sciendo

Civil and Environmental Engineering
Vol. 20, Issue 1, 194-203, DOI: 10.2478/cee-2024-0016

THE EFFECTIVENESS OF INNOVATIVE SYSTEMS TECHNOLOGIES IN SMART BUILDING STRUCTUERS

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Abstract

Today's industrial processes use a variety of smart structure systems technologies. Various construction devices can significantly enhance a structure's ability to adapt to environmental changes. Smart structures are essential to the development of building technology. These forms of technologies are developing intelligent structural systems that behave like living systems and can perceive their environment. The objective of the research is to examine the connection of these professional systems, which become increasingly dependent over time. The research acknowledges and give emphasis to the significant role played by different types of systems (passive, semi-active, active, and hybrid) in formative the scope of construction through the analysis of novel techniques and innovative approaches. The paper state the assorted classification of smart structure schemes that have a significant role to serve the cycle life of the structure by reducing severe subjected damage to it. The study aims to investigate how these schemes of callings are inseparably connected, creating ever more advantageously as time goes on. The think about state and recognize the significant part of different categories of schemes (inactive, semi-active, active, and hybrid schemes) within the development scope through examination, unused methods and inventive strategies. The paper displayed the different categories of shrewd structure schemes that have a critical part to serve the cycle life of the structure by diminishing serious subjected harm to it.t. Furthermore, the research also demonstrated the smart structure's useful behavior, which is taken into account at every stage of the civil engineering design process.

Keywords:

Active control system;
Passive system;
Hybrid control system.
Semi-active system;

1 Introduction

A keen structure may be a building (structure) that has adaptive systems, which enhanced the ability of the structure to detect and resist altering of an environment as shown in fig 1. However, two types of loads that subjected the structure (buildings), dynamic and static, such as earthquakes and gravity, are carried and transmitted by basic civil engineering structures[1]. Smart frameworks that can autonomously control themselves in reaction to environmental changes are called adaptive systems [2]. As a result of being accompanied by artificial systems, structures acquire intelligence that enables them to self-monitor and adapt to natural changes [3]. The ability of the smart structure is to recognize changes in the atmosphere and structure system detect problems in damaged areas, and store and analyze measured data. Moreover, directing suitable steps to be taken right away in order to develop system operation and keep structural reliability and protection. The research is still a pioneering and progressing technology to use techniques that have adaptive system which can made reduction in the wind impact and seismic reaction of huge building structures [4]. The idea of a smart structure (adaptive system) is presented as a high-tech system that, when put in a building of structures, responds intelligently to climatic changes via ability and features[5].

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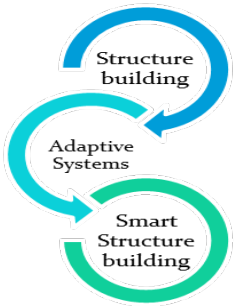


Fig. 1: Smart system role in the design operation of a structure.

2 Why smart structures are significant?

Because of the limitations in the conventional approach to building design, researchers were motivated to explore alternatives. Researchers were compelled to look at an alternative method of structural design due to the following issues with the conventional method[1]:

- The material dampening is kept to a least to dissipate dynamic energy.
- Stiffness is solely used by structures to sustain loads (wind and earthquake loads).
- Energy dissipation potential and limited load resistance. As a result, they are unable to adapt to environmental disturbances like earthquakes or wind that change continually.

3 Purpose of research

This exploratory research seeks to understand both the characteristics of smart structures in civil engineering and what makes conventional structure smart. The main objective is to investigate the significance and employment of intelligent adaptive systems as accommodative methods in construction, in addition their influence on behaviour of structures in structural engineering. An outline of the insights frameworks getting transmission structures as well as the categorization, analysis, and behaviour these systems. Furthermore, the study goal to explore structures linked by adaptive system to create smart building.

4 Damping Systems

By contributing to energy dissipations, dampers are used to minimize the responses of the structure and to limit the structure damage during a major earthquake. Installing dampers in an existing building structure that have limited ability for lateral stiffness that permits control of the story drift within the necessary constraint and retains its desirable functions amid an seismic tremor.

The components of a damping system include connections between dampers, structural elements, dampers collection, elements of structure, and members of the structure that transmit loads into the seismic-resisting system and damping devices and then to the foundation fig 2. So by linking the damping system with the intelligent system can be obtained adaptive structure for any environmental change[6].

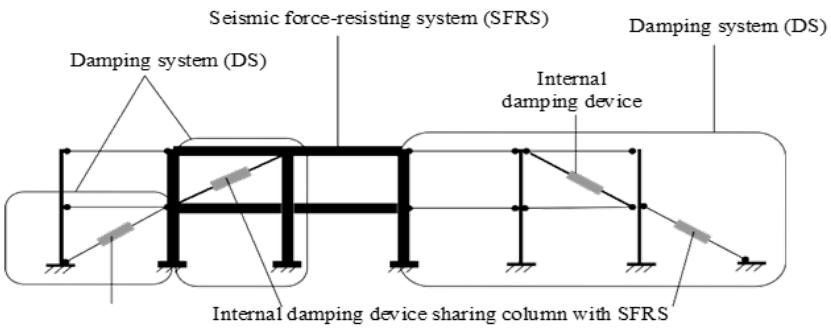


Fig. 2: Damping system and damping device [6].

