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THE BEHAVIOR OF ENERGY DISSIPATION DEVICES AND SEISMIC ISOLATION DURING NEAR-FAULT GROUND MOTIONS

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Abstract:

Strong motion records with extended speed pulses, a high magnitude, and considerable displacements in areas around the source are produced by the action of directivity. Constructions exposed to this type of earthquake should be able to sustain significant deformations and quickly release enormous amounts of energy. Power dissipation and seismic design technologies were created recently in order to lessen the disastrous effects of earthquakes in general. There are varying opinions regarding these devices' efficacy in preventing near-fault earthquakes. The objective of this study is to numerically analyse how two different types of seismic safety systems respond to near-fault earthquakes. A useful set of data for the study of numerical models is provided by the unique characteristics of near-fault earthquakes. The heat removal mechanisms employed were buckling restricted braces and a hybrid separation system composed of poroelastic dampers and steel helical springs. Basic models are evaluated nonlinearly with seismic safety devices. The results show that the responses of the two buildings evaluated with protective devices cannot be described by a single ground motion characteristic. Several of the responder parameters show significant variation.

Keywords: near-fault, isolation seismic ,energy dissipation.

1. Introduction

For a couple of years, energy absorption systems for earthquake applications were in development, with a substantial rise in implementations beginning in the mid-1990s. A passive power dissipation system's main purpose is to lessen the inelastic heat transfer demand on a structure's frame system. As a result, the frame system suffers less damage. There are a variety of passive power dissipation technologies on the market or under research. Viscous fluid absorbers, viscous solid shock absorbers, friction shock absorbers, and iron dampers are the most often employed devices for earthquake resistance of structures. Tuned weight and adjusted liquid absorbers, both of which are largely used for wind vibration analysis, recentering valves, and phase transition valves are other technologies that might be categorised as passive power dissipation devices. In fact, semiactive dampers are a type of controllable gateway node that passively resist relative movement between their endpoints but have adjustable mechanical qualities. Variable-orifice absorbers, magneto -

rheological dampers, and magneto - rheological dampers are examples of such dampers.

In other nations, such as Japan, semiactive dampers were utilised to control seismic reaction, but not in the U. S.. The increased use and growth of energy absorbing devices has resulted in a number of articles published that specifies the operating principle and mathematical modelling of such gadgets, as well as the analysis of frameworks integrating such devices and their applications to various engineering structures. In addition, a state-of-the-art and state-of-the-practice article on the general subject of additional dissipation of energy was published recently, which included both active and passive structural control mechanisms.

Investigations realized by Naeim F. et al., 1999 indicated that increasing the damping of the isolation device, reduces the displacement but increases the accelerations and inter-story drift. Nevertheless, there is no indication of the seismic parameter controlling the structural response when the record possesses long pulses of velocity and displacement or how to control the dimensions of the isolations system before the presence of the mentionedpulses.Numerousanalysisanddesignproceduresforstructureswithpassiveenergydissipation systemsarepresentinspecializedliterature(HansonandSoong,2001).There are documents and standards which establish requirements for such structures (AISC341,2005).Buttherearenotmanydevelopmentsaboutthedissipationdevicesrequirements in structures which could be submitted to near-fault ground motion. The purpose of this study is to compare the responses of two different types of seismic protection systems when they are exposed to near-fault ground motion. The near-fault ground motion's properties are discussed. For numerical methods, a set of ground motions of this sort is chosen. Two constructions are considered: one with energy absorbing devices and another with a hybrid isolator system made up of steel springs and poroelastic dampers. A nonlinear time historical analysis was conducted. The impact of soil movement factors on structural reactions was also investigated using both kinds of earthquake protection systems.

2. Near-faultgroundmotionsselected

2.1.Basic Energy Dissipation System Principles for Seismic Applications

The major rationale for using energy dissipation devices in a construction is to prevent structural components from deforming. The degree to which a device may achieve this purpose is determined by the fundamental structure's intrinsic features, the devices and its interconnecting elements' attributes, the ground motion's characteristics, and the boundary condition under investigated. Specific the wide range of values for each of these parameters, a comprehensive set of nonlinear response-history evaluations is usually required to decide which energy absorbing system is better suitable for a given situation. The idealised architecture of Fig. 1 will be studied when exposed to a single historical seismic record to demonstrate the effect of implementing energy absorbing systems in constructions. Although a design engineering examination of a real structure would necessitate far more in-depth assessments than those shown in this simple model, it serves as a vehicle to demonstrate the basic concepts of heat removal systems for earthquake applications. A one-story, one-bay moment resistant frame with mass MO, weight WO, lateral rigidity KO, and lateral toughness YO is the idealised structure. The structure's intrinsic vibration period, TO, is 0.535 seconds.

damping (in the absence of any passive energy dissipation device)is assumed to be 5% ofcritical.

