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Quantitative Analysis of Psychological Response Against Vibration in Bridge Design

Influence de la réaction psychologique à la vibration, dans le projet de ponts

Einfluß der psychologischen Reaktion gegen Schwingungen im Entwurf von Brücken

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Structural serviceability is considered as a very important factor in modern design concept of bridge and building structures.

It is reported that, although it may be a rare example, an old man on a foot bridge encountered an impediment in walking against the unpleasantness produced by the bridge vibration. In the United States, inhabitants in a tall building often complains of the unpleasantness against wind induced vibrations (1).

Pedestrians on a bridge or inhabitants in a tall building recognize the vibrations as unpleasantness, when the vibration intensity is beyond a certain level, whereas they are not affected by the vibration if it is weak.

This unpleasantness is to be considered as a sort of emotional response which causes a motivation to action. In other words, unpleasantness is associated with human consciousness which is not governed only by vibration magnitude or psychological scale measured by means of experimentally obtained physical quantity.

Modern bridges or buildings should not be designed on the basis of only mechanical responses against physical actions and excitations. Human emotions or their subjective responses should be also integrated on the design.

In this direction, first of all, the psychological scale must be clearly specified. Generally it is the practice to take subjective responses of testees on a simplified model structure in a laboratory in order to estimate the psychological scale. The nonlinear relationship between the physical and the psychological quantities are thereafter plotted on proportional scale.

In the following paragraphs, are presented some observations and discussions on human responses against foot bridge vibration, in which both Miwa's (2) and Kobori's (3) psychological scales are employed. It is noted that although the both scales are based on an almost identical experiment, the results are summarized in different fashions with respect to frequency domains, equal sensation curves and the treatment of compounded vibrations. Consequently the both scales are not necessarily propotional.

In order to establish the functional relationship between the emotional responses of pedestrians on foot bridges and the corresponding psychological scale, field surveying of human responses was performed for pedestrians on twenty three foot bridges during time period from 8 A.M. to 5 P.M. in Tokyo. At the same time, recorded was the vertical vibrations at the center point of each bridge. Fig. 1 shows a part of measured values in the psychological scale for some measured bridges. In this study, the category of emotion was specified into five ranges as shown in Table 1, and parameters such as sex, profession, group and so on are taken as the factors against emotion.

A part of the results of analyses based on the questionnaires to users is given in Fig. 2. It is found that even identical vibration affects quite differently upon the subjective responses of pedestrians who are standing and of pedestrians who are walking. Pedestrians who are standing on a bridge recognize the vibration sharper than those who are walking.

Table 1 Category of Perceptions

1	Imperceptible
2	Barely perceptible
3	Distinctly perceptible
4	Strongly perceptible
5	Severe

Table 2 Vibration Greatness

Factor \ Emotion		Imperceptible	Barely imperceptible
Standing		0.10	0.13
Walking			
	Men	0.32	0.35
	Women	0.31	0.32
	Businessmen	0.30	0.38
	Laborers	0.37	0.40
	Students	0.32	0.34
	Housewives	0.25	0.28
	Children	0.36	0.27
	Single	0.33	0.37
	Group Talking	0.39	0.31
	Group Not talking	0.30	0.26
	Business	0.33	0.37
	Shopping	0.27	0.27
	Walking	0.26	0.20
	Miscellaneous	0.32	0.34

