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THE ALLEVIATION OF VIBRATION INDUCED STRUCTURAL DAMAGE ANXIETY

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1. INTRODUCTION

People are often subjected to high levels of whole body vibration without objection or complaint. For example, when travelling in road vehicles, trains, aircraft, ships and elevators. The inducement of whole body vibration can also be perceived as pleasurable. For example, babies are rocked in the arms of their parents, children and teenagers enjoy the thrill of fairground rides and the old folks enjoy the low frequency vibration of the rocking chair.

If similar levels of vibration from external sources are perceived by people in their own homes then strong objections and complaints are often received. The human response to whole body vibration stimulus can vary dramatically depending upon the situation of the subject. In many cases it is not the direct physical adverse effect of vibration on the human body but could be due to several psychological reasons for example:-

(i) the feeling of intrusion into private property

(ii) the 'nothing in it for me' feeling

(iii) the 'unable to stop it' feeling

(iv) not knowing when it will stop

(v) the fear of structural damage to the property.

Vibration in homes can be caused by activities such as piling, ground compaction, drop forge hammering, blasting and demolition or by transport such as road or rail traffic.

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In many cases the vibration magnitudes are only just over the level of perception but can be the cause of extreme anxiety and complaint. Anxiety is a psychological feeling of dread [1] that often occurs when a person is faced with events that they perceive as threatening to them. This particularly happens when they feel uncertain as to whether they are able to deal adequately with the situation.

There is a common misconception that if the magnitude of vibration is perceivable then it must be causing some degree of damage. This can lead to extreme distress and it is often the Vibration Consultant/Engineer or Environmental Health Officer (EHO) who is expected to alleviate this anxiety even though they may have had no specific training in this task.

This task is often made more difficult for the Engineer/EHO as:

(i) they are only called in after the work has started and complaints have been received

(ii) many minor cracks in buildings (which could have remained unnoticed for years) are found.

2. SOME PSYCHOLOGICAL FACTORS AFFECTING ANXIETY

To alleviate the fear or dread of a building being damaged due to perceivable vibration it is useful to have an understanding of some of the psychological factors which can effect human reaction to stressful events, the most important of these are predictability and controllability.

2.1 Predictability

Psychological research over the past three decades has shown that a subject's negative reaction to vibration, noise or shock is reduced if they are predictable rather than unpredictable [e.g. 2, 3]. This result is perhaps not surprising since predictability gives the subject the opportunity to prepare for the event in a way that minimizes its adversiveness. However, many operators of plant that cause perceivable environmental vibration, are under the impression that if local residents are informed about the activities they will complain more.

In most cases the opposite is true. Being able to predict when a stressful event is likely to occur and its duration, even if the individual cannot control it, usually reduces the severity of their anxiety. With unpredictable stressful events there is no safe period; with predictable events the individual can relax to some extent between events [4].

2.2 Controllability

Control of, or even simply the perception of control of, adverse events can also have an effect on reaction. In one study [5] the effect on subjects who had the option of terminating a randomly presented aversive stimulus was much less than those who had no perceived control. This is true even though the subjects did not avail themselves of the control opportunity. In another experiment [6] subjects who believed that they could control shock durations showed lower autonomic (peripheral nervous system) reactivity to the shock than did subjects who did not perceive control over the same stimuli.

An example is given to illustrate the practical aspects of the psychological factors. A construction company were carrying out vibratory piling within 8 m of residential properties [7]. The Industrial Noise and Vibration Centre (INVC) were consulted and the following procedure was followed:-

(i) all of the local residents were informed of when and why the piling was to be carried out (predictability).

(ii) they were told that it is likely that they would feel their house shake and they would notice fixtures rattling but the vibration would be carefully monitored by an independent engineer at all times to ensure that is does not exceed the set criterion (more predictability).

(iii) they were told where the engineer, who was carrying out the monitoring, could be contacted so that the process would be stopped (or modified) if they felt it was too severe (controllability).

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The magnitude of the vibration (PPV at 2.4 mm/s predominately in the 16 Hz 1/3 octave band centre frequency as shown in figure 1). Although this is well above the level of perception no complaints were received.

This is in stark contrast to previous work carried out by the same construction company (with the same equipment producing similar magnitudes of vibration) where no information was relayed to the local residents. Here the complaints were so strong that the work was almost stopped.

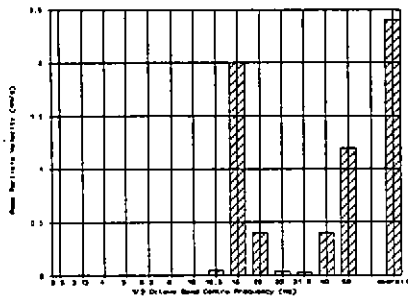

Figure 1. ***Example of 1/3 octave band spectrum from vibro piling at 8 m.***

3. COMMUNITY RELATIONS PROGRAMME

Where the vibration is generated by relatively short term construction (or similar) work, good community relations with the local residents are of paramount importance. The reason why the work is being carried out should be relayed. If the work has some benefit to them, however slight residents are more likely to tolerate it without complaints. Complaints are obviously more likely if residents do not want the construction work carried out (there is nothing in it for them). Community relations programs should, ideally, be set up before any work is started (unfortunately, they rarely are).

