



## Energy Balance on Steel Structure with Pall Damper under Blast Loading

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**ABSTRACT:** Plenty of factors produce the input energy to a structure. Earthquakes and Blats each one induces an energy to the structure and it must balance between input energy and the cumulative internal energies; otherwise, damage will happen in the structure. Blast is one of the rare occurrences that can happen in the life time of a building. The number of explosive attacks on civilian structures has recently increased. Energy absorbers have being paid attention in order to control the vibrations. One of these energy absorbers is Pall damper. Considering the essence of Blast, which is the result of releasing energy, and the basis of energy absorbers which plays the role of getting the input energy of the structure, investigating the energy balance in structures having energy absorbers can help us understand the behavior of structures under Blast loads truly. Thus, in this study, it is tried to focus on the behavior of steel structures having Pall friction damper under various Blast loading, by use of energy balance concepts.

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### 1. INTRODUCTION

Various loads can endanger the safety of a structure in its lifetime [1], earthquake, Blast, wind and occurrences such as impulse by something can induce an external load to the structure [2]. A structural system should be able to resist against predicted loads that might happen during the using time of structures [3]. Different lateral loads carrying systems are the most important part of a structure to act against mentioned factors [4]. Along with intensifying terroristic attacks in the World a need to assess buildings under Blast loads became essential. Blast resistant gates are required to be lightweight and able to mitigate extreme loading effect [5]. Excessive dynamic response of bridges under extreme loads may cause local member damage, serviceability issues, or even failure of the whole structure. in this study, it is tried to focus on the behavior of steel structures having Pall friction damper under various Blast loading, by use of energy balance concepts.

### 2. PALL FRICTION DAMPER

In 1980, Pall and his colleagues began investigating dissipation of energy in structures during earthquakes by means of friction. In that study, the structural movements were limited by device that worked like an automobile brake to dissipate kinetic energy. These studies led to the development of the Pall friction damper in 1982 [6]. This system basically consists of a series of steel plates which can be connected

together by highly resistant steel bolts and are allowed to slip under a predetermined load. When an earthquake occurs, friction dampers slip for a predetermined load before the frame is damaged or collapses. This will allow the major part of the seismic energy to be depreciated via friction. Actually, buildings remain in the elastic range and are able to bear the disastrous seismic forces [6]. The Pall friction damper consists of a set of special steel plates that can generate the necessary frictional performance. These plates are bolted together with high-strength screws, and they are designed not to slip during wind. These dampers slide over each other at the determined optimum slip load before structural members yield, and they dissipate a large portion of earthquake energy. As Fig. 1 shows, for a given force and displacement, friction dampers essentially dissipate more energy than other kinds of passive dampers.

### 3. METHODOLOGY

The input energy to the structure (external work) can be transformed to kinetic energy, strain energy and lost energy

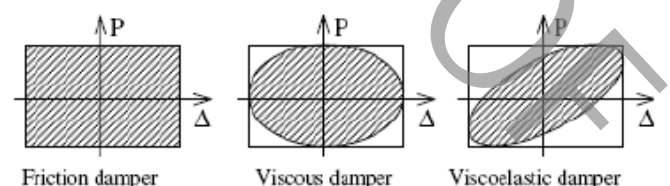


Fig. 1. Hysteresis loops for different dampers

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by damping. Here, the energy has been precisely defined. External work is the work that is conducted by input energy; for instance, the work that is done by the gravity acceleration on the mass of a structure. The gravitational force does the external work via moving the building. The energy which has been input to the system (external work) should equal to internal energies. The internal energy (the work of deformation) is calculated in the following equation:

The strain can be divided to elastic (reversible) and plastic (irreversible).

#### 4. RESULTS AND DISCUSSION

The input energy in structures can be depreciated in many ways. The input energy to the structure (external work) can be transformed to kinetic energy, strain energy and lost energy due to damping. Strain energy itself is categorized to elastic strain energy and plastic strain energy. In elastic strain energy which happens because of elastic deformations, the energy is reserved in members as potential energy and in case of unloading and turning back to the situation before loading, this energy will be released. In plastic strain energy due to permanent deformations in structure and members, the energy will be lost as heat and it is irreversible. Different factors of damping in structures cause different sorts of energy loss in structures. Hence, the input energy in ordinary structures will be lost via the inherent damping of structure, kinetic energy, elastic strain energy and plastic strain energy.