The results from non linear response-history analysis of the bare frame[Fig.1(a)]when it is subjected to the horizontal com- ponent of a certain earthquake ground motion reveals thatplastic hingesforminthegirder,themaximumdriftis1.03%ofthe height of thestructure, and the corresponding displacement duc- tility demand is 3.08. At the end of theearthquake,the structurehas a residual drift of 0.12%of thestoryheight.

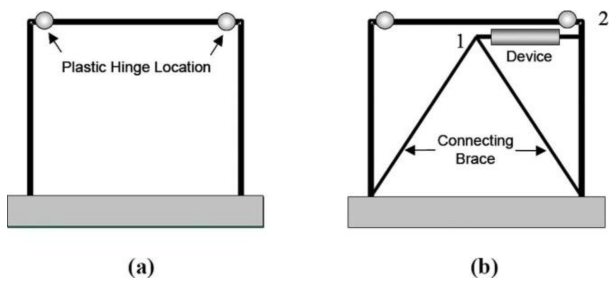

Fig.1. Framewithoutandwithpassiveenergydissipationdevices

3. STRUCTUREWITHENERGYDISSIPATIONDEVICE

Inthissectionwestudyasteelframedescribedby HansonandSoong(2001).Thedimensionsoftheframeare1.32 m for 1.32 m in plan,and 5.69 m in height.Thementioned authors evaluated the frame, with and without visco elastic and friction devices.A scaled 1940 El Centro earthquake with 0.6g peak acceleration is considerer as the designearthquake. For the present paper a study of this framewascarried outwithbucklingrestrainedbraces(BRB),AISC341,2005.Theyconstituteonetypeofpassiveenergydissi pation devices. These devices contribute to the dissipation of the energy entering thestructure during an earthquake. They can be build with low cost and with basic technology,even in countries with emergent technologies.TheBRBwasdesigned sothatthe inter-story drifts were similar to the indicated by Hanson and Soong (2001) for the structure withviscoelasticdevices.InadditiontotheElCentroearthquakeweconsideredtheearthquakesdescribedi nthesection2.TheseacelerogramaswerenamedasC.M.1yC.M.2 for the Cape Mendocino (Cape Mendocino andPetroliastation),I.V.fortheImperialValley (BondsCornerstation),L.P.fortheLomaPrieta(Corralitosstation),Northr.1and Northr.2 forthe Northridge(RinaldiandSimiValleystation).

Theresponseparameterconsideredwastheroofdisplacementrelatedtotheframe'sheight, the inter-story drift, the seismic base shear, as well as bending and axial effort in onecolumn of the first floor. A more detailed description about the design oftheBPR and thestructural response under the different earthquakecan be found in Palazzo et al. (2008). Thereductionofthestructuralresponsewith BRPrespectthe freestructureisshownin Figure 2.

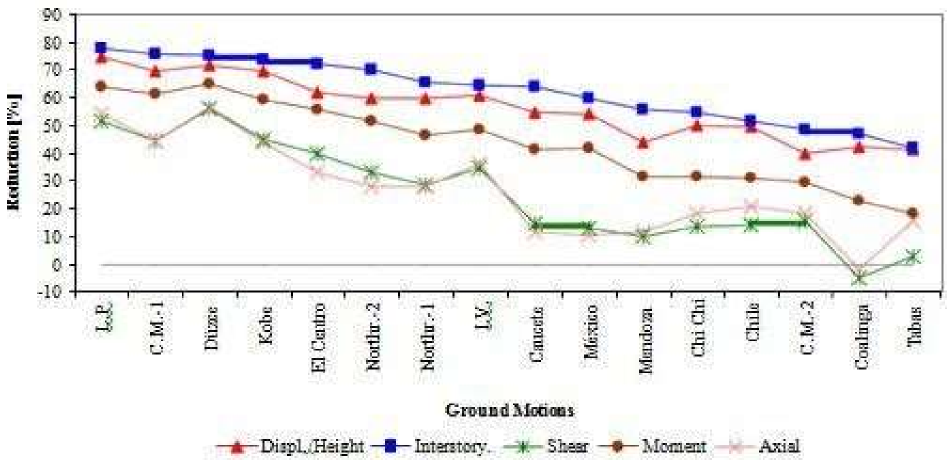

Figure 2 Reduction of the structural response with/without BPRSTRUCTUREWITHSEISMICISOLATIONDEVICE

