Newsletter #26
Employing USBM RI 8507 Recommendations for
Assessing the Possibility of Cosmetic Cracking in Engineered Structures

Table 1 — Transient vibration guide values for cosmetic damage

Line (see Figure 1)	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 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commerical type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above
NOTE 1 Values referred to are at the base of the building (see 6.3). NOTE 2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.			

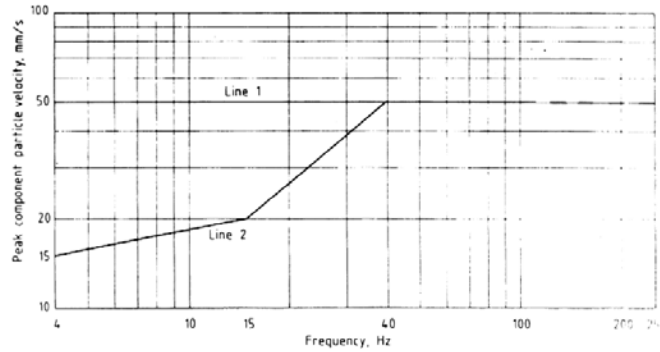

Figure 1 — Transient vibration guide values for cosmetic damage

Table 1 (left) showing engineered (reinforced or framed) structures to have greater cosmetic crack resistance than residential structures. British Standard BS 7385-2 (1993) Evaluation and measurement for vibration in buildings — Part 2: Guide to damage levels from ground-borne vibration. Figure 1 (right) Graphical description of the higher allowable peak particle velocities for engineered structures – line 1.

Even though in USBM RI 8507's "safe blasting vibration criteria were developed for residential structures" they can be employed with confidence for engineered structures and other vibration sources when conditions are similar. Application to engineered structures is made possible through both experimental results and physics-based principles. These principles are: 1) at similar applied stress and strain levels, stronger materials are less susceptible to cosmetic cracking than weaker materials, 2) regardless of the name of a structural type, if its dynamic response properties are similar to those of a residential structure, it will respond in the same way as a residential structure.

When considering structures that have similar response properties, those that are constructed with stronger materials are less susceptible to cosmetic cracking. Consider first those constructed with Drywall. The lower bound of the Z curve in 8507 is based upon cracking of distressed, older structures whose walls were constructed of plaster and lathe as discussed in Newsletter 2. On page 59 of RI 8507 Siskind et al write

"Modern Drywall (gypsum board) interior-walled homes are apparently more capable of withstanding vibrations, since the paper-backed wallboard is relatively stiff and non-brittle. Only two studies specifically examined Drywall damage from blasting, Wiss' (57) and the new Bureau of Mines measurements [RI 8507]. The lowest vibration level corresponding to very minor crack extensions was ~.79 in/sec (structure 20), and many non-damage observations were made at levels exceeding 2.0 in/sec. Consequently, there is little justification in using the conservative 0.50 in/sec or anything lower for modem construction, and in this case ~.75 in/sec is a good minimum criterion. The conservative 2.0 in/sec is justified for the high-frequency blasts, even though the 5-pct value is 3.2 in/sec. This is based on the lowest observed damage value of 2.2 in/sec and the fact that no observations were made of damage corresponding to the "threshold" criteria of the other studies. Construction and excavation blasting will often fall in this high-frequency category."

Now consider concrete masonry unit, CMU, (cinder block) walls. Since concrete and cement mortar comprising the masonry walls are stronger than the materials comprising the gypsum cored paper covered drywall nailed to wood stud walls, masonry walls are inherently stronger. In 2000 Siskind in his summary work implied the same in the chapter on Vibration Induced Cracking in Homes and Safe-Level Criteria. In the section on Degrees of Blast Damage he says "Because of the relative strength of masonry compared to plaster cored wallboard, cracks in concrete and/or masonry would not be expected to occur without extensive super structure damage"

Next consider unreinforced concrete. As described in the section on basement walls in my book Construction Vibrations (pg 363), a model blast experiment showed that unreinforced concrete is even stronger than masonry. Crawford and Ward detonated charges in a 2.4 x 2.4 x 1.8 m (8 x 8 x 6 ft) box built with walls of concrete and masonry. The masonry walls failed at 75 mm/s and the concrete walls failed at 254 mm/s. See the book for details of the experiment. Suffice it to say, concrete is stronger than masonry walls.

Engineered structures, generally constructed with cementitious materials, are stronger and less susceptible to blast induced cracking than residential structures. As shown in Table 1, the greater cosmetic crack resistance of engineered structures is explicitly stated in the British Standard BS 7385 Part 2 : Guide to damage levels from ground-borne vibration (1993) in Table 1. Table 1 shows that engineered (reinforced or framed) structures can sustain higher PPV levels than residential structures. Table 1's grater allowable PPVs for engineered structures is graphed in Figure 1.

Furthermore, if PPVs at an engineered structure do not exceed the more restrictive allowable PPV line (2), there is greater assurance that the engineered structure will not sustain cosmetic cracking from a vibratory source.

