damage Factors that are important and the ranking of their potential to influence structural damage. From this, a new template for data capture has been proposed for recording damage to light structure founded on unsaturated expansive soils.

Reference

1 Department of Human Services, *Sustaining our housing: Asset management strategy 2004-2009*, Department of Human Services, Melbourne, Australia, 2004.

2 Standards Australia, *AS2870-1996 Residential slabs and footings-construction*, Standards Australia International, Australia, 1996.

3 P Giudici, *Applied Data Mining: Statistical Methods for Business and Industry*, John Wiley & Sons, England, 2003.

4 D. Tamraparni, *Exploratory data mining and data cleaning*, John Wiley & Sons, USA, 2003.

5 Bureau of Rural Sciences, *Integrated Vegetation Map online*, Commonwealth of Australia, Australia, 2003.

6 J McAndrew (ed), The geological Map of Victoria in Geology of Australia ore deposits, *The Eighth Commonwealth Mining and Metallurgical Congress Australia and New Zealand,* 1965.

7 G D Aitchison and B G Richards, A Broad-scale Study of Moisture Conditions in Pavement Sub grades throughout Australia, Butterworths, UK, 1965.

8 K J McManus, D Lopes and N Y Osman, The influence of drought cycles on the Thornthwaite moisture index contours in Victoria Australia, *An International Conference on Problematic Soils.* 2, pgs 357, CI-Premier Conference Organisation, Singapore,. 2003.

9 N Y Osman and K J McManus, The ranking of factors influencing the behaviour of light structures on expansive soils in Victoria, Australia, *Proceedings of the Eighth International Conference on the Application of Artificial Intelligence to Civil, Structural and Environmental Engineering,* Civil-Comp Ltd, Scotland, 2005.