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DOUBLE-PENDULUM VIBRATION ISOLATION FACILITY FOR THE ELECTRIC CONTROL CUBICLE OF THE VERTICAL CEMENT MILL

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1. INTRODUCTION

1995, 17th of January in the early morning, the great earthquake had attacked near Kobe in Japan. The tremendous destroied spectacle which could not be expected over our experience has been standing there. Big concrete building ,piers, high way road, bridges etc. as well as wooden private houses were broken completely. It is not only old one but also new one. The earthquake that is called an epicentral earthquake was caused due to movement of the active fault. And those destructions are caused due to not only horizontal forces but also vertical force. About 1G of vertical force acted upon all structures in this area, and it may have been bigger rather than the horizontal force. The typical destructions were caused by the buckling due to the vertical force, as shown in Fig.1. Designing some structures, the horizontal force due to earthquake was only considered with 0.2 ~ 0.4G until now. From these experiences, the vertical force may be considered in design. And now the safty factor and vertical force are re-examining in the organization.

The vibration isolation facilities for architectures, structures, industrial facilities etc. are recently taking notice of more and more. And some architectures which install vibration isolation facilities as shown in Fig.2 try to be designed by way of experiment. Meanwhile, some active control system that use principles of dynamic dumpers, pendu-lums, sloshing etc. try to be applied to high rise buildings and ships. It is gradually known that these technologies are available for preventing vibration. These technologies are attached much importance more and more to keep not only good environment but also to draw high quality performance from precision machines and measuring instruments. We are subsequently under the necessity of developing various kind of preventing vibration technologies .

This paper presents the case study that is the remedy of vibration reduction of the electric control cubicle by double-pendulum vibration isolation facility.

2. FEATURE OF DOUBLE-PENDULUM VIBRATION ISOLATION FACILITY

The mechanism of vibration isolation system which reduce the large amplitude of vibra

tion may tend to be complicated. Such as the pendulum vibration isolation system may be suitable for reducing like this vibration. As the length of pendulum is getting longer and longer, its natural frequency becomes smaller and smaller. This is favorable to reducing vibrations. While this is adverse to installing the vibration isolation facility, because it is necessary to get larg space in order to set up long pendulum.The double- or multi-pendulumsystem as shown in Fig. 3 may improved this adverse condition, on the other hand, it is possible to set up it at small space by folding up long pendulum. The natural frequency of multi-pendulum may be equivalent to that of single pendulum which sum up each length of multi-pendulum, if the middle weight M1 is enough less than the payload weighted M2 . The natural frequency of double-pendulumis shown by eq. (1) .

$$\nu^2=\frac{1+\mu}{2}\left\{\nu_1^2+\nu_2^2\pm\sqrt{(\nu_1^2-\nu_2^2)^2+4\nu_1^2\nu_2^2\mu\frac{1}{1+\mu}}\right\}$$

$$\nu_1^2=\frac{g}{l_1}\ ,\quad \nu_2^2=\frac{g}{l_2}\ ,\quad \mu=\frac{M_2}{M_1} \qquad (1)$$

$$\nu=2\pi f$$

This system is effectively suitable for wide frequency range i.e. from low frequency to high frequency, and for 2-horizontal directional vibration components.

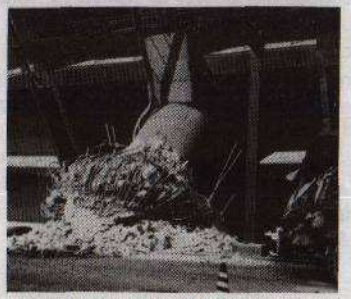

Fig.1 DESTRUCTION OF HEIGH WAY PIER BY EARTHQUAKE

3. CASE STUDY APPLICATION OF DOUBLE-PENDULUM TO VIBRATION ISOLATION FACILITY

This case study is that double-pendulum vibration isolation facility is applied to the electric control cubicle which is shaken by the vertical cement mill. The schematic diagram of installation of the vertical mill is shown in Fig.4. This cubicle is installed on the steel-structure where is located next the vertical cement mill. Especially horizontal vibrations are more dominant than that of vertical. And some electrical parts, such as elec-trical points and IC-circuits

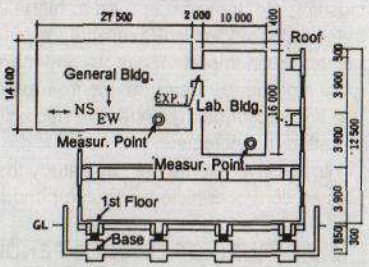

Fig.2-1 VIB.-ISOLATION FOR BUILDING

in the cubicle have been damaged by the vibrations. Life of some electrical parts becomes very short. Some countermeasures, such as the remedyby using isolation rubber and the remedy by using reinforcements between cubicle and structure had been tried, but a complete countermeasurs had not been found out until this remedy presents.

MAX. ACCELERATION

Unit : cm/s^2	DIRECTION		
Position	EW	SN	UP-DOWN
Lab. Bldg. (with Isolation)			
ROOF	273	198	334
1st Floor	253	148	266
Base	265	272	232
General Bldg. (without Isolation)			
ROOF	677	965	368

Fig.2-2 FEATURE OF VIB.-ISOLATION BY BIG EARTHQUAKE'95/17/Jan.

3-1. VIBRATION ON VERTICAL CEMENT MILL BASE

Vibration on a mill base was about 65 ~ 70 μ m in vertical direction, immediately after this mill-plant was completed, when this was operated under 244 ~ 280 ton/Hr disposed quantity. And after 6-months, this vibration was reduced and was saturated with about 18 ~ 26 μ m in vertical direction. Time history of vibration and vibration accelaration spectra on a mill-base was shown in Fig.5 and Fig.6.

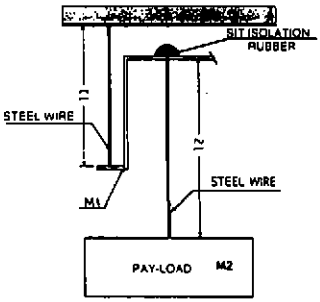

Fig.3 STRUCTURE OF PENDULUM VIBRATION ISOLATION

3-2. VIBRATION ON THE CUBICLE

Magnitude of vibrations on the electric control cubicle are that; Vibration Accerelation Level (shown by VAL) in X-direction is average 79 dB, VAL in Y-direction is average 87dB, VAL in Z-direction is average 84dB, and dominant frequencies are respectively 16Hz in X-direction, 12.5Hz in Y-direction,16Hz in Z-direction, where X-direction is along longitudinal axis of cubicle line, Y-direction is perpendicular to X-direction and horizontal, Z-direction is perpendicular to the ground , X-axis and Y-axis.

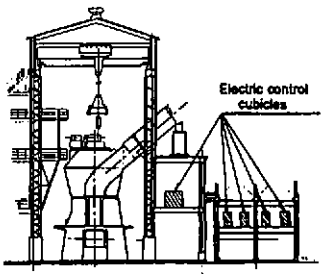

Fig.4 SCHEMATIC DIAGRAM OF VERTICAL CEMENT MILL

3-3. VIBRATION REDUCTION CRITERION

As there is no regulation and no criterion of VAL for the electric cubicle, limited VAL of 1/3 oct band level should be respectively decided less than 70dB as criterion. And it becomes very useful criterion that the extreme, dominant level components are not contained in the vibration acceleration spectrum, that is ,the envelop of the spectrum is smoothly.

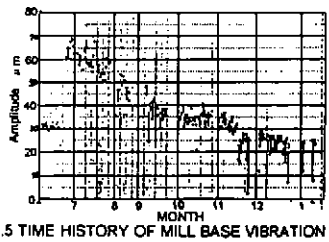

Fig.5 TIME HISTORY OF MILL BASE VIBRATION

3-4. RESULTS

The vibration acceleration spectrum on the cubicle ,after the double-pendulum vibration isolation facility was completed, are shown in Fig.7. The part of oblique lines means vibration reduction which was gotten by the remedy. We could confirm the expected vibration reduction as shown in table-1 and no extreme,dominant band level components as shown in Fig.7. 3 years past , since this remedy had been done, there has been no trouble in the electric control cubicle.

4. CONCLUSION

Recently, It is becoming increasingly many to use the vibration isolation technologies for many kind of precision machins, instruments and facilities. We could confirm that multi-pendulum vibration isolation facility is very suitable for preventing relative large displacement of vibration, horizontal vibrations and broad band frequency range.

This technologies may be applied to various kind of access floor-systems for computer room, opical instrument room, some electron microscope etc. as well as various general machines.

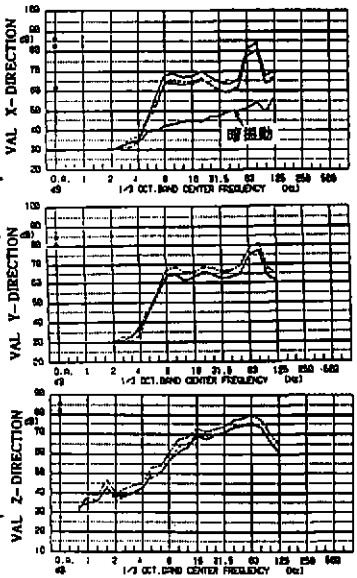

Fig.6 VAL-SPECTRUM OF MILL BASE VIBRATION

Table -1 VAL on the cubicle before / after remedy

	X-Dir.	Y-Dir.	Z-Dir.
Before Remedy			
Peak Freq.	16 Hz	12.5 Hz	16 Hz
VAL	75 dB	84 dB	81 dB
After Remedy			
VAL	65 dB	60 dB	70 dB
VAL-Reduction	10 dB	24 dB	11 dB

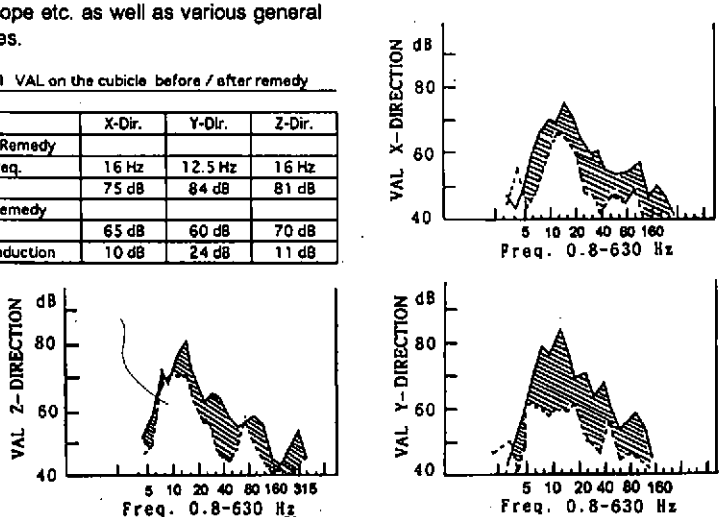

Fig.7 COMPARISON BETWEEN VAL-SPECTUM ON THE CUBICLE BEFORE REMEDY AND THAT AFTER REMEDY