



Seismic response of a ground supported water tank isolated by a Variable Frequency Ball Isolator (VFBI) under variable friction coefficient

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Abstract: The purpose of this study is to investigate the way ground-supported water tank behaves to seismic events. Investigations were conducted on the broad and slender storage tanks isolated using a variable-frequency ball isolator (VFBI) and under distinctive near-fault ground motions. For this investigation, Newmark's linear acceleration technique was used. VFFPI and VFPS-VFBI were compared with tanks isolated by using VFBI with different coefficient of friction in order to assess the seismic reaction of a tank isolated by VFPI-VFPS and to demonstrate the usefulness of VFBI with variable friction coefficient. According to the findings of the research, the base shear of the VFFPI is less than that of the other isolation devices, and the impulsive and convective displacement were found greater across each of the storage tanks. Moreover, slender tanks exhibit greater base shear than broader ones when VFBI-isolated tanks are exposed to different friction coefficients. Furthermore, in contrast to other isolators, VFBI isolators along with the variable friction coefficient performed well across all assessed parameters.

Keywords: VFBI with variable friction, Broad and Slender tank, base Isolation, near-fault Earthquake Motions, VFPS-VFPI, VFBI-VFPS, VFFP

1.INTRODUCTION:

Common applications for liquid storage containers include water distribution systems, industrial processes, and nuclear power plants, where they hold potable water, potentially explosive substances, and nuclear fuel, respectively. Liquid storage tanks are potentially very important buildings since their collapse during a seismic event might cause secondary risks. As a result, protecting liquid storage containers from major earthquake events is now crucial. Base isolation is a well-known seismic protection method used in earthquake-prone locations. Base isolation mostly stems from the need to lengthen the building's initial time by allowing little lateral movement of the foundation. This silent seismic control device requires no additional electricity to operate; it is activated simply by the motion of an earthquake. Seismic waves are absorbed and deflected by isolation technology at the base before they enter in to the structure. Given that this system contributes extra energy to a building, these strategies prevented damage during ground-based movement and halted the superstructure from accelerating fast (Panchal and Jangid, 2008). Pure friction (PF), frictional pendulum system (FPS), a variable-frequency pendulum isolation (VFPI), conical frequency pendulum isolation (CFPI), and the polynomial frequency pendulum isolation (PFPI) are some of the moving isolation systems that have been developed. (Panchal and Jangid, 2008) Studied

Seismic response of fluid storage tank isolated with Variable Friction Pendulum Isolation examined in under near fault ground movement. To investigate the possibility of VFPS in a tank, the earthquake response of a tank using VFPS has been compared to a similar tank that had been separated by FPS. (2011, D.P. Soni, B.B. Mistry, and V.R. Panchal).

Aspect ratio in the tank, Initial time, coefficients of the friction and variation in frequency factor (FVF) for both surfaces that slide are the important variables addressed in the current study. The structure under investigation was an enormous collection of 20-fault earthquakes that destroyed liquid storage tanks employing DVFPI. The current study analyzed four alternative combinations of the DVFPI design parameters utilizing the coefficient of friction and duration of both the upper and bottom sliding surfaces. In 2018, Tsompanakis and Tsipianitis The primary objective of this test is to figure out how easily containers may break when exposed to sliding bearings. An approximation model has been built to capture the fluid tank dynamic interaction and achieve a reasonable balance between computational effectiveness with reliability. Quartle bearings (QFPBs) and triple bearings (TFPBs) are considerably more resistant to earthquakes than single bearings (SFPBs). In accordance with Selemah and El-Sharkawy (2011), seismic activity in base-isolated thin and broad cylindrical liquid-filled ground tanks has been studied. Furthermore, the author has performed sensitivity analysis to evaluate the influences of the friction pendulum system's coefficient of friction, isolating duration, and tank proportions on the critical response of the tank. (Ambrosini, Curadelli, and Compagnioni, 2018). The present investigation examined at the seismic stability of sliding concave bearings (SCB) for broad, thin steel atmospheric containers for storage. Two structural parameters, rotational dimensions and the base shear force are used to assess the SCB's performance. Researchers looked at six various kinds of actual Earth motions. The key element of a SCB isolator is an articulated spherical surface which allows for relative movement. One of the most significant methods that energy is lost while sliding is through friction.