To keep energy balance, the structure tries to produce equilibrium by means of elastic and plastic deformations, damping and kinetic energy regarding to the external work and standing against input energy to the system. In the Fig. 2 the curves for different energies and external work in structure under 1-100 scenario are shown. Base on these curves in moment frame structure, the input energy to the structure is dissipated using plastic strain energy, elastic strain energy, kinetic energy and energy loss by inherent damping. In fact, for keeping energy balanced the work of external force equals the mentioned energies. In structures having Pall friction dampers, plastic strain energy in structure which is a part of lost energy in the system is divided into two parts; plastic

strain energy of structural elements (beams and columns) and plastic strain energy that is dissipated by Pall friction dampers. In fact, in structures having Pall friction dampers, the dissipated energies of structure comprise plastic strain energy in elements and Pall friction dampers and energy loss due to inherent damping of system itself. According to Fig. 2, the external work of two systems are roughly equal under 1-100 scenario. Elastic energy in the center of Time axis does not start from zero because existence of gravitational loads and rotations and elastic deformations cause the elastic energy to be reserved in the structure as potential energy. For this reason, due to existence of gravitational loads this energy does not reach zero after analysis ends and it remains in the structure as reserved energy. In 1-100 scenario, in moment frame structure, a great part of external work is transformed to plastic strain energy in members, whereas, in the structure having Pall friction damper, the lost energy of dampers caused the other elements to lose lesser plastic strain energy and so, experience lesser damage.

#### 5. CONCLUSIONS

In this research, it has been tried to investigate the behavior of steel structures having Pall friction dampers under different scenarios using the concept of energy balance. For this, two Moment-Frame steel structures have been designed for 100% and 75% of design lateral load. The structure which has been designed for 75% of lateral loads, has been equipped with Pall friction dampers. The structures have been loaded and analyzed under 12 different scenarios after being designed and modeled nonlinearly. At first, the performances of structures have been compared by means of the rotations of plastic hinges and the maximum drifts of stories. The results of this section have shown that in little blast loads, such as explosion of 100 kgs of TNT in the distance of 1 to 10 meters, drifts and plastic hinges rotations in structures having Pall friction dampers are lesser than Moment-Frame structures.

This trend of declining the response of structure is obvious in other scenarios in this research. By investigating the balance between internal energy and the external work in structures, it can be seen that the existence of Pall friction dampers could reduce the share of plastic strain energy in structural elements in energy balance and as a result, it could reduce damage to some extent. For instance, in the scenario of explosion with 1000 Kgs TNT in 10 meters distance, the share of plastic strain energy in beams and columns in the structure without dampers, which has been designed for 100% of lateral loads, has been 59% and the same value in the structure having Pall friction damper, which its moment frame had been designed for 75% of lateral loads, has been 16.1%. This phenomenon indicates that Pall friction damper can play a crucial role in energy balance. Finally, the behavior of the structure having Pall friction damper has been compared under seismic and blast loads. Results show that the role of Pall friction damper in energy dissipated in earthquake loading scenario is more than blast; which has a root in extremely quick loading in blast rather than earthquake.

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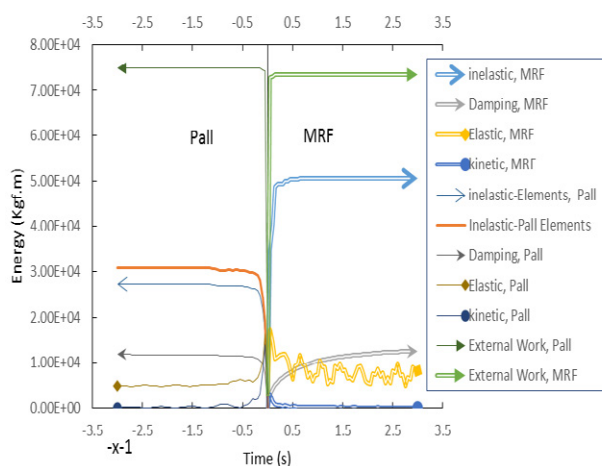


Fig. 2. the energy curve of structures in 1-100 scenario

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