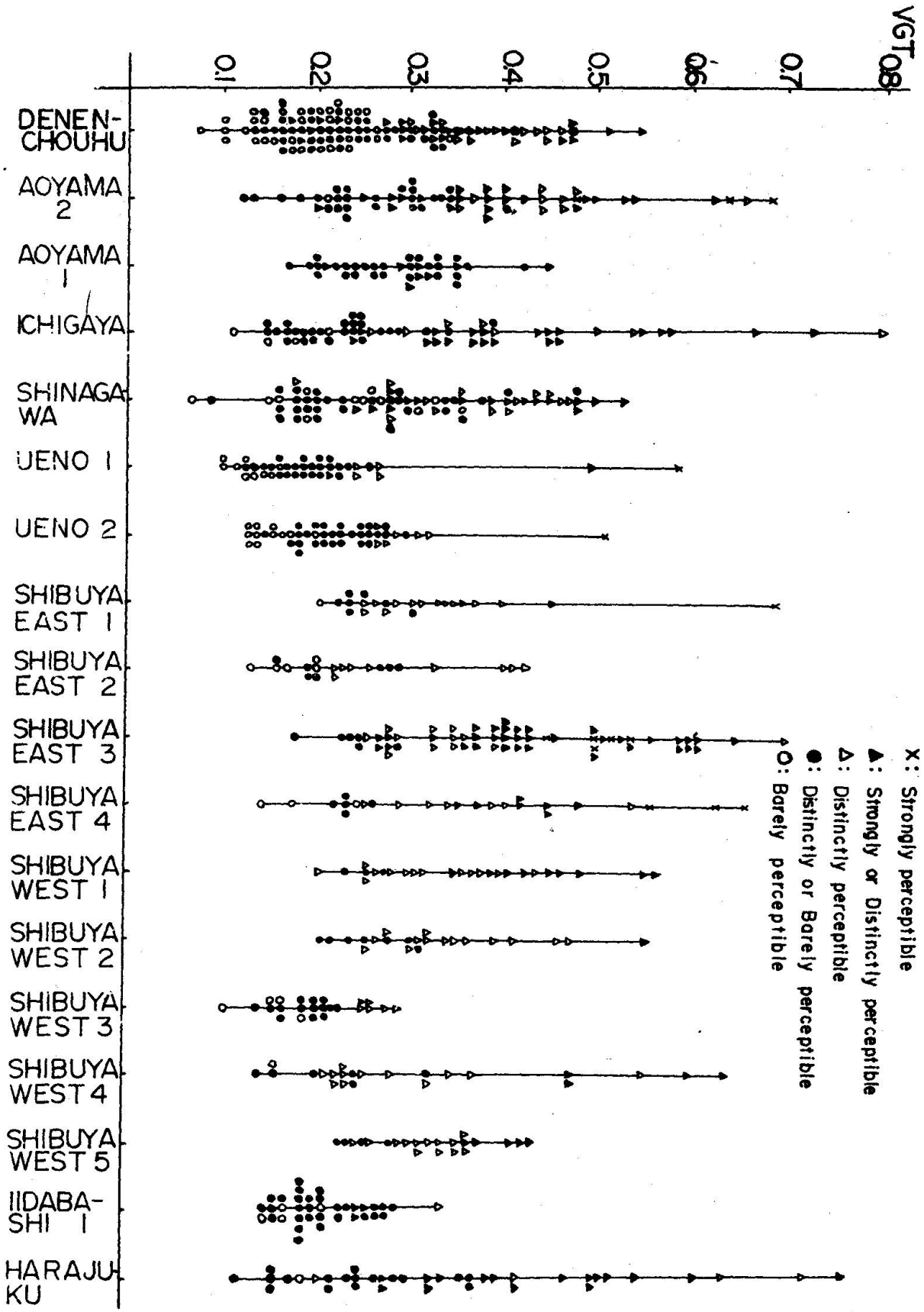

Fig. 1 Measured Vibration Greatness

It is found that there were few cases in which pedestrians had realized the vibration after they were questioned, although they did not feel any shake while walking. Table 2 shows the values of psychological greatness corresponding to the value 50 % of cumulative distribution curves for emotions of pedestrians on foot bridges. The following observations can be made through the surveying.

For the imperceptible emotion, walking persons feel the vibration three or four times greater than when standing, whereas for the barely perceptible emotion, it becomes as two or three time great as in simply standing. It is also observed that the vibration greatness of imperceptible emotion in office area is recognized to fall into the barely perceptible emotion in residential area.

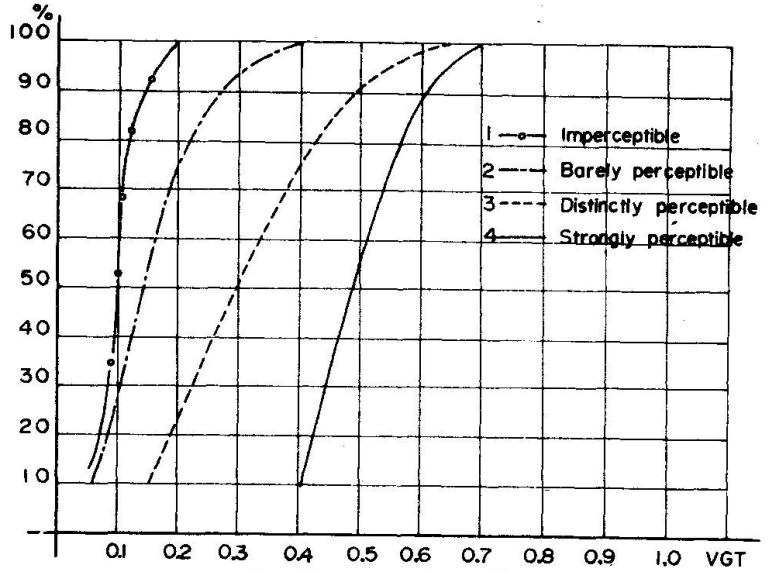

Fig.2-A Standing

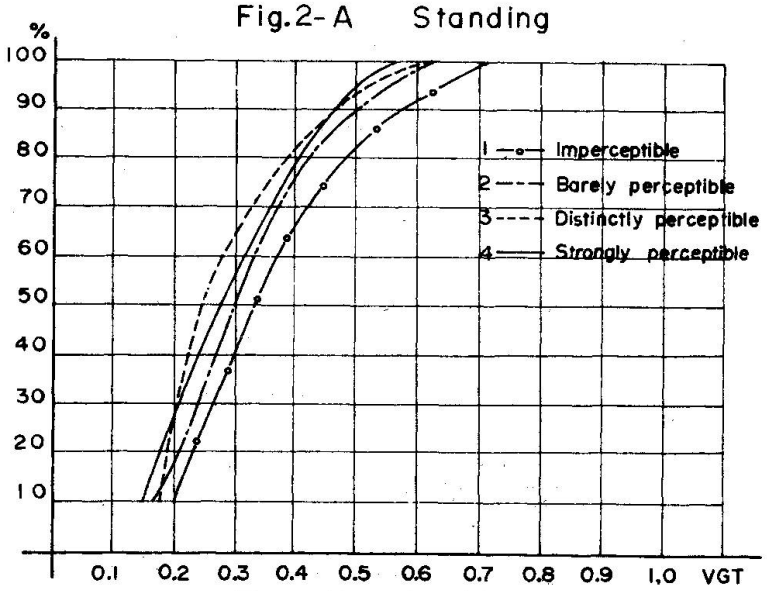

Fig.2-B Walking

Cumulative distribution curves for Emotions of Pedestrians on Foot-bridges

The algebraic average of the values of the imperceptible emotion in Table 2 turned out to be 0.3. The ratio of the numbers of vibration greatness which have, for example, the values less than 0.3 is analyzed against the total observations for each parameter gEI/wl^4. Then the ratio is plotted against gEI/wl^4 in Fig. 3. The curve of vibration greatness can be shown in the different manner. Fig. 4 shows that the curve of vibration greatness against predominant frequency has an upper bound and an lower bound. Most of foot bridges will be fallen into their ranges.

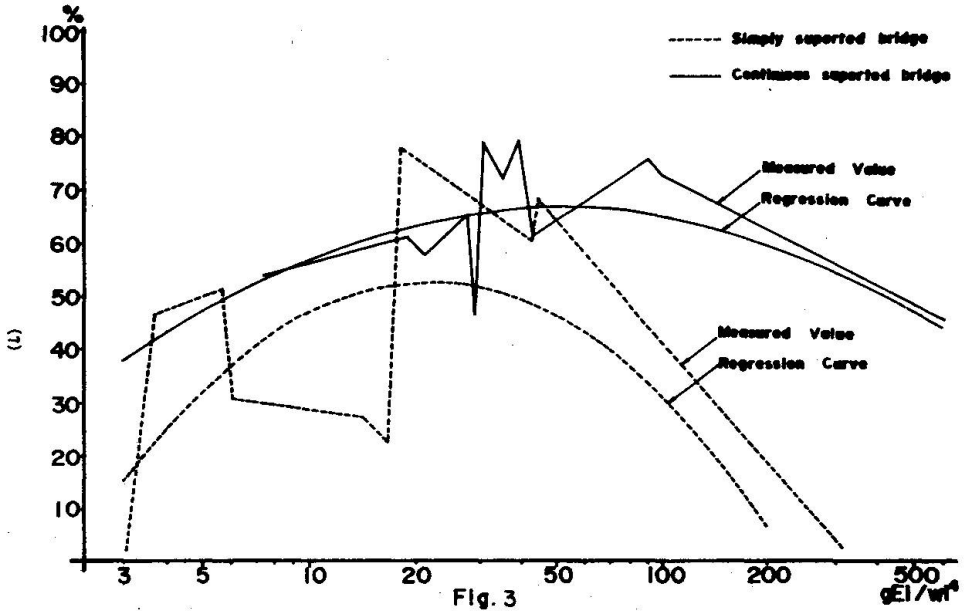

Fig. 3

Probability curve that pedestrians feel such that vibrational greatness is greater than 0.3.

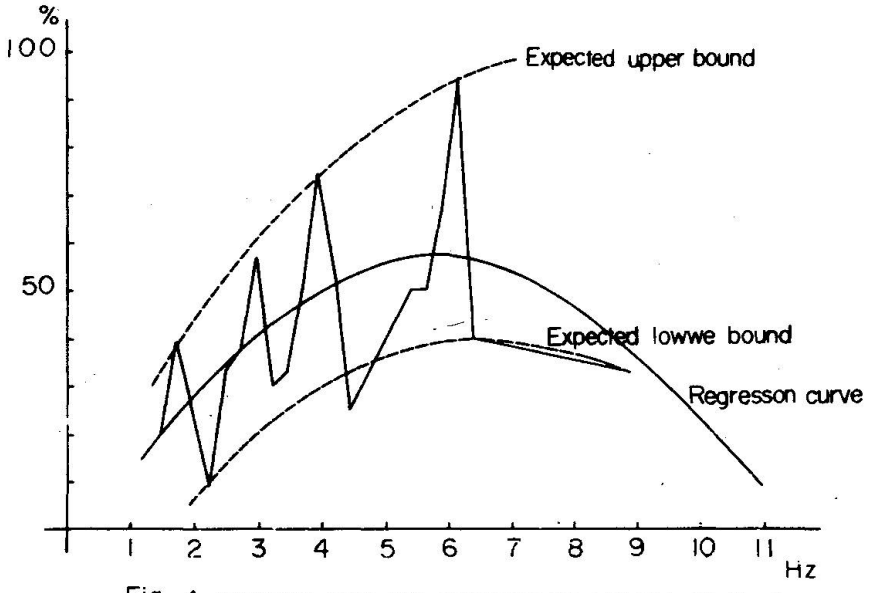

Fig. 4 Probability curve that pedestrians feel such that vibrational greatness is greater than 0.3

By making use of Fig. 3 or Fig. 4, the structural parameter can be properly chosen such that probability that at least half of pedestrians feel the vibration can be put below a prescribed level.

On the basis of the aforementioned study, human responses against bridge vibration can be integrated into the decision of the structural design parameter.

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SUMMARY

Psychological responses of pedestrians on foot bridge vibration are measured and discussed. Then, structural serviceability is emphasized as one of the criteria in the decision of structural design parameters.

RESUME

On a caluclé et commenté les réactions psychologiques des piétons à la vibration d'une passerelle. C'est ainsi que la serviciabilité est considérée comme un des critères de choix des paramètres du projet.

ZUSAMMENFASSUNG

Die psychologischen Reaktionen der Fussgänger auf Fussgängerbrücken wurden gemessen und diskutiert. Sodann wird die Nutzung als eines der Kriterien bei der Wahl der Entwurfsparameter hervorgehoben.