Report Concerning the Vibration Levels Associated with the Proposed Demolition of the FGD Structures at Gelderland Power Station, Nijmegen, Netherlands

BROWN AND MASON GROUP LIMITED

R21.10976/1/1/DW
Date of Report: 18 January 2021

QUALITY MANAGEMENT

Report Title:	Report Concerning the Vibration Levels Associated with the Proposed Demolition of the FGD Structures at Gelderland Power Station, Nijmegen, Netherlands
Client:	Brown and Mason Group Limited
Report Number:	R21.10976/1/1/[redacted]
Issue Date:	18 January 2021

Prepared By:

[redacted]

[redacted]

Vibrock Limited
Shanakiel
Ilkeston Road, Heanor
Derbyshire, DE75 7DR
Tel: +44 (0) 1773 711211
Fax: +44 (0) 1773 711311
Email: vibrock@vibrock.com
Web: www.vibrock.com

CONTENTS

TABLES

FIGURE

1.0 INTRODUCTION

1.1 The demolition of the FGD Structures at Gelderland Power Station is proposed to be undertaken by the use of controlled explosive charges.

1.2 Such a use of explosives will give rise to a certain amount of energy both within the ground and within the atmosphere.

1.3 Accordingly, Vibrock Limited, an independent firm of noise and vibration consultants, have been engaged by Brown and Mason Group Limited to study the demolition proposals in order that:

i) these vibration levels can be quantified, and

ii) the significance of these levels can be assessed.

1.4 The weight and height of the structures to be demolished has been supplied by Brown and Mason Group Limited.

1.5 The demolition method statement for the event provides further information concerning the collapse mechanism and blast design including details concerning quantity and location of explosive charges.

2.0 GENERATION OF VIBRATION FROM EXPLOSIVE DEMOLITION

2.1 In general, the use of explosives for the demolition of structures is liable to give rise to both ground and airborne vibration. Detonation of the explosive itself may generate ground vibration, although it is usual for the majority of explosive to be located within the structure and above ground level and hence this source of vibration is generally minimal.

2.2 It is usually the airborne vibration or air overpressure generated by the explosive that is of most significance owing to the fact that the individual charges are often not able to be totally confined. Once detonation occurs, the impact of the structures with the ground will be a further source of vibration. In this case the vibration will be predominantly generated within the ground with any air vibration of a minimal magnitude.

3.0 GROUND VIBRATION

3.1 Vibration can be generated within the ground by a dynamic source of sufficient energy. It will be composed of various wave types of differing characteristics and significance collectively known as seismic waves.

3.2 These seismic waves will spread radially from the vibration source decaying rapidly as distance increases.

3.3 There are four interrelated parameters that may be used in order to define ground vibration magnitude at any location. These are:

Displacement	-	the distance that a particle moves before returning to its original position, measured in millimetres (mm).
Velocity	-	the rate at which particle displacement changes, measured in millimetres per second (mms^{-1}).
Acceleration	-	the rate at which the particle velocity changes, measured in millimetres per second squared (mms^{-2}) or in terms of the acceleration due to the earth's gravity (g).
Frequency	-	the number of oscillations per second that a particle undergoes measured in Hertz (Hz).

3.4 Much investigation has been undertaken, both practical and theoretical, into the damage potential of blast induced ground vibration. Among the most eminent of such research authorities are the United States Bureau of Mines (USBM), Langefors and Kihlström, and Edwards and Northwood. All have concluded that the vibration parameter best suited as a damage index is particle velocity.

3.5 Studies by the USBM have clearly shown the importance of adopting a monitoring approach that also includes frequency.

3.6 Thus the parameters most commonly used in assessing the significance of an impulsive vibration are those of particle velocity and frequency which are related for sinusoidal motion as follows:-

$$PV = 2 \pi f a$$

where	PV	=	particle velocity
	π	=	pi
	f	=	frequency
	a	=	amplitude

3.7 It is the maximum value of particle velocity in a vibration event, termed the peak particle velocity, that is of most significance and this will usually be measured in three independent, mutually perpendicular directions at any one location in order to ensure that the true peak value is captured. These directions are longitudinal (or radial), vertical and transverse.

3.8 Such maximum of any one plane of measurement is the accepted standard worldwide and as recommended by the British Standards Institution and the International Standards Institute amongst others. It is also the basis for all the recognised investigations into satisfactory vibration levels with respect to damage of structures and human perception.