2.THE CONCEPT OF VFBI AND VFBI ACCOMPANIED BY VARIABLE FRICTION

Friction pendulum isolation system has expected constraints due of the continuous time period and re-storative force characteristic. An isolator referred to variable frequency ball isolator (VFBI), invented by Ravi Chi-tikireddy (2005), prevents these limitations but retains the benefits. The periodic oscillations of the VFBI constantly reduce with increase in sliding movement. the sliding phase starts when the base shear produces the highest extreme friction effect, which is provided by an isolated system. at the point at which the drifting phase induce, as a consequence of reduced degrees of resistance capabilities and to the curved state of the slide surfaces, structure stays in sliding phase regardless of the conditions of seismic disturbance. A sliding surface of the frequency curves has been used when creating the sliding isolator. The structural basement is assumed to be rigid and the friction pendulum devices are viewed as mass-less rigid spherical discs, with radius r , which can roll across their circular concave faces or radius R . The cou-lomb friction is characterized by its coefficient μ . The force generated by friction is considered to be in-dependent of the velocity when the motion is initiated.

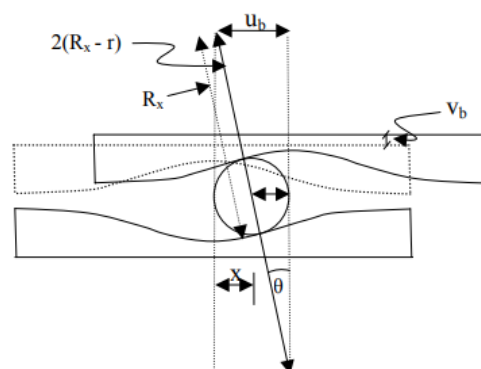


Figure 1. Variable frequency ball isolation system

The Friction oscillation isolation method has many drawbacks owing to constant and restorative force attributes. A unique isolator known as a variable frequency ball isolator (VFBI), suggested by Ravi Chitikireddy (2005), tackles these limitations while preserving the advantages. The oscillation frequencies of the VFBI constantly decline with the rise in slide movement. The physical form of the VFBI may be articulated thus.

$$Y = k \left(1 - \exp \left(\frac{x^2}{a} \right) \right) \quad (1)$$

The friction coefficient of the variable Frequency Ball Isolator (VFBI) with different friction may be discovered by the use of the following equation: μx = the value of the friction coefficient for sliding displacement, x . It was recently discovered that the minimum coefficients of friction of VFBI with changing frictional is 0.8 time the coefficient of friction of other typical sliding surfaces. This suggests that VFBI is an ideal way of decreasing friction and improve the effectiveness of sliding isolation device.

$$\mu(x) = \sqrt{\left(0.8\mu + 0.1 \frac{x}{R} \right)^2} \quad (2)$$

Where μx = friction coefficient at sliding displacement, x

The smallest coefficient of friction of VFBI with varying frictional is 0.8 time a friction coefficient of another typical sliding surface.

3. NUMERICAL STUDY

In this present study, slender and broader liquid storage tanks separated with VFBI along with varying friction are evaluated and compared with liquids storage tanks that are separated with VFPS-VFPI, VFPS-VFBI and VFFPI. New-mark's linear acceleration approach is applied to examine the equation of motion. Figure 2 and 3 exhibit the Numerical models of the Fluid storage tank isolated with VFBI and the Mathematical Models of VFBI. Six distinct near-fault accelerations have been employed as source ground motions. Table 1 demonstrates the properties of isolated liquid storage slim and broad tanks. Table 2 demonstrates that several near-fault earth motions were employed in the current investigation. All ground-based movements have a specified peak acceleration (PGA).