This building possessesthree levels with concrete structure, masonry walls and concreteslab.Plantdimensionsare
8.00 x 7.60 m. When a participation of 25% of the live load is assumed, the weight of thebuildingis2570KNand2910KNwhenaparticipationtheliveloadis100%.Thebuilding period is 1.00 s with seismic isolation and 0.17 s, for the same building, but withfixed base (Tornello M.and Sarrazin M.,2007) (Figure 3.a).Seismic isolation deviceconsist of four steel spring packages (GCS, GERB® Control Systems) andviscoelasticdamperswith vertical axis(Gerb Visco□) (Figure 2.band 2.c).The devices installedcorrespond to the modelEQ-07witha vertical load capacity of 921KN,averticalstiffness of 35.40 KN/mm and a horizontal stiffness of 4.73 KN/mm. The damping designwas26%inhorizontaldirectionand13%inverticaldirection.Amodelinfiniteelements in 3Dwas used in the design of the building with seismic isolation (Figure 4Right).Damping force–Velocity ratio of the visco elastic damper isshown in Figure 4Left.

(a) (b) (c)

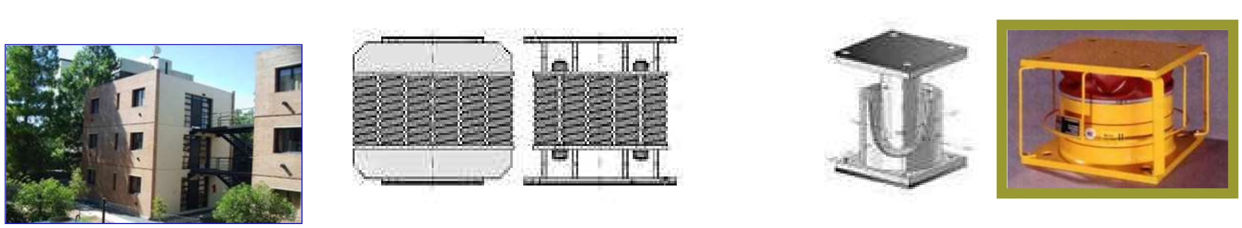

Figure 3: (a) Building with seismic isolation. (b) Steel spring packages (GERB®ControlSystems).(c) ViscoelasticDampers(GERBVisco®)

Structural response is obtained by time history non linear dynamic analysis.The softwareused for such target wasthe SAP2000 (CSI, Computer and Structures,2003). The analysisis based on the proper of the viscous linear damping and not proportionality between thestiffnessandmass.Isusualtocarryoutthedirectequationsintegrationoftheofmovement bearing in mind the forces in the isolator or in the viscous damper. In this casethe unbalanced non lineal force inevery time stepareanalysed by mean of a number ofreduced structural modes (Stuardi et al., 2005). The method of direct integration of theequilibrium equations represents appropriately the behaviour of the seismic isolation butonly it allows to analyse deterministic sign inthe time dominion. Preliminarystudies(Tornello and Sarrazin, 2007) compared the structural response obtained in theoretical formbetweenthebuildingwithseismicisolationandanotherwithfixedbaseofidenticalcharacteristics.

Toobtainthestructuralresponse,thecomponentsofgroundmotionsselectedwereconsideredtobeseismic demandsforthebuilding.Somestructuralresponsesofdisplacements, inter-story drift and accelerations can be observed in Figure 5. A moredetailed of the design in the isolationsystems and the structural response obtained underdifferentseismic recordscan befoundinSarrazinetal.(2007).

