Chapter 9

Conclusion

Seismic base isolation is now a well accepted concept in most countries all over the world for effective mitigation of earthquake disasters. Many seismic isolation devices have been developed, patented and implemented in a limited way for both new structures and retrofitting of existing structures. However wide-spread use of these devices is not found, probably due to the higher cost and their limited effectiveness under a variety of ground motions.

Near-field ground motions and low frequency ground motion pose a significant challenge to the effectiveness of most isolators. Typically most isolators have a typical frequency of around 0.5 Hz (Time period of 2 s) and as a result ground motions with dominant frequencies in this range create a problem of significant amplification. Near-field ground motions have pulse type excitations having frequencies approximately in this range may create problems for base isolated structures. Similarly low frequency earthquakes (with dominant frequencies in the range of 0.5 Hz to 1 Hz) may also create problems.

Amongst various isolators available, sliding type isolators are relatively more effective due to lesser dependence of their effectiveness on the frequencies of ground motions. However many isolation device having a defined time period may not perform well under near-field and low frequency ground motions and the responses are characterized by high displacements or accelerations or both. Variable Frequency Pendulum Isolator (VFPI) could be an exception to this due to its variable nature of isolation frequency.

In this research work an attempt has been made to study the effectiveness of various types of sliding isolators like PF, FPS, CFPI and VFPI under near-field ground motions and low frequency ground motions through extensive analytical studies. VFPI being possible candidate for effectiveness under such ground motions, modification like varying the coefficient of friction at pre determined location has been proposed to further improve the effectiveness of this isolator. A best set of VFPI parameters have been arrived at to make its effectiveness independent of frequencies of ground motions.

Based on the studies carried out in this research work following conclusions are drawn.

1. The performances of sliding isolation system mainly depend upon two parameters *viz.*, geometry of isolator and value of coefficient of friction. Period of isolator depends upon geometry of isolator. Higher is the period of isolator higher is the initial stiffness of isolator. High initial stiffness controls the sliding of isolator. But it leads to higher storey acceleration as large amount of energy has been transferred to super structure. On the other hand lesser is the period of isolator lower is the initial stiffness of isolator. Lower initial stiffness leads to higher sliding of isolator and controls the storey acceleration. Lower value of coefficient of friction leads to higher sliding as the frictional force is the predominant parameter to control the sliding of isolator. But at the same time it controls residual displacement as lower value of coefficient of friction have strong restoring force. Also it controls storey acceleration as due to higher sliding large amount of energy has been dissipated at isolator level. On the other hand higher value of coefficient of friction leads to lower sliding, higher residual displacement and higher storey acceleration.
2. Almost all isolators are effective under far field ground motion, VFPI usually being more effective amongst them. Further VFPI has a wide range of geometrical parameters to chose depending on the design requirements and have a better choice.
3. Under the action of pulse type and low frequency earthquakes the sliding of isolator is very high. The sliding may be up to the geometrical limit of isolator in isolators such as FPS, which makes this isolator ineffective under the action of such type of earthquakes. Even for the isolators with no geometrical limits such as PF, CFPI and VFPI the sliding is excessive than practical limits. Obviously excessive sliding leads to high residual displacement. This fact makes sliding isolators ineffective under the action of such ground motions.
4. To control the sliding of isolator three options are available. To increase initial stiffness or to decrease initial period of isolator, to vary the coefficient of friction along the geometry of isolator and to change the coefficient of friction at pre defined point from centre of isolator. Increasing the initial stiffness leads to higher acceleration and decreasing the isolator period leads to higher sliding. Varying the coefficient of friction along the geometry of isolator is practically difficult to achieve. Changing the coefficient of friction at pre defined location is practical solution. By implementing higher value of coefficient of friction in peripheral portion of isolator will control the excessive sliding of isolator. Such case is referred to as variable coefficient of friction case.
5. Variable coefficient of friction is very much effective to control the structural responses when sliding of isolator is too high due to constant coefficient of friction. On the other hand if sliding of isolator is less in case of constant coefficient of friction, variable coefficient of friction is not much effective.

