RIGID MASS ON SLIDING FRICTION

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INTRODUCTION

Although Coulomb friction has been used extensively in base isolator design such as LRB and R-FBI. The objective of this study was to assess the frictional properties of Teflon (trade name of PTFE, polytetra-fluoro-ethylene) sliding on itself under dynamic excitation. Previous experiments on Teflon-Steel interfaces have been reported in Ref.2 but, this study is specifically based on finding the isolation characteristics of Teflon only, for such applications. Shaking table experiments were conducted on unfilled Teflon with varying bearing pressures and frequency of excitation. The Teflon interfaces inhibit high acceleration input to the rigid mass beyond 0.10 g and is the basis of an efficient base isolation system. These values are much lower then the Steel-Teflon interfaces.

TESTS

With the above objective, a 40 cm by 30 cm and 30 cm high rigid mass model of mild steel was constructed. The testing was performed on the 3.0 by 2.0 m actuator controlled shaking table. All experiments were carried out at a room temperature of 6.0 $°C$. A view of the test setup in Figure 1 shows a rigid box supported by four 1.0 cm^2 Teflon elements on a 5.0 mm thick unfilled Teflon sheet of 70.0 cm by 60.0 cm size. The Teflon elements were epoxy bonded to an acrylic section and then to the mild steel base of the box. The bearing pressure is increased by inserting steel plates up to a total of 70.0 kgf, which were bolted to the base of the box. The Teflon sheet below is bolted to a steel sheet and then on to the shaking table.

The shaking table was driven at a sinusoidal acceleration with frequencies of 1.5, 2.0, 3.0, 4.0 and 5.0 Hz. The amplitude of input acceleration was steadily increased from zero to 0.45 g or the displacement limit of the table especially for 1.5 and 2.0 Hz. One servo type accelerometer was each placed on the shaking table and inside the box to record acceleration. In addition four transducers, two each produced a record of the box's absolute and relative displacements. All values were recorded at a LPF (low pass filter) of 28.0 Hz. The box was tested with a mass of 53.5, 89.57 and 123.32 kgf including the accelerometer's mass, resulting in a bearing pressure of 1.31, 2.19, 3.02 N/mm^2 respectively. The test was repeated thrice for each input frequency and pressure to avoid ambigous and absurd data. The box did behave as a rigid body and the maximum friction coefficient could be obtained by dividing the maximum mass acceleration by g when the box is sliding. The initiation of sliding was doubly confirmed from the relative displacement transducers and the change in waveform shape of the box acceleration.

RESULTS

The analysis of the experiment was carried out by producing plots of, input acceleration against the box acceleration (Fig. 2 and 3), input acceleration against the absolute mass displacement, and the peak input velocity against the mass acceleration (Fig. 4), and are discussed below. The basic trend in Figure 2 indicates an increase in the coefficient of kinematic friction with the input acceleration, and is true for all values of the input frequencies. Starting from zero the input and box acceleration are the same until a relative displacement, indicating sliding lowers the mass acceleration. The graph beyond 0.1 g till 0.45 g induces no further acceleration to the rigid mass, rather than a slight increase from the value at 0.1 g. The above results are very encouraging for the intended purpose of isolation, strongly indicated by the Teflon interfaces used. The second obvious result is the lowering of the coefficient of friction or the mass acceleration with increases in the bearing pressure. This is elaborated in Figure 3 for an input frequency of 3.0 Hz only and for the bearing pressures tested. All other frequencies show a similar decrease and need not be described here. Although previous studies by Constantinou et al. for Teflon-Steel interfaces showed a constant coefficient of friction for all frequencies. This present study does show a slight increase in the initial coefficient of friction, when the the sliding starts, from 1.5 Hz to 3.0 Hz and a slight decrease there of till 5.0 Hz input frequency. Such a change needs more thought and experimentation to be declared conclusive.

The plot of input velocity shown in Figure 4 against the mass acceleration shows an increase in the coefficient of friction with increases in the input frequency, at constant amplitude of the velocity of excitation. This can also be interpreted as, at constant kinetic energy of shaking the coefficient of friction decreases with a decrease in the input frequency. The minimum values from the velocity graph is obviously the static coefficient of friction for each bearing pressure. The Teflon interfaces were seen to conserve an initial sticking mode until the amplitude of acceleration was greater than μg and a continuous slip-slip motion; except an instantaneous sticking when the relative velocity is zero. But the behaviour is contradicted by the prediction of the Coulomb's theory stick-slip motion between, $0.537 < \mu g/A < 1.0$. However, this experiment shows positive results of transmitting no high acceleration response to the mass because of continuous sliding and slip-slip tendencies of the Teflon interfaces. Further experimental studies to evaluate the response to a verified earthquake excitation and a soft spring of low frequency attached are continuing, and shall be reported in due course of time.