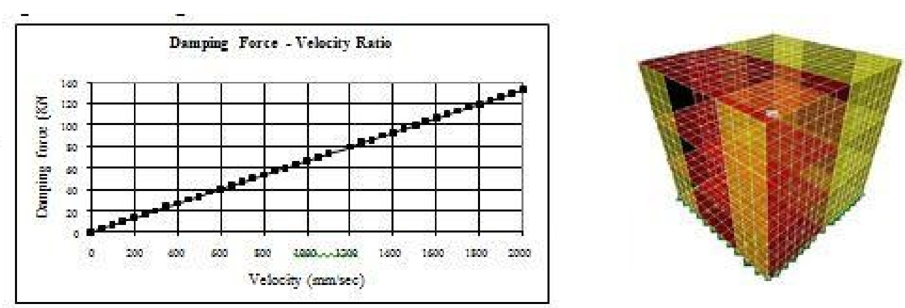

Figure4(Left)DampingForce–Velocityratio(Right)Structuralmodel

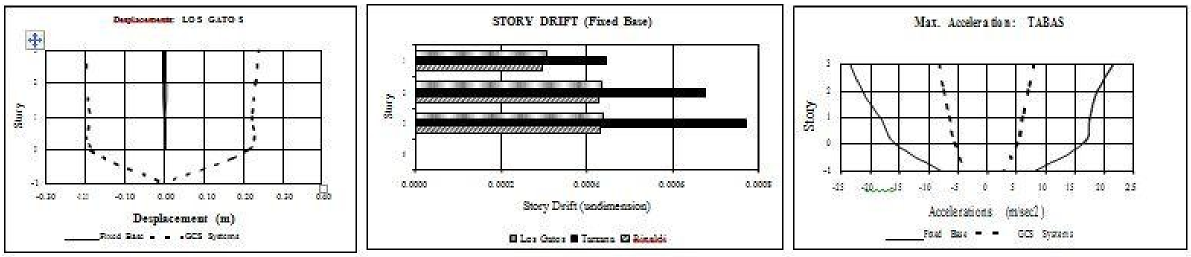

Figure5:(Left)Horizontaldisplacements.(Middle)StoryDrift.(Right)HorizontalAcceleration

Severalparametershavebeenusedtocharacterizegroundmotion.Themostfamiliarparameters are PGA, PGV and PGD (peak ground acceleration, velocity and displacement).Lara et al.(2004) demonstrated that the Maximum Variationof Ground Velocity (MVGV) isanimportant cause of inelastic response for somestructures. MVGV is the largest peak topeakvalueinthegroundvelocity.It showedthatnear-faultgroundmotion

withdirectivityeffectstendtohavehighPGV/PAGratio.Thisratiodramaticallyinfluences response characteristics. In this research a new parameter is proposed namedEquivalentDisplacementtotheMaximumVelocityPulse(DEQUIV).

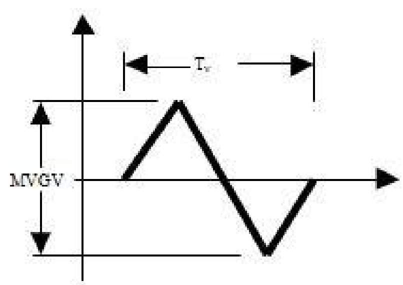

Figure6EquivalentDisplacementtotheMaximumVelocityPulse

Initially, several parameters were considered to characterize ground motion such as: PGA,PGV, PGD,T_V and MVGV. Some of them were combined parameter, such as PGV/PGA,PGV/PGDandD$_{EQUIV}$.Authorsconsideredasthemoresignificantparameterfortheevaluation of the structuralperformancewithseismicisolation: a) peak ground velocity,PGV; b) period of pulse in the velocity-time history, T_v; c) peak ground velocity peakground