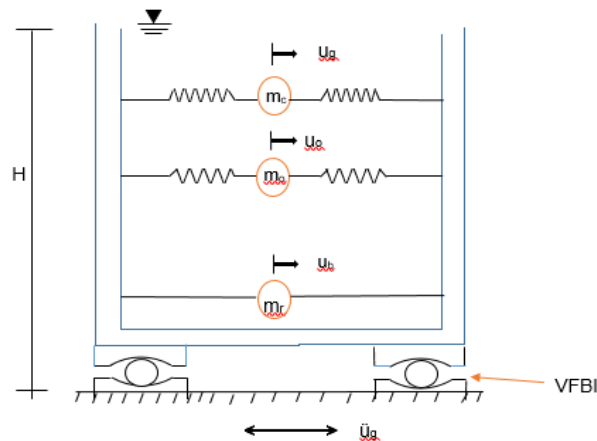


Figure 2 Numerical representation of a Liquid storage tank separated with VFBI

Parameters	Slender tank	Broad tank
Damping ratio, ξ_c and ξ_i	0.5% and 2%	0.5% and 2%
Elastic modulus, E	200 Gpa	200 Gpa
Aspect ratio, S (H/R)	1.85	0.6
Density of mass, ρ_s	7900 Kg/m ³	7900 Kg/m ³
Tank Height (H)	11.3 m	14.6m
Natural Frequency	0.273 and 5.963 Hz	0.123 and 3.944 Hz
Isolation period (T _b)	2 sec	2 sec
Friction coefficient(μ)	0.05	0.05

Table 1 Properties of the liquid storage tank

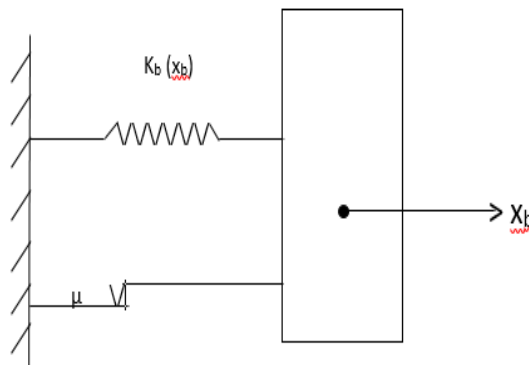


Figure 3 Modelling of VFBI.

Table 2. Descriptions of near-fault ground motions

Earthquake	Year	Record Station	Time (sec)	PGA (g)
Imperial Valley, California	October 15, 1979	El Centro Array #5 (EQ11)	39.420	0.37
Imperial Valley, California	October 15, 1979	El Centro Array #7 (EQ21)	36.900	0.46
Northridge, California	January 17, 1994	Newhall (EQ31)	60.000	0.72
Landers, California	June 28, 1992	Lucerne Valley (EQ41)	49.284	0.71

Earthquake	Year	Record Station	Time (sec)	PGA (g)
Imperial Valley, California	October 15, 1979	El Centro Array #5 (EQ11)	39.420	0.37
Northridge, California	January 17, 1994	Rinaldi (EQ51)	14.950	0.89
Northridge, California	January 17, 1994	Sylmar (EQ61)	60.000	0.73

4.RESULT AND DISCUSSION

The final result of peak responses of multiple variables such as base shear, convective displacement, impulsive movement and isolation displacement.

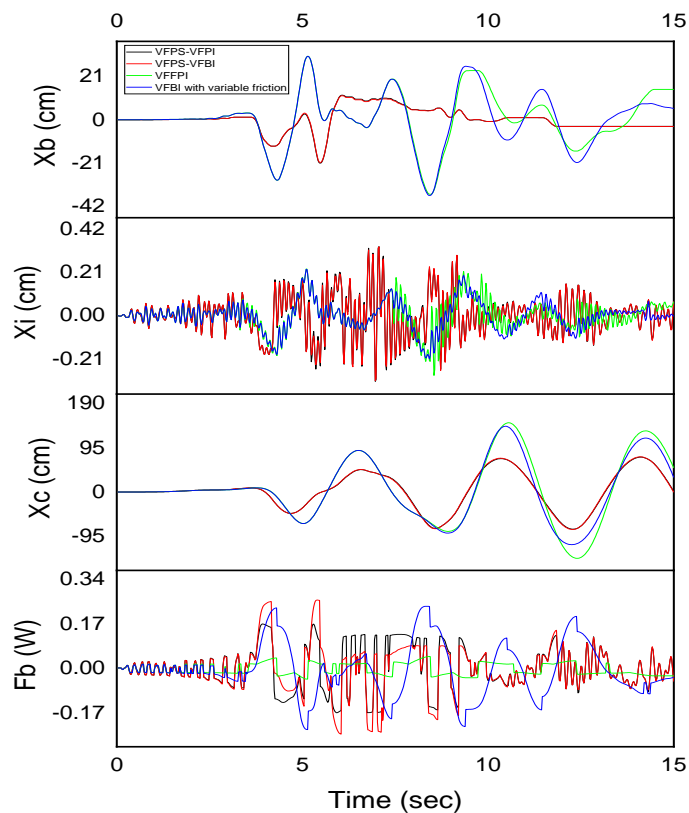


Figure 4 Time versus Base Shear(Fb), Convective displacement(Xc), Impulsive Movement(xi) and The Displacement of Isolator in Broad Tank (Xb) with VFPS-VFPI, VFPS-VFBI, VFFPI, and VFBI under different friction under Northridge, 1994 (Newhall)