Dynamic response properties of the USBM residential structures fall within the bounds of expectation as shown in Chapter 6 of Construction Vibrations. Thus it is expected that typical engineered structures will respond in a fashion similar to the USBM residential structures. As described in Figure 6-4 of Construction Vibrations the USBM one and two story structures had natural frequencies that varied from 3 to 10 Hz and damping ratios from 2 to 8%. These observed dynamic properties are normative. The expected natural frequency of any building is equal to 1/(0.1N) where N = the number of stories. Thus a one story structure has a higher (10 Hz) expected natural frequency and a 2 story building is lower, 5 Hz. The observed values for the USBM residential structures fall within this range as shown in Figure 6-4.

Another, earlier British Standard, also explicitly describes that engineered structures are less susceptible to cosmetic cracking than residential structures as illustrated by in Table A.2 below on the next page. As stated in the standard "This annex provides simplified and helpful guidelines for classifying buildings according to their probable reaction to mechanical vibrations transmitted by the ground. The left portion of the table lists 8 structure types in the columns, which are described in the 8 rows of the table to the right. The column encapsulated in green is that for "single and two story houses and buildings of associated uses made of lighter construction using lightweight materials". Each building type – column – is subdivided with a foundation type. Foundation type "Ba"(= spread footing "B" on rock "a") is encapsulated in gold for building types 2-6. As defined on the left column of the left portion, ***the level of acceptable vibration decreases in a downward direction.***

Comparison of the gold squares shows that the single story moderately light weight open type industrial building (column 3) has a higher level of acceptable vibration than does the residential structure (column 7) with both buildings on spread footing on rock (Ba). The standard goes on to say "In assessing the effect of vibration on building components it should be noted that the dynamic stresses corresponding to a p.p.v. of 10 mm/s, range typically from only 0.4 % to 2.3 % of the allowable design stress for some specific building materials [4]. A method of estimating peak stress from p.p.v. is given in annex B of BS 7385-1:1990".

REFERENCES

British Standard BS 7385-2 (1993) Evaluation and measurement for vibration in buildings — Part 2: Guide to damage levels from ground-borne vibration

British Standard BS 7385-1 (1990) Evaluation and measurement for vibration in buildings — Part 1: Guide for measurement of vibrations and evaluation of their effects on buildings. ISO 4866:1990

Table A.2: Classification of buildings according to their resistance to vibration along with the definitions of structural types (categories). As shown by the gold squares Category 3 (single story moderately light weight open type industrial building) has a higher level of resistance than does Category 7 (houses) when on the same foundation type (Ba – spread footing on rock)

Table A.2 — Classification of buildings according to their resistance to vibration and the tolerance that can be accepted for vibrational effects

Class of building[a]	Category of structure (see Table A.1): 1	2	3	4	5	6	7	8
	Categories of foundations (capital letters) and types of soil (lower case letter) (see clause A.5 and clause A.6)							
1	A a							
2	A b	A a	A a	A a				
3		A b B a	A b B a	A b	A a A b			
4		A c B b	B b	A c	A c B a B b			
5		B c	A c		B c	B a		
6		A f		A d	B d	B b C a	B a	
7			A f	A e	B e	B c C b	B b C a	
8						B e C c	B c C b	
9		B f				C d	B d C c	A a
10			B f			C e	B e C d	A b
11				C f	C f		C e	B a
12						C f		B c C a
13							C f	B d C b C c
14								C d C e C f

← Level of acceptable vibration decreasing

[a] High class number = high degree of protection required.

Category of structure	
1	Two- and three-storey industrial, heavy-frame buildings of reinforced concrete or structural steel, clad with sheeting and/or infilling panels of blockwork, brickwork, or precast units, and with steel, pre-cast or *in situ* concrete floors Composite, structural steel and reinforced concrete heavy industrial buildings
2	Five- to nine-storey (and more) blocks of flats, offices, hospitals, light-frame industrial buildings of reinforced concrete or structural steel, with infilling panels of blockwork, brickwork, or precast units, not designed to resist earthquakes
3	Single-storey moderately lightweight, open-type industrial buildings, braced by internal cross walls, of steel or aluminium or timber, or concrete-frame, with light, sheet-cladding, and light panel-infilling, including earthquake-resistant types
4	Two-storey, domestic houses and buildings of associated uses, constructed of reinforced blockwork, brickwork or precast units, and with reinforced floor and roof construction, or wholly of reinforced concrete or similar, all of earthquake-resistant types
5	Four- to ten-storey domestic and similar buildings, constructed mainly of lightweight load-bearing blockwork and brickwork, calculated or uncalculated, braced mostly by internal walls of similar material, and by reinforced concrete, preformed or *in situ* floors at least on every other storey.
6	Two-storey domestic houses and buildings of associated uses, including offices, constructed with walls of blockwork, brickwork, precast units, and with timber or precast or *in situ* floors and roof structures
7	Single- and two-storey houses and buildings of associated uses, made of lighter construction, using lightweight materials, pre-fabricated or *in situ*, separately or mixed

← Resistance to vibration decreasing