3.9 In the UK, British Standard 7385 states that there is little probability of fatigue damage occurring in residential building structures due to blasting. The increase of the component stress levels due to imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. Non-structural components (such as plaster) should incur dynamic stresses which are typically well below, i.e. only 5% of, component yield and ultimate strengths.

3.10 All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

4.0 DAMAGE CRITERIA

4.1 Various authorities around the world have undertaken detailed research into determining the vibration levels necessary for the possible onset of damage to property. The United States Bureau of Mines (USBM) have reviewed all relevant published data, both theoretical and practical, to augment their own considerable research. They are, therefore, considered to be the foremost authority on this subject.

4.2 When defining damage to residential type structures the following classifications are used:

Cosmetic or threshold	-	the formation of hairline cracks or growth of existing cracks in plaster, drywall surfaces or mortar joints.
Minor	-	the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.
Major or structural	-	damage to structural elements of a building.

4.3 Published damage criteria will not necessarily differentiate between these damage types but rather give levels to preclude cosmetic damage and therefore automatically prevent any more severe damage.

4.4 The comprehensive research programme undertaken by the USBM in the late 1970's (R.I. 8507, 1980) determined that vibration values well in excess of 50 mms^{-1} are necessary to produce structural damage to residential type structures. The onset of cosmetic damage can be associated with lower vibration levels, especially at very low vibration frequencies, and a limit of 12.7 mms^{-1} is therefore recommended for such relatively unusual vibration.

4.5 A further USBM publication (Bureau of Mines Technology Transfer Seminar, 1987) states that these safe vibration levels are ".... for the worst case of structure conditions ....", and that they are ".... independent of the number of blasting events and their durations", and that no damage has occurred in any of the published data at vibration levels less than 12.7 mms^{-1}.

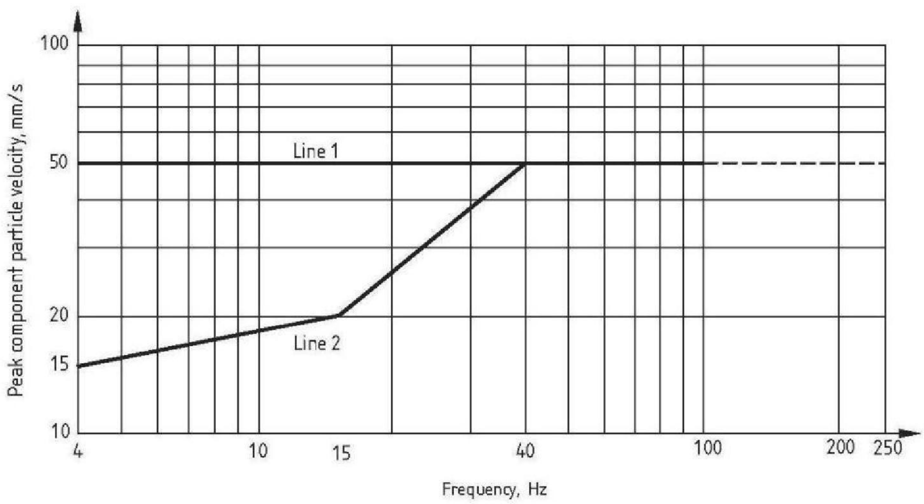
4.6 Within their publication on this subject (S.E.E. Conference 1991) reconfirms these safe vibration criteria and states that ".... these studies have since been widely adopted by the users and regulators of explosives to develop and demonstrate safe blasting practices." and that "In the ten years since their publication, nothing has appeared to replace them or even significantly add to the data base."

4.7 In addition, the British Standards Institution's structural damage committee have investigated blast induced vibration with respect to its damage potential. They contacted some 224 organisations, mainly British, and found no evidence of any blast induced damage at levels less than those recommended by the USBM.

4.8 This investigation culminated in British Standard 7385: Part 2: 1993, Evaluation and Measurement for Vibration in Buildings, entitled Guide to Damage Levels from Groundborne Vibration.