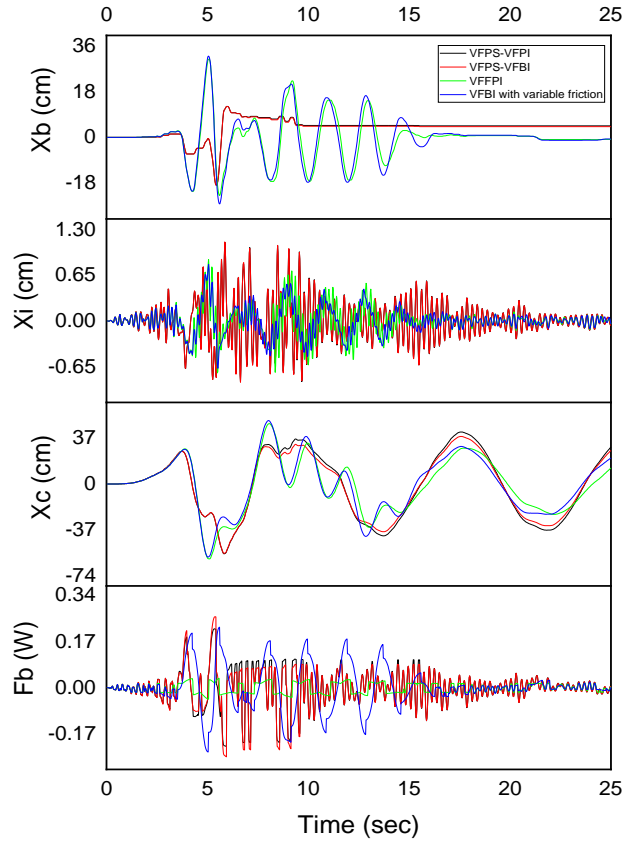


Figure 5 Time versus Base Shear(Fb), Convective displacement(Xc), Impulsive Movement(xi) and The Displacement of Isolator of Broad Tank (Xb)isolated with VFPS-VFPI, VFPS-VFBI, VFFPI, and VFBI under different friction under Northridge, 1994

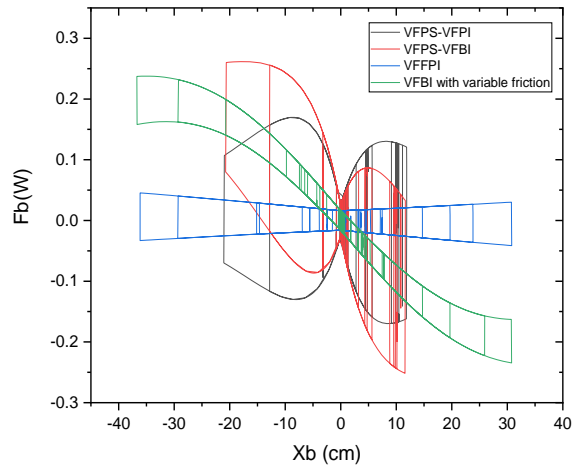


Figure 6 Hysteresis loop of VFPS-VFPI, VFPS-VFBI, VFFPI and VFBI with variable friction of Slender tank under Northridge, 1994 (Newhall)

Table 3. Comparison of VFPS-VFPI, VFPS-VFBI, VFFPI and VFBI with variable friction of Slender tank under different Earthquake excitations

