Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 51 (1986)

Artikel: Quality assurance for buildings in ground movement areas

Autor: Nawar, George

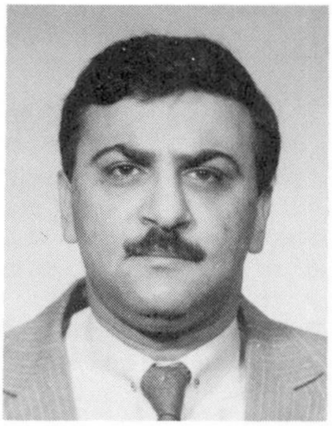
DOI: https://doi.org/10.5169/seals-39578

Quality Assurance for Buildings in Ground Movement Areas

Assurance de la qualité pour des bâtiments en zone de tassement

Qualitätssicherung von Gebäuden in Bergsenkungs-Gebieten

George NAWAR
Special Projects Engineer
Department of Housing
Bexley, NSW, Australia



George Nawar, born 1949, graduated in 1977, and received his Masters in 1983. Since graduation, he has been responsible in the N.S.W. Department of Housing for investigating structural aspects in residential construction.

SUMMARY

This paper provides a practical example of planning quality assurance for Civil Engineering Structures at areas subject to the risk of mining subsidence. It highlights a procedure based on the identification and quantification of risk parameters, establishment of acceptable risks and methods of utilizing the hazard scenario to achieve an acceptable level of performance.

RÉSUMÉ

Cette contribution fournit un exemple pratique de l'assurance de la qualité de constructions de génie civil dans des régions sujettes au risque d'affaissement minier. Elle présente une procédure basée sur l'identification et la quantification des paramètres du risque, l'établissement de risques acceptables, et les méthodes de scénarios de dangers potentiels, afin d'atteindre un niveau de performance acceptable.

ZUSAMMENFASSUNG

Der Beitrag behandelt die Planung der Qualitätssicherung für Ingenieurbauten anhand eines Beispieles aus einem Bergsenkungs-Gebiet. Das angewendete Verfahren stützt sich auf die Identifikation und Quantifizierung von Risiko-Kenngrössen, die Festlegung akzeptierbarer Risiken und die Methode der Gefährdungsbilder. Seine Anwendung führt zu einem befriedigenden Verhalten von Bauwerken.

INTRODUCTION

The New South Wales Mine Subsidence Board was enacted in 1961 to provide payment of compensation and/or repair damages to surface structures caused by mine subsidence, following the extraction of coal and shale. The Board was also given powers to define areas subject to high risks of subsidence movement and control all surface improvement in these areas by approving its development through guidelines aimed at maintaining an equitable balance between maximum utilisation of mineral resources and minimum liability caused by related damage to surface development.

This paper is based on the results of a study carried out by the author to formulate such guidelines for the southern mine subsidence districts in N.S.W.

1. IDENTIFICATION OF THE RISK

The risk is defined as the damage to buildings caused by surface movement as a result of underground mining. Surface movement is described in terms of its components [1] as subsidence (s), tilt (g), strain (e) and curvature (ρ). Damage to buildings is caused by the combined effect of these parameters which vary considerably depending on the depth and extent of mining, type and layout of the structure as well as ground conditions [2]. The number of annually reported incidents of damage have increased by more than ten fold since 1962 with similar proportional increase in compensation and repair costs.
The characteristics of damage to other buildings caused by mining subsidence is very similar to that caused by other foundation conditions, [3] to the extent that each type of damage could not be isolated when both damages occur concurrently. For this purpose, positive identification of subsidence damage was limited to areas subject to mining activities with the inevitable shortcoming of assuming that all damage is caused by subsidence in these areas. Depsite this broad identification, 58% of the reported damage was easily proven to have been caused by other than mining subsidence.

2. QUANTIFICATION OF THE RISK

Quantitative evaluation of the risk provides a useful tool for direct comparison under variable conditions as well as being a necessary parameter in all benefit cost analysis. In this example, the risk is analysed into two main components:

2.1 Probabalistic Component

This phase is concerned with the probability that subsidence will take place at a given location. It depends on the likelihood of the following events.

a) Mining taking place at that given location (P1). This phase is time dependent and is estimated over a period of 20 years by consultation with the lease holders in a given location.

b) Full extraction (P2). This phase depends on the proximity of development to major surface features requiring protection by reduction of extraction level.

c) Critical width of extraction (P3).
The probability of subsidence caused by single seam extraction (Pss) is then estimated by the product of probabilities such that (Pss) = (P1, P2, P3) and the probability of multi-seam extraction is taken as (Pms) = (Pss1, Pss2, Pss3). These values are plotted on a map of the given location to provide a quantitative scenario of the probabalistic risk component, (Figure 1).