3.1 Building Surveys

Building surveys should be carried out to identify existing cracks and minor damage to nearby buildings before the work is carried out. Guidance on the risks involved in evaluation and inspection of buildings and structures is provided by the HSE [8]. The report should, ideally include a description of the house, a description of the rooms, a sketch of the floor plans, a description of the foundations and basement and a description of the plot. Suggested field inspection report forms are given by Dowding [9].

3.2 Community Education

An education programme should be set up for the affected community. During individual or community meetings the following basic facts should be relayed:-

(i) human beings are far more sensitive to vibration and noise than buildings are

(ii) slamming doors and foot stamping may vibrate buildings more than the proposed vibration [10]

(iii) cracks are caused by a variety of naturally occurring phenomenon such as temperature changes [11]

(iv) homes contain numerous cracks (of which owners are often unaware) that increase in number and size each year [12]

(v) most cracks are cosmetic and are not structurally harmful

(vi) an independent engineer will be monitoring vibration magnitudes and they will have the power to stop the work if level approach accepted guidelines.

This information is most easily transmitted through a well-publicised community meeting and should be followed by several residential crack surveys.

3.3 Monitoring Cracks During Vibration

It is advisable to monitor the size of any cracks that have been recognized as having the potential for expansion. This can be done with the use of 'Demec' gauges or vernier callipers which require the adhesion of small studs or screws on either side of the cracks. The distance between the studs can then be accurately measured with the gauge. Alternatively 'Avongard' tell-tales (or similar) can be fitted across the cracks which enable direct reading in vertical and horizontal directions with an accuracy of 1.0 mm.

4. CRITERIA

Before the local community can be reassured that no damage will occur the engineer will, of course, have to first have a high degree of certainty that this is indeed the case. While methods have been given on the assessment of annoyance from whole body vibration [13, 14], up until recently, there were no British Standards giving guideline values for vibration induced building damage. Foreign Standards were relied upon such as th. Swiss Standard SN 640312 [15] or more commonly the German Standard DIN 4150 [16] as shown in figure 2. For blasting the U.S. guidelines are often used [17] as shown in figure 3. In 1992 the British Standard BS 5228 [18] provided guideline values for piling vibration and in the same year a draft British Standard BS 7385 Part 2 [19] was issued (following BS 7385 Part 1 : 1990 [20]). Unfortunately the criteria in the two Standards are at variance as shown in figure 4.

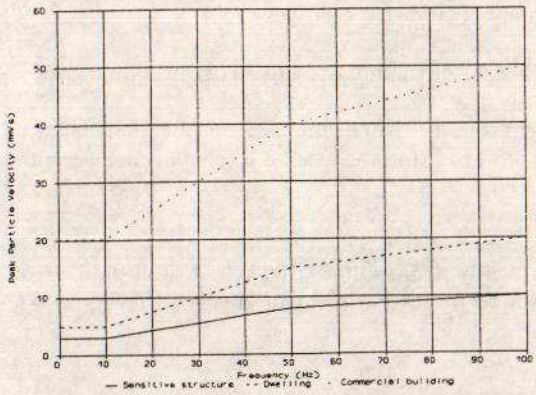

Figure 2. ***Curves representing guideline values of foundation vibration velocity as a function of frequency for evaluating the effects of short term vibration. (From DIN 4150 1986).***

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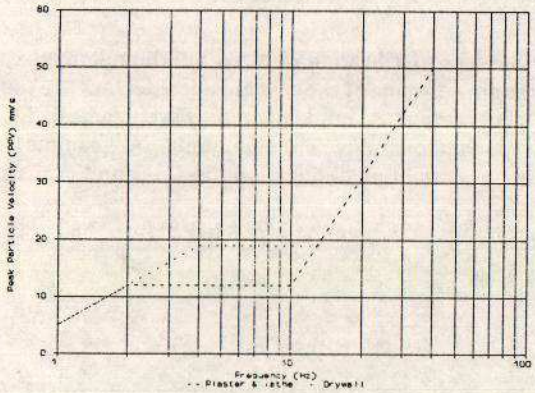

Figure 3. ***Curves representing guideline values of foundation vibration velocity as a function of frequency for evaluating the effects of blasting vibration. (From U.S Bureau of Mines (1980).***