Earthquake Considered (Near Fault)	Isolator	Slender Tank Variables				Broad Tank Variables			
		Base Shear (Fb/W)	Xc (cm)	Xi (cm)	Xb(cm)	Base Shear (Fb/W)	Xc (cm)	Xi (cm)	Xb(cm)
Imperial Valley 1979 (Array # 5)	VFPS-VFPI	0.1698	157.6774	0.2279	15.85	0.1877	125.8922	0.8777	6.5494
	VFPS-VFBI	0.2609	158.4301	0.2518	15.8467	0.2109	125.6212	0.8781	6.5493
	VFFPI	0.0473	270.1349	0.3634	38.4908	0.0399	427.8022	1.115	28.8148
	VFBI with VF	0.2378	239.0857	0.2747	41.5094	0.2118	134.5759	0.5694	23.2151
Imperial Valley 1979 (Array # 7)	VFPS-VFPI	0.1698	178.0574	0.2817	19.7826	0.2161	107.7828	1.0465	12.6857
	VFPS-VFBI	0.2616	177.8496	0.2606	19.7846	0.2555	107.5353	1.0467	12.6863
	VFFPI	0.0488	309.8587	0.3104	40.5258	0.0412	174.449	1.1414	30.5397
	VFBI with VF	0.2378	232.6693	0.2946	42.8531	0.234	113.3492	0.7794	30.4865
Northridge 1994, (Newhall)	VFPS-VFPI	0.1699	79.5807	0.3576	21.0722	0.2171	56.4737	1.1436	18.771
	VFPS-VFBI	0.2617	80.2302	0.3551	20.7401	0.2616	56.1246	1.1479	18.7831
	VFFPI	0.0455	148.4275	0.3004	36.1341	0.0413	60.6501	0.8773	30.6877
	VFBI with VF	0.2377	140.96	0.2271	36.7352	0.2359	59.1587	0.8036	31.893
Landers (Lucerne-Valley)	VFPS-VFPI	0.1698	158.5161	0.4649	13.4466	0.1737	195.9361	0.9951	5.3955
	VFPS-VFBI	0.2572	159.515	0.4595	13.3268	0.193	196.2436	0.9944	5.3915
	VFFPI	0.0517	236.408	0.3393	44.4656	0.0372	245.1572	0.9209	25.3662
	VFBI with VF	0.2377	213.3378	0.2418	42.9583	0.2179	198.7633	0.6005	24.6523
Northridge 1994, (Rinaldi)	VFPS-VFPI	0.1698	91.1644	0.3234	43.7967	0.2577	68.1444	1.0218	42.4576
	VFPS-VFBI	0.2616	91.2299	0.3108	43.7947	0.2616	68.1605	1.022	42.4605
	VFFPI	0.0563	145.4062	0.3731	50.8135	0.0594	106.4038	1.6423	55.2389
	VFBI with VF	0.2377	134.0452	0.3431	52.2951	0.2377	80.1327	1.4352	55.2306
Northridge 1994,	VFPS-VFPI	0.1699	98.9265	0.3122	25.8147	0.2153	53.6042	1.1695	12.0403
	VFPS-	0.2616	96.501	0.3122	25.8142	0.2535	53.4157	1.2093	12.0658

(Sylmar)	VFBI								
	VFFPI	0.067	238.2874	0.6353	66.0995	0.0546	185.6242	1.6654	48.4343
	VFBI with VF	0.2379	203.3546	0.6574	71.7383	0.2378	83.5241	1.3642	50.2592

CONCLUSIONS

The seismic response of broad and slender liquid storage tanks isolated using variable frequency ball isolators (VFBI) is evaluated and compared with VFPS-VFPI, VFPS-VFBI, VFFPI under multiple near-fault ground shaking scenarios.

The following conclusions can be drawn:

1. It seems that in broad tanks, VFBI and VFFPI produce more isolation displacement than VFPS-VFPI and VFPS-VFBI. However, in slender tanks, isolation displacement is noticeable in VFBI with variable friction compared to all other devices employed.
2. The response of VFPS-VFBI and VFPS-VFPI in terms of base shear, convective and impulsive displacement, and isolation displacement are essentially equal to each other, with minimal variations identified among them.
3. Impulsive displacement is more in VFFPI than in other isolators in both tanks. The variations between VFPS-VFBI and VFPS-VFPI are identical in impulsive displacement.
4. As identified in the impulsive displacement, the Convective displacement is also observed with identical pattern, with VFFPI confirming larger convective displacement than other device across both tanks.

The base shear of VFPS-VFBI and VFBI with variable friction is greater than other isolation devices. However, the base shear of VFFPI has reduced compared to other isolations in both tanks.

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