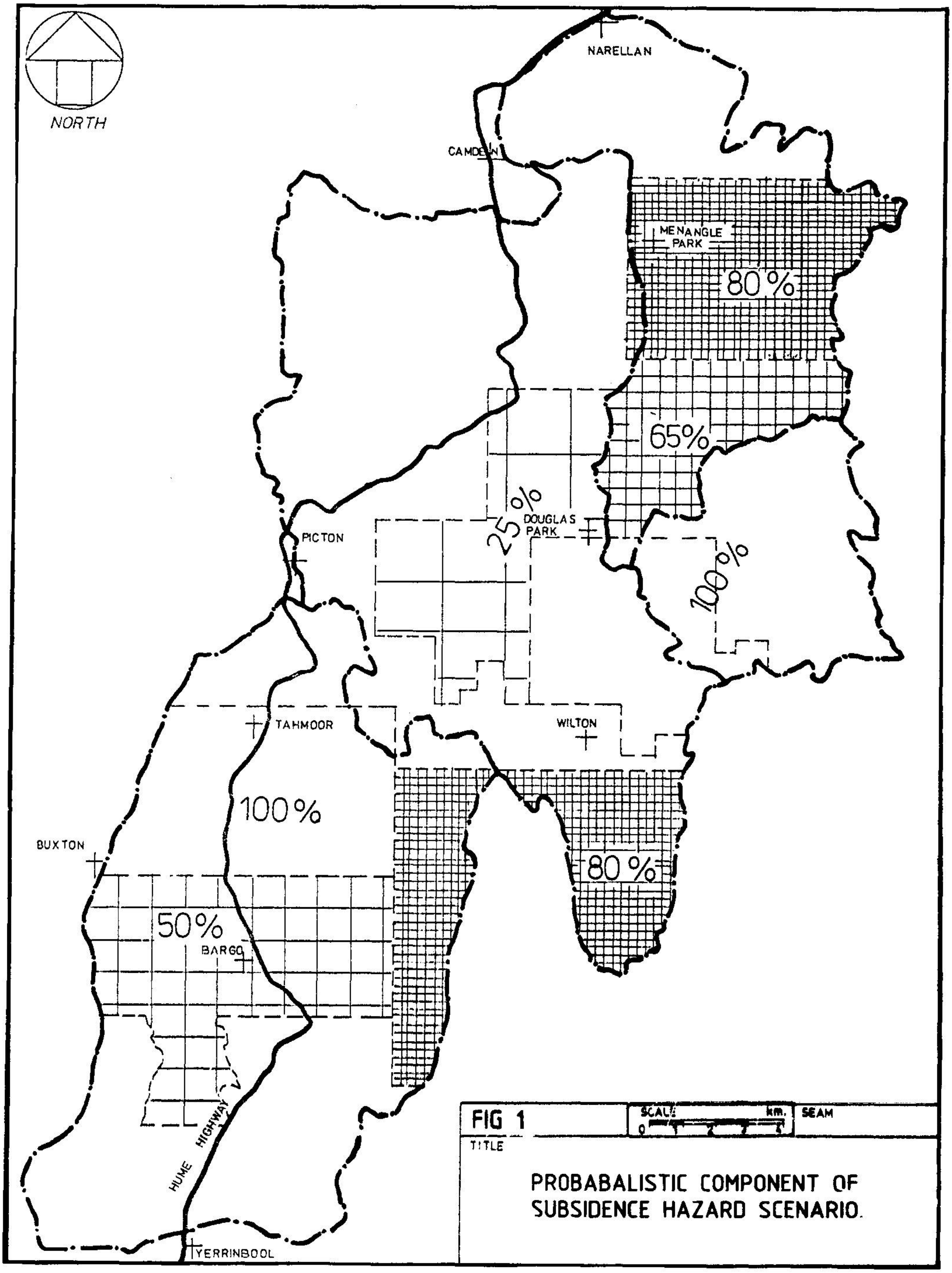


FIG 1

PROBABALISTIC COMPONENT OF SUBSIDENCE HAZARD SCENARIO.

2.2 Deterministic Component

This phase deals with the relationship between subsidence occurance and its consequent damage to structures.