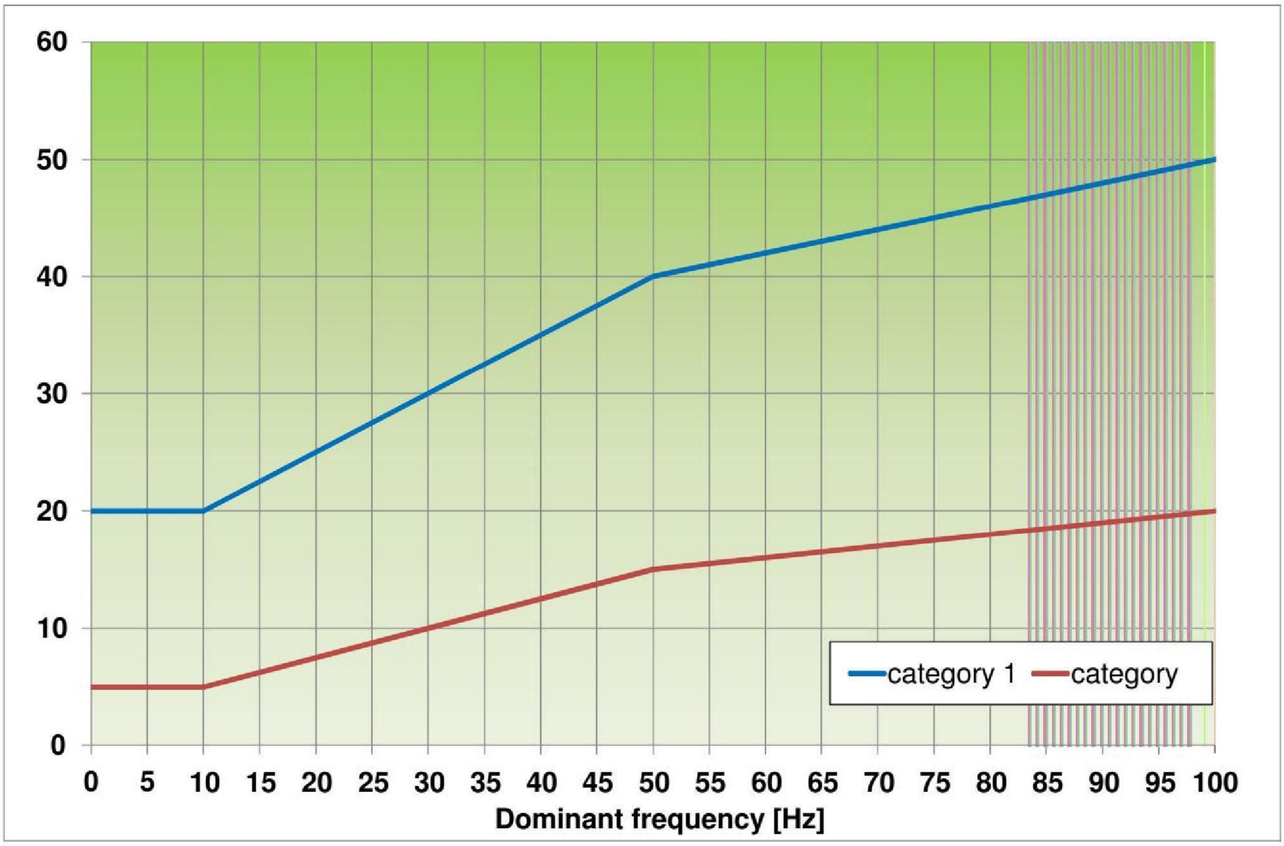
4.9 British Standard 7385 gives guide values to prevent cosmetic damage to residential type property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mms^{-1} is recommended, whilst above 40 Hz the guide value is 50 mms^{-1}. Industrial and commercial premises are assigned higher thresholds. These vibration criteria reconfirm those of the USBM.

Line	Type of Building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mms^{-1} at 4 Hz and above	50 mms^{-1} at 4 Hz and above
2	Unreinforced or light framed structures Residential or light commercial buildings	15 mms^{-1} at 4 Hz increasing to 20 mms^{-1} at 15 Hz	20 mms^{-1} at 15 Hz increasing to 50 mms^{-1} at 40 Hz and above
Note 1 – values referred to are at the base of the building Note 2 – for line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded			



4.10 In the Netherlands guidance is provided within document SBR Vibration Directive A: Damage from Construction: 2017. Similar to BS 7385: Part 2, building categories are assigned with relevant criteria as detailed below.

Category	Omschrijving
1	• Parts of the support structure, if they consist of reinforced concrete or wood. • Parts of a structure that are not part of the support structure (e.g. separation structures), if they consist of reinforced concrete or wood. • Supporting structures of structures, not buildings, consisting of masonry such as pillars of viaducts, quay walls and the like.
2	• Parts of the support structure of a building, if they consist of masonry. • Parts of a building that do not belong to the support structure, such as separation structures consisting of non-reinforced concrete, masonry or brittle stony materials.