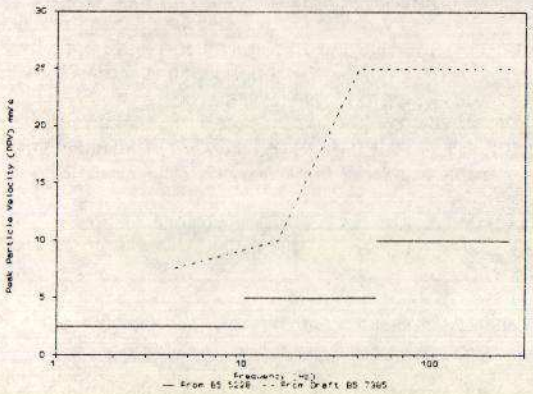

Figure 3. ***A comparison of the guideline values given BS 5228 Part 4 (1992) and Draft BS 7385 Part 2 (1992) for continuous pile driving vibration in residential buildings. Below these values minor (cosmetic) damage is unlikely to occur.***

5. CONCLUSIONS

The anxiety caused from the fear of vibration induced building damage can be greatly reduced if a basic understanding of some of the psychological factors are understood and a community relations programme is implemented. Psychological factors include predictability and (perceived) controllability. The community programme should include pre-vibration damage surveys, community education meetings and crack monitoring.

It is more useful if the community programme is started before the commencement of the works.

6. REFERENCES

[1] S. SUNDERLAND, 'Macmillan Dictionary of Psychology', *Macmillan Press Limited*, London (1991).

[2] L A PERVIN, 'The Need to Predict and Control Under Conditions of Threat' *Journal of Personality*, **31**, 570 -587, (1963).

[3] P BADIA, J HARSH, & B ABBOTT, 'Choosing Between Predictable and Unpredictable Shock Conditions: Data and Theory', *Psychological Bulletin*, **86**, 1107-1131 (1979).

[4] R KATZ & T WYKES, 'The psychological Difference Between Temporally Predictable and Unpredictable Stressful Events: Evidence for Information Control Theories', *Journal of Personality and Social Psychology*, **48**, 781 - 790 (1985).

[5] D C GLASS, J E SINGER & L N FRIEDMAN, 'Psychic Cost of Adaption to an Environmental Stressor' *Journal of Personality and Social Psychology*, **12**, 200 - 210, (1969).

[6] J H GEER, G C DAVISON & R J GATCHEL, 'Reduction of Stress in Humans through nonveridical perceived control of aversive stimulation' *Journal of Personality and Social Psychology*, **16**, 731 - 738, (1970).

[7] K SCANNELL, 'Vibration from Construction Works', *Industrial Noise and Vibration Centre Report*, (1992).

[8] HEALTH AND SAFETY EXECUTIVE, 'Evaluation and Inspection of Buildings and Structures', *Health and Safety series booklet HS(G)58*, HMSO Books, London (1990).

[9] C H DOWDING, 'Blast Vibration Monitoring and Control', *Prentice-Hall Inc., Englewood Cliffs NJ 07632, USA*, (1985).

[10] K SCANNELL, 'An Introduction to Structural Damage Caused by Vibration and Shock', *A presentation for the Institution of Environmental Health Officers*, The Strand, London (1991).

[11] J F WISS and H R NICHOLLS, 'A Study of Damage to a Residential Structure from Blast Vibrations' Special Publication, *American Society of Civil Engineers, New York*, (1974).

[12] A J HOLMBERG, N A LUNDBORG and G RUNQUEST, 'Ground Vibrations and Damage Criteria', *Report R 85 for the Swedish Council for Building Research (BFR) by the Swedish Detonic Research Foundation, Stockholm*,(1981).

[13] BRITISH STANDARD BS 6472 : 1992 'Evaluation of human exposure to and measurement of vibration in buildings' *BSI, London*, (1992).

[14] K SCANNELL 'Assessing annoyance from vibration using vibration dose values' *Proc. I.O.A. Vol 12 Part 7*, (1990).

[15] SWISS STANDARD SN 640312 'The Effects of Vibration on Structures', *Swiss Association Standards, Switzerland*, (1978).

[16] GERMAN STANDARD DIN 4150 Part 3 'Structural Vibration in Buildings - Effects on Structures', *Deutsche Norm, Berlin*, (1986).

[17] US BUREAU OF MINES 'Structure Response and Damage Produced by Ground Vibration from Surface Blasting'. *Report of Investigation 8507, USA* (1980).

[18] BRITISH STANDARD BS 5228 : Part 4 'Code of Practice for noise and vibration control applicable to piling operations, *BSI, London*, (1992).

[19] DRAFT BRITISH STANDARD BS 7385 : Part 2 'Measurement and Evaluation of Vibration in buildings - Guide to the Damage Levels from Groundborne Vibration' *BSI, London*, (1992).

[20] BRITISH STANDARD BS 7385 : Part 1 'Mechanical Vibration and shock - Vibration of buildings - Guidelines for the measurement of vibrations and evaluation of their effects on buildings' *BSI, London* (1990).

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