In order to quantify this phase, the relationships between different components of ground movement were derived in terms of seam properties (i.e. depth h & thickness m) at critical width extraction as shown in figure (2).
Seam thickness (m) in this relationship is substituted by the maximum subsidence (S) which is linearly related by the equation (S) = 0.65(m), [4]. This relationship provided the basis for the two fundamental aspects of the analysis:

1. Quantifying the critical combinations of subsidence parameters along a subsidence wave into the following conditions as shown in Stages I to IV, (Figure 3).

a) Maximum tensile strain and convex curvature at which subsidence is 20% and tilt is 50% of their corresponding maximum values.

b) Maximum tilt at 50% of maximum subsidence and corresponding to no strain and no curvature.

c) Maximum compressive strain and concave curvature corresponding to approx 50% of maximum tilt and 85% of maximum subsidence.

d) Maximum subsidence at which no tilt strain or curvature occurs.

2. Converting subsidence induced conditions into damage parameters by assessing the separate effects of subsidence induced strains, tilts and curvature on the structures.

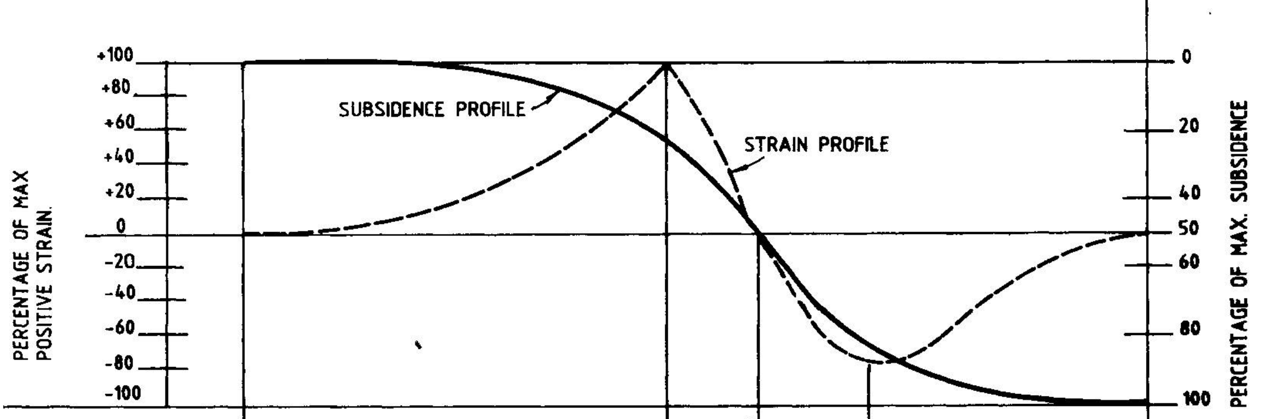
Strains represent the rate of lateral ground displacement, and affect the structure by its corresponding horizontal displacement in the building through the interaction between building footings and its immediate foundation material. Damage caused by strain is sensitive to the depth of footings, size of building and type of foundation material. This condition was found to be of minor significance [2] for small to medium size builidngs on shallow footings.
Tilt represents the rate of change in vertical movement, and affects the structure by its corresponding differential vertival displacement which is directly related to the structure length and height. This condition was proven [2] to be the most significant cause of most subsidence damage in small buildings. Curvature represents the rate of change in tilt and causes damage by its corresponding tilt component. Finally, the combined effect of all subsidence induced movement as defined by the critical conditions in 1 above were analysed [2] and the design condition assessed as that of maximum tilt as described in condition II, (Figure 3).

At this stage damage to buildings has been directly related to the values of ($^S/h$) and could then be plotted on maps of the given location to represent the deterministic risk component, (Figure 4).