4.11 Any doubt that such low levels of vibration are perfectly safe should be dispelled by considering the strain induced within a residential type property from daily environmental changes and domestic activities. This is confirmed within the 1987 USBM publication which quotes that daily changes in humidity and temperature can readily induce strain of the order that is equivalent to blast induced vibration of from 30 - 75 mms^{-1}. Typical domestic activities will produce strain levels corresponding to vibration of up to 20 mms^{-1} and greater.

4.12 It is for this reason that many domestic properties will exhibit cracks that may be wrongly attributed to demolition activities. There are many additional reasons why properties will develop cracks, for example:-

Fatigue and ageing of wall coverings.
Drying out of plaster finishes.
Shrinkage and swelling of wood.
Chemical changes in mortar, bricks, plaster and stucco.
Structural overloading.
Differential foundation settlement - particularly after times of prolonged dry spells.

5.0 AIRBORNE VIBRATION

5.1 Whenever an explosive is detonated transient airborne pressure waves are generated.

5.2 As these waves pass a given position, the pressure of the air rises very rapidly to a value above the atmospheric or ambient pressure. It then falls more slowly to a value below atmospheric before returning to the ambient value after a series of oscillations. The maximum pressure above atmospheric is known as the peak air overpressure.

5.3 These pressure waves will comprise of energy over a wide frequency range. Energy above 20 Hz is perceptible to the human ear as sound, whilst that below 20 Hz is inaudible, however, it can be sensed in the form of concussion. The sound and concussion together is known as air overpressure which is measured in terms of decibels (dB) or pounds per square inch (p.s.i.) over the required frequency range.

5.4 The decibel scale expresses the logarithm of the ratio of a level (greater or less) relative to a given base value. In acoustics, this reference value is taken as 20×10^{-6} Pascals, which is accepted as the threshold of human hearing.

5.5 Air overpressure (AOP) is therefore defined as:

$$\text{AOP, dB} = 20 \text{ Log} \frac{\text{(Measured pressure)}}{\text{(Reference pressure)}}$$

5.6 Since both high and low frequencies are of importance no frequency weighting network is applied, unlike in the case of noise measurement when an A - weighted filter is employed.

5.7 All frequency components, both audible and inaudible, can cause a structure to vibrate in a way which can be confused with the effects of ground vibrations.

5.8 The lower, inaudible, frequencies are much less attenuated by distance, buildings and natural barriers. Consequently air overpressure effects at these frequencies can be significant over greater distances, and more readily excite a response within structures.

5.9 Should there be perceptible effects they are commonly due to the air overpressure inducing vibrations of a higher, audible frequency within a property and it is these secondary rattles of windows or crockery that can give rise to comment.

5.10 In a blast, airborne pressure waves are produced from the following main sources:

(i) Material displacement.
(ii) Ground induced airborne vibration.
(iii) Lack of confinement of explosive charges.

5.11 Meteorological factors over which an operator has no control can influence the intensity of air overpressure levels at any given location. Thus, wind speed and direction, temperature and humidity at various altitudes can have an effect upon air overpressure.

5.12 Comprehensive investigations into the nature and effects of air overpressure with particular reference to its damage potential have been undertaken by the United States Bureau of Mines who have also reviewed all other published data on this subject (R.I. 8485, 1980). The weakest parts of most structures that are exposed to air overpressure are windows. Poorly mounted, and hence prestressed windows might crack at around 150 dB (0.1 p.s.i.) with most cracking at 170 dB (1.0 p.s.i.). Structural damage can be expected at 180 dB (3.0 p.s.i.). The USBM air overpressure research is detailed within BS 6472-2:2008.

5.13 The latest recommendations by the United States Bureau of Mines are as follows:-

Instrument Response	Maximum Recommended Level
0.1 Hz high pass	134
2.0 Hz high pass	133
5.0 or 6.0 Hz high pass	129
C - Slow	105 dB(C)

5.14 This set of criteria is based on a minimal probability of the most superficial type of damage in residential-type structures, the single best descriptor being recommended as the 2 Hz high pass system.

Deze pagina's zijn reeds openbaar of niet openbaar. Voor de reden verwijzen wij u naar het woo-besluit en de inventarislijst.

14 - 22

5.1.2f