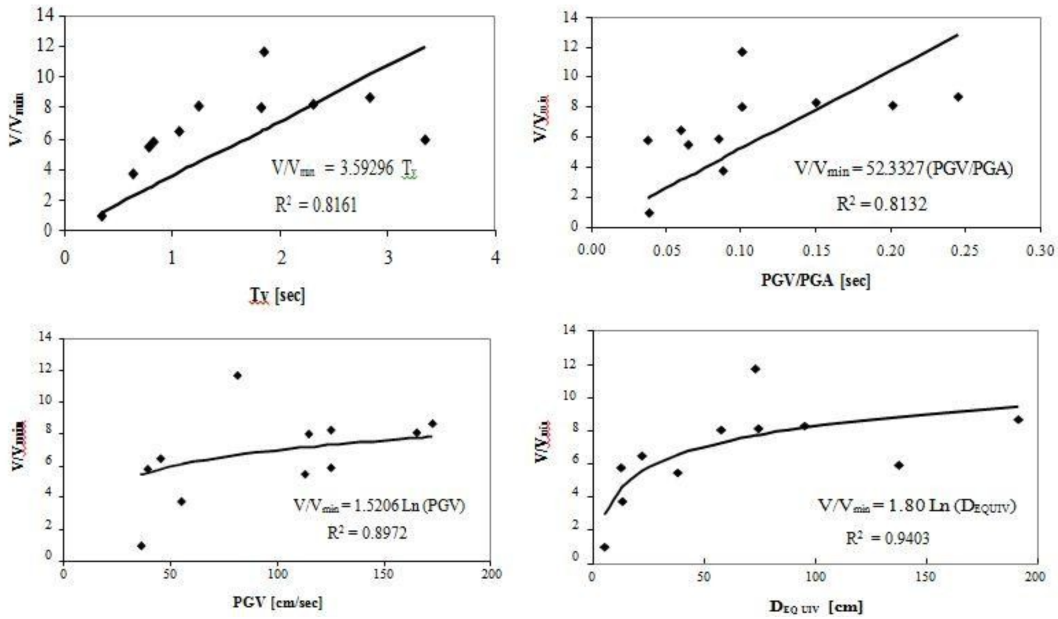

Figure7.RelationshipbetweenparametersT$_v$,(PGV/PGA),PGV,D$_{EQUIV}$and(V/V$_{min}$)response.

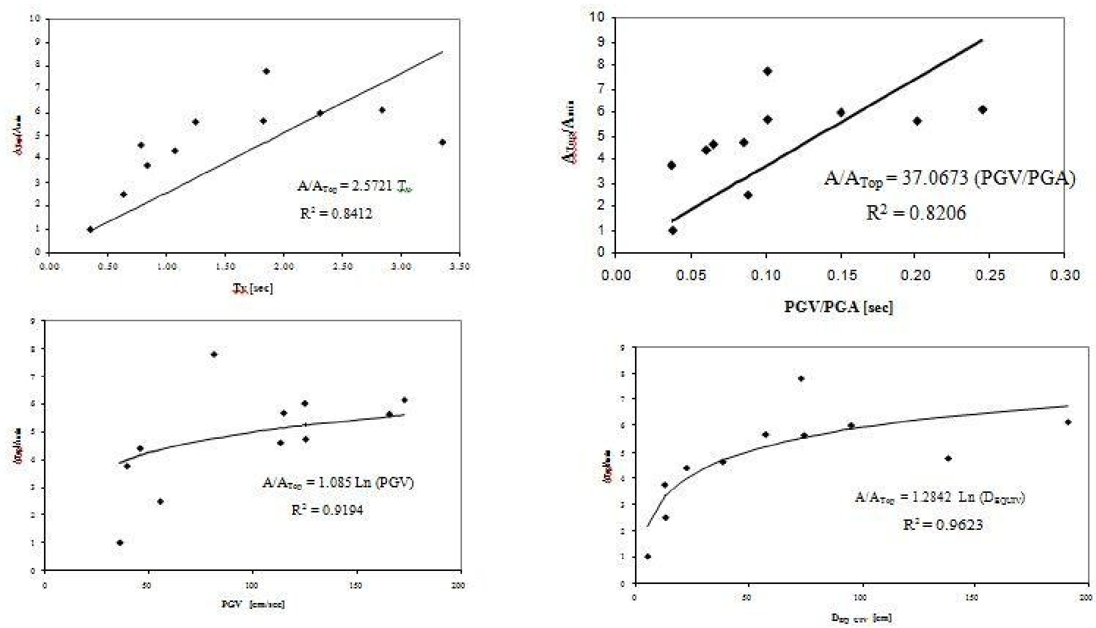

Figure8.RelationshipbetweenparametersT$_v$,(PGV/PGA),PGV,D$_{EQUIV}$and(A$_{Top}$/A$_{min}$)response

StructureswithDissipationofEnergydevices

The Figure 9 shows the relationships between the seismic base shear (V/V_{min}) and thegroundmotionparameters.Similarly,Figure9showstheserelationshipsforroofdisplacement (D_{top}/D_{min}). For the acceleration roof this relationship is very similar (it's notdrawn).