5 Smart Scheme of Structure

Enhancement of smart scheme of structures emphases of various aspects, which represented by assimilation and sensors device reducing and shrewd materials in the elements of the structure. [7]. The

effectiveness of smart schemes is revealed by their ability to create connection with the outside world. The utilization of intelligent materials or sensors in the linking between components of building structure ensures safety and durability of structure. The features of smart structures include observing, self-repair control, awareness of the surroundings, self-monitoring, and structures that require for maintenance reduction. [8].

6 Technology of Smart Structure in Structural Engineering

The established approach for designing structures (like bridges, towers, and buildings) faces limitations concerning load capacity and energy consumption. Confronted with forces and the need to dissipate mechanical energy, these structures heavily rely on low damping and stability. However, they remain in danger due to their inability to adapt to the changeable effects of wind and earthquakes. Enhancing flexibility and structural strength to resist greater external forces two key measures were involved: increase size of the cross-section of crucial elements and utilizing resilient materials of building. [1]. Consequence in a plan that's both ineffectual and expensive. However, wastefulness of standard to-resist seismic tremor and wind plans provoked the joining of intelligent innovation within the respectful building advancements [9]. It is attainable to perform the taking after with savvy structure innovation:

- Enhance structures by integrating devices into the conventional design for increased earthquake resistance.
- Enable structures to dissipate kinetic energy and endure reduced seismic forces.
- Significantly enhance the structural systems of excitation performance, offering an attractive solution for improving structural safety and reducing repairs costs.
- A smart structure can save resources and labour in construction, reducing structural burden and overall costs.

7 The Systems of Adaptive Structure

The types of adaptive systems in civil engineering can be categorized into the following, as illustrated in Figure 3:

- In-active schemes (Base-isolation and Passive Energy-Dissipation schemes).
- Semi-active schemes (Semi-active damper schemes).
- Active schemes (Dynamic control structure).
- Hybrid schemes (Hybrid control structure).

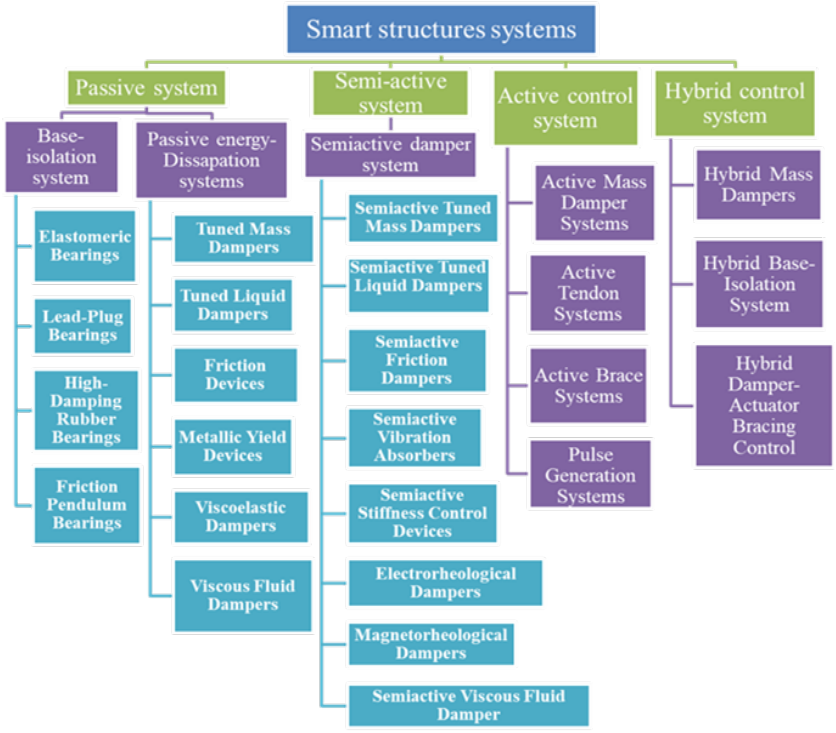


Fig. 3: Diagram of Savvy structure framework.

7.1 Inactive system

A inactive scheme “passive system” may be a basic scheme with a straightforward, effectively created component to resist certain jolts. But it cannot have the capacity to adjust to any alter within the outside environment since this framework needs the quality and outside faculties to fortify and react [1].

1) Base-isolation scheme: Essential separation could be a appropriate illustration the effect of detached controller methodology can be utilized. An versatile premise is gotten by rising a structure on a specific moo horizontal strength material; however, the following section introduces the types of this system [10].

2) Elastomeric bearings: were initially created from natural rubber; subsequently, steel plates or shims were added to enhance their performance. In fig 4, schematic of rubber bearing with steel shims is shown.

3) Lead-Plug Bearings: is made by inserting a lead core into the bearing, the drawback of the bearing of elastomeric has fewer damping qualities may be removed. The middle of the elastomeric bearing often has a prepared hole that is somewhat smaller than the lead plug sees fig 5.

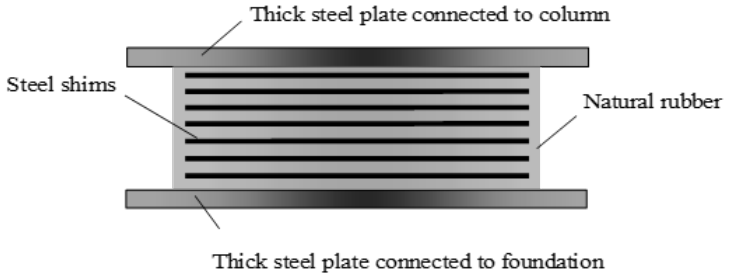


Fig. 4: Bearing base of elastomeric with steel plates [10].