3. ACCEPTABLE RISK

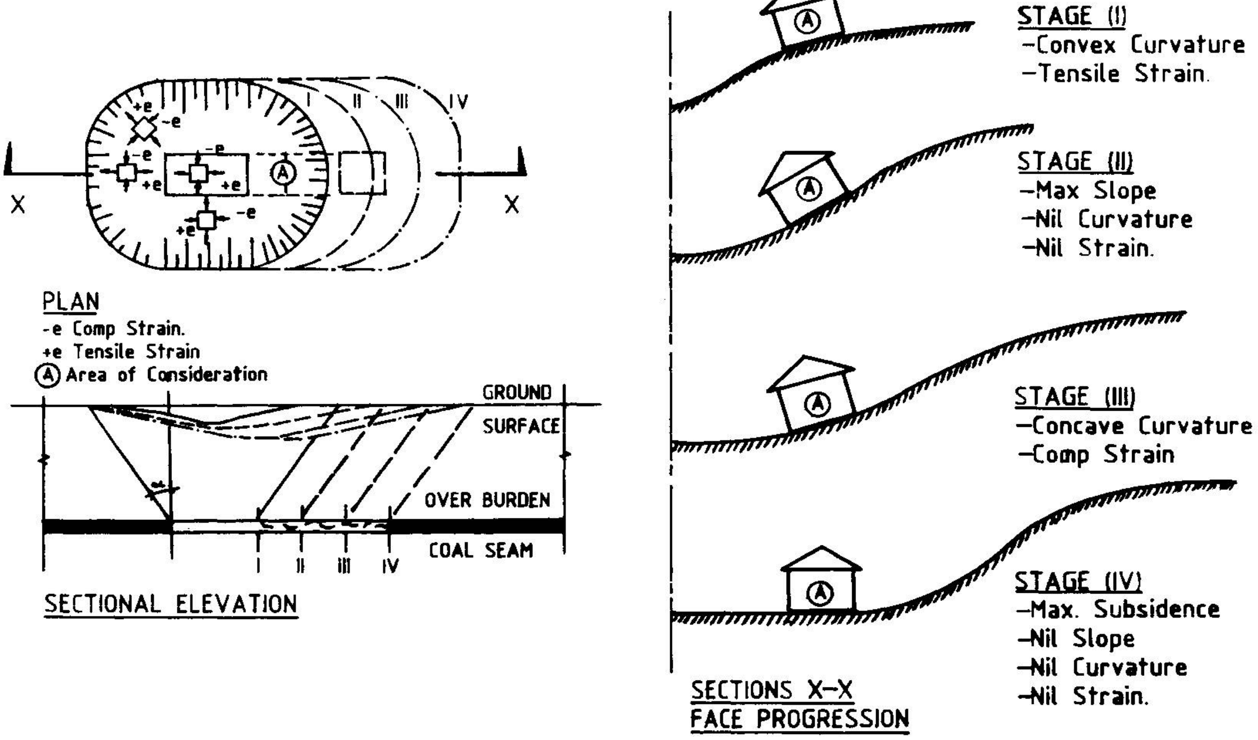
The issue of acceptable risk is a fairly emotional topic and tends in most applications to be governed by political constraints which are not necessarily based on equitable cost effectiveness. In this example considerable efforts were made to achieve acceptable risk by classifying subsidence induced damage into five categories and by relating each category to its corresponding subsidence induced tilt, for five types of construction as shown in table (1). This classification is based on maximum crack widths in walls and floors as related to differential vertical displacement.

FIG 2 TYPICAL SUBSIDENCE PARAMETERS FOR A CRITICAL WIDTH OF EXTRACTION.



DISTANCE FROM CENTRE OF TROUGH IN TERMS OF h	1.40h	0.7h	0.56h	0.39	NIL
SUBSIDENCE IN TERMS OF S		0.20	0.5	0.85	1.00
TILT IN TERMS OF S/h		1.30	2.75	1.25	
STRAINS IN TERMS OF S/h	NIL	0.65	NIL	0.51	NIL
CURVATURE IN TERMS OF S/h^2		20.75	NIL	15.0	

FIG 3 EFFECTS OF FACE PROGRESSION ON SURFACE STRUCTURES.



Repair costs were estimated from the description of typical damage as percentage of replacement cost and acceptable damage is related to movement limits for houses, table (2), acceptable risk in terms of (S/h) could then be directly related to acceptable damage in terms of cost penalty.

TABLE 2, MOVEMENT LIMITS FOR HOUSES [6]

Type of Construction	Limit as a function of length.	Absolute Limit (mm)
Clad Frame	1/300	40
Masonry Veneer	1/500	25
Articulated Masonry Veneer	1/800	15
Articulated Masonry	1/800	15
Full Masonry	1/2000	7

4. MANAGEMENT OF THE RISK

Now that the risk is defined and quantified, and we know how much of that risk is tolerable, the next step is to manipulate these factors in planning to achieve safety and quality assurance. To this end planning aims at either reducing the risk, or improving the capacity of buildings to sustain this risk, or both. In this example both measures were adopted as follows.