6. In case of near-field ground motion, on SDOF system, it is observed that sliding of FPS is least and that of CFPI is too high. Sliding of VFPI (T_i = 1 s) is higher than FPS and that of VFPI (T_i = 2 s) and PF is further higher than FPS. Residual displacement of VFPI (T_i = 1 s) is least and that of PF is maximum. Residual displacement of FPS and CFPI are nearly equal and are higher than VFPI (T_i = 1 s). Residual displacement of VFPI (T_i = 2 s) is further higher. Storey acceleration of VFPI (T_i = 2 s) are least and that of FPS are very high. Storey acceleration of PF and CFPI are slightly higher than VFPI (T_i = 2 s) and are nearly equal. Storey acceleration of VFPI (T_i = 1 s) are further higher. It is found that there is marginal difference in sliding and residual displacement of VFPI (T_i = 2 s) when compared to other isolators and both these values are within practical limit. Hence it is concluded that **VFPI (T_i = 2 s), FVF = 2 at d_f = 0.4 m to 0.6 m is the most effective** isolator to control **NFR, SDOF** responses.
7. In case of near-field ground motion, on MDOF system, it is observed that sliding displacements are lowest for FPS. Sliding displacements of VFPI (T_i = 1s) is higher than FPS and that of VFPI (T_i = 2 s) is further higher. Residual displacement of VFPI (T_i = 1 s) is least and of PF is too high which makes PF ineffective. Residual displacement of FPS and VFPI (T_i = 2 s) are marginally higher than VFPI (T_i = 1 s) and are close to each other. Storey acceleration found minimum for PF and maximum for FPS. Storey acceleration of VFPI (T_i = 2 s) are higher than PF and of VFPI (T_i = 1 s) are further higher. Hence it is concluded that **VFPI (T_i = 2 s), FVF = 2 at d_f = 0.4 m to 0.6 m is most effective** isolator to control **NFR, MDOF** responses.
8. In case of low frequency narrow band and broad band ground motions, SDOF system, it is observed that the sliding displacement is less. Hence as discussed earlier the variable coefficient of friction is not much effective for these cases. But in case of low frequency medium band ground motion, SDOF system, it is observed that the sliding displacement is quite high. In this case FPS is not effective due to resonant amplification problem. Sliding of CFPI is higher than both VFPI and PF. Both VFPI and PF sliding are close to each other. Residual displacement of PF is too high. Residual displacement of VFPI (T_i = 2 s) is slightly higher than CFPI and that of VFPI (T_i = 1 s) is least. Storey acceleration of VFPI (T_i = 2 s) and PF are least and are nearly equal. Whereas storey acceleration of VFPI (Ti = 1 s) and CFPI are higher and are nearly equal. Hence it is concluded that **VFPI (T_i = 2s), FVF = 5 to 7 at d_f = 0.4 m** is most effective to control **medium band** low frequency excitation.
9. In case of low frequency narrow band and broad band ground motions, MDOF system, it is observed that the sliding displacement is less. Hence as discussed earlier the variable coefficient of friction is not much effective for these cases. But in case of low frequency medium band ground motion, MDOF system, it is observed that for FPS sliding and residual displacements are well controlled. But storey acceleration is quite high. Hence FPS is not much effective. Sliding of CFPI is higher than both VFPI and PF. Both VFPI and PF sliding are close to

each other. Residual displacement of PF is too high. Residual displacement of VFPI (T_i = 2 s) is slightly higher than CFPI and that of VFPI (T_i = 1 s) is least. Storey acceleration of VFPI (T_i = 2 s) and PF are least and are nearly equal. Whereas storey acceleration of VFPI (Ti = 1 s) and CFPI are higher and are nearly equal. Hence it can be concluded that **VFPI (T_i = 2 s), FVF = 6 to 8 at d_f = 0.3 m** is most effective to control medium band excitation.

10. Overall it can be concluded that VFPI (T_i = 2 s) is the most effective isolator to control all types of ground motions. Again changing the coefficient of friction at pre defined location from centre of isolator improves the effectiveness of VFPI (T_i = 2 s). The **VFPI (T_i = 2 s)** having **FVF = 2, 6 and 7** at **d_f = 0.3 m to 0.4 m** is the most suitable isolator to **control all types of ground motions**.