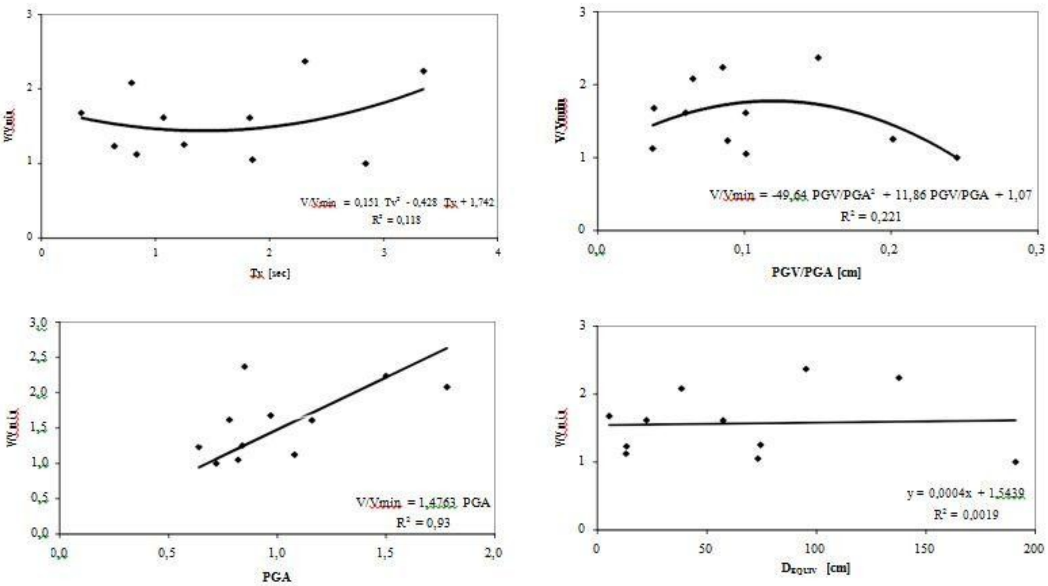

Figure9:RelationshipbetweenparametersT$_v$,(PGV/PGA),PGAandD$_{EQUIV}$vs.(V$_i$/V$_{min}$)response

For the relationship between seismic base shear and roof displacement respect groundmotion, trend with acceptable correlations for the PGA parameter was found. Thus, Figure10 show that if the PGA parameter increase, seismic base shear and roof displacement alsoincrease (in alinearshape).Forotherearthquake parameters there are trend lines, butwithlargedispersions(R^2<25%).

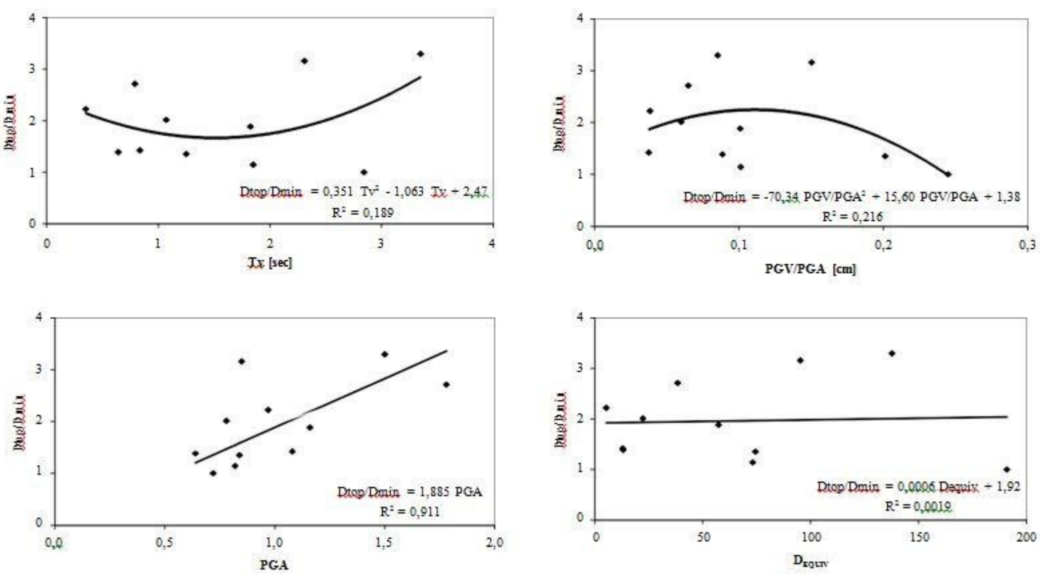

Figure10:RelationshipbetweenparametersT$_v$,(PGV/PGA),PGAandD$_{EQUIV}$vs.(D$_{top}$/D$_{min}$)response

5. Conclusions

The findings reveal that there is no one ground motion characteristic that can be used to characterise the responses of the two structures tested with protective devices. There is a lot of variation in several of the response parameters. Ingeneral,forthestructurewithseismicisolation,an increase in the ground motions parameter indicate major values of structuralresponse.Forthecasesstudied,theparametersTvandDEQUIV,presentclearertendencies for de shear base and the acceleration. For the structure with BRB, if the PGAearthquake parameter increases, the response parameters also increase in a linear shape.Withtheotherparametersthatcharacterizethegroundmotion,trendwithahighcorrelationwas notfound.

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