4.1 Risk Reduction

By optimisation of the probabalistic hazard scenario (Figure 1) to minimise the effects of mining subsidence on surface structures. This is achieved by the establishment of a long term plan to govern the relationship between both mining and building activities in aspects such as geographical location, rate and extent of development, as well as the type and sequence of each development. This plan is implemented and controlled by the governing bodies such as the Department of Mineral Resources, Mine Subsidence Board and local Councils.

4.2 Improving Structures Capacity to Sustain the Risk

By optimisation of the deterministic hazards scenario (Figure 4) to minimise the effects of subsidence movement on surface structures. This is achieved by developing design methods aimed at improving the capacity of structures to withstand ground movement. Mehtods such as:

a) Isolating footings from surrounding ground movement by over excavation and back-filling with compactable material, avoiding deep footings and selecting flat rafts where possible in order to reduce friction forces on the underside of footings.

b) Designing footings to resist lateral and vertical differential movement by increased stiffness.

c) Making allowance to reduce the impact of damage caused by differential movement by articulation of the superstructure, maintaining uniform structural stiffness and making provisions for future relevelling including re-grading of sewer and storm water.

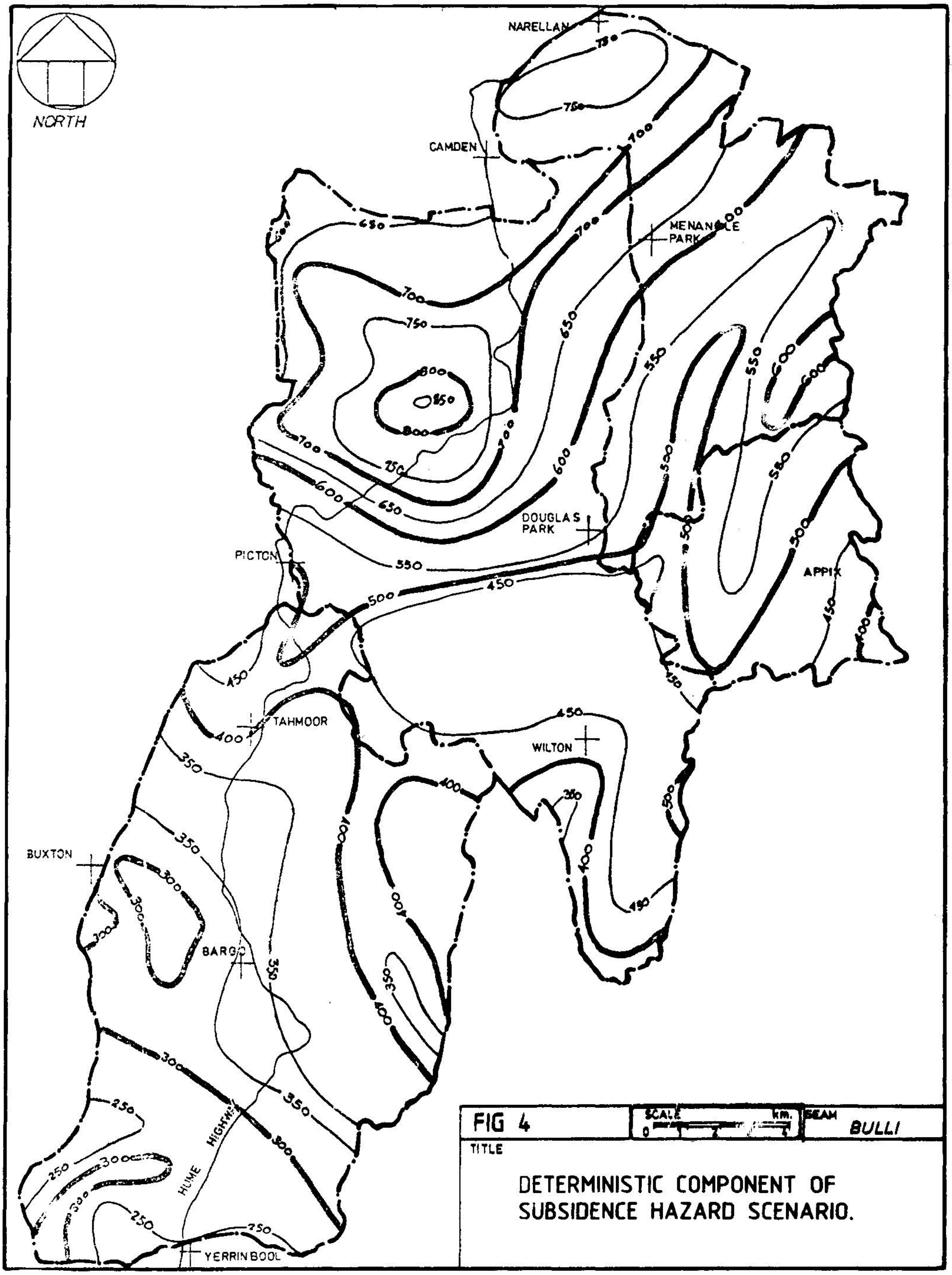


FIG 4 | SCALE km. 0 1 2 3 4 | SEAM BULLI

TITLE

DETERMINISTIC COMPONENT OF SUBSIDENCE HAZARD SCENARIO.

TABLE 1. CLASSIFICATION OF DAMAGE CAUSED BY TILT IN STRUCTURES UP TO 3.6m HIGH AS RELATED TO

i. SLOPE OF BUILDING g. GROUND TILT mm/m S/h. SEAM PROPERTIES mm/m

DEGREE & CLASS OF DAMAGE		CLAD FRAME	BV (ART).	BV	FB (ART).	FB	FLOOR CRACK WIDTH	WALLS CRACK WIDTH	DESCRIPTION OF TYPICAL DAMAGE	REPAIR COST
0 Negligible	i	1:300	1:500	1:800	1:800	1:2000	0.3 mm	0.1 mm	Hairline cracks not identifiable without magnifying glasses.	Nil
	g	5.2	3.2	2.0	2.0	0.8				
	S/h	2	1.2	0.8	0.8	0.3				
1 Very Slight	i	1:200	1:300	1:500	1:500	1:800	1.0	1.0	Isolated, rarely visible cracks at external wall. Easily treated during normal decoration.	Nil
	g	7.3	5.2	3.2	3.2	2.0				
	S/h	3	2	1.2	1.2	0.8				
2 Slight	i	1:150	1:200	1:300	1:300	1:500	2.0	5.0	Fine but noticeable cracks - easily repaired Doors & windows stick slightly.	1%
	g	10.5	7.3	5.2	5.2	3.2				
	S/h	4	3	2	2	1.2				
3 Moderate	i	1:100	1:150	1:200	1:200	1:300	4.0	15.0	Cracks impair weather tightness. Doors & windows stick - small sections may need replacement.	3-15%
	g	15.6	10.5	7.3	7.3	5.2				
	S/h	5.5	4	3	3	2				
4 Severe	i	1:75	1:100	1:150	1:150	1:200	7.5	25	Extensive repairs partial replacement. Repairs to frame.	10-20%
	g	20.8	15.6	10.5	10.5	7.3				
	S/h	7.5	5.5	4	4	3				
5 Very Severe	i	1:150	1:175	1:100	1:100	1:150	10	30	Structural integrity impaired. Building frame distorted. Major replacements	20%
	g	30	20.8	15.6	15.6	10.5				
	S/h	11	7.5	5.5	5.5	4				

This aspect has been covered by codification as design for mining subsidence is included in the Australian Standard on Residential Slabs and Footings [6].

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the NSW Department of Mineral Resources and Mines Subsidence Board for their assistance in carrying out the study and to Professor Owen Ingles for his constructive comments.

REFERENCES

[1] Subsidence Engineering Handbook, National Coal Board Mining Department, London, 1975.

[2] NAWAR G., Performance of Masonry Dwellings Under Ground Conditions Caused by Mining Subsidence. Proc., Inst. of Engineers Conference, Brisbane, 1985. (pp 26-31).

[3] INGLES O.G. & NAWAR G., Effects of Soil, Footings and Construction types on the Structural Performance of Domestic Dwellings. Proc., Quality Assurance, Codes, Safety and Risk in Structural Engineering and Geomechanics. Monash University, 1984. (pp 50-55)

[4] Frankham B.S. & MOULD G.R., Mining Subsidence in N.S.W. Proc., The Australian Istitute of Mining and Metallurgy, New Zealand, 1980.

[5] RYNCRAZ T., Ergebnisse von Modell Versuchen über den Einfluss von Oberflächenlasten auf den Absenkungstrog (poln), Arch górn 8 (1963), 111/28

[6] Dr. 85108, Draft Australian Standard on Residential Slabs and Footings. April, 1985.

KEYWORDS

Building Performance - Ground Movement.
Subsidence damage.

Leere Seite
Blank page
Page vide