CONCLUSIONS

The above experiment was conducted keeping in view the passive isolation applications of Teflon and was thus excitation acceleration controlled. The information gathered could be useful in any such implementations and the following is concluded for the friction and isolation properties of the Teflon interfaces.

1. The coefficient of friction decreases with an increase in the bearing pressure.
2. Friction increases with the input excitation acceleration and provides isolation of 0.12 g for 0.45 g input acceleration.
3. The coefficient of friction does not seem to be constant for all frequencies.
4. No stick-slip was observed in Teflon interfaces and a continuous slipping is concluded after the initial stick, resulting in no high acceleration response transmitted to the mass.
5. If an actual structure of 1 - 10 Hz natural frequency is designed using Teflon interfaces, it is intended to produce similar isolation results, though its natural frequency should be kept well outside the common earthquake frequency in that area.

REFERENCES

[1] P. Villagio, 'An Elastic Theory of Coulomb Friction', Archive for Rational Mechanics and Analysis, Vol. 70, 1979, pp 135-143.

[2] M. C. Constantinou, J. Caccese and H. G. Harris, 'Frictional Characteristics of Teflon-Steel Interfaces under Dynamic Conditions' , Earthquake Engineering and Structural Dynamics, Vol 15, 1987, pp 751-759.

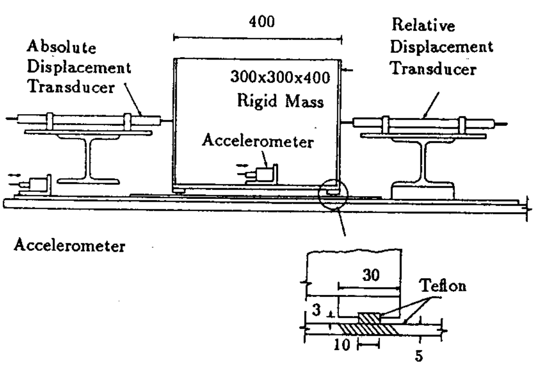

Figure 1 : Experimental Setup and Model (all dimensions are in mm)

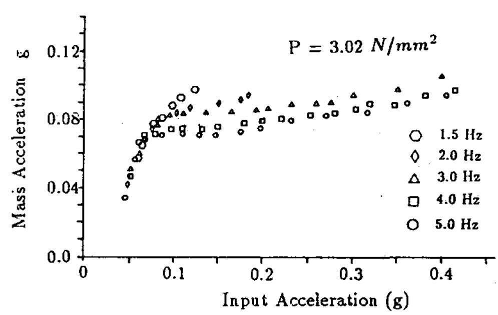

Figure 2 : Effect of Input Frequency on Mass Acceleration

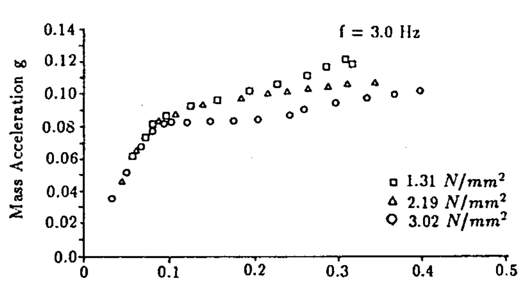

Figure 3 : Effect of Bearing Pressure on Mass Acceleration

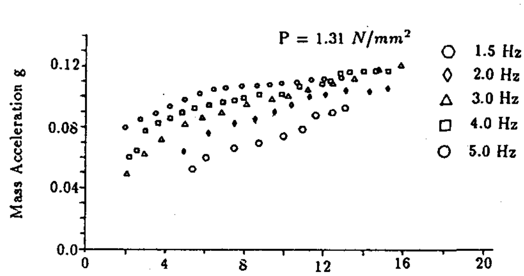

Figure 4 : Mass Acceleration Vs Peak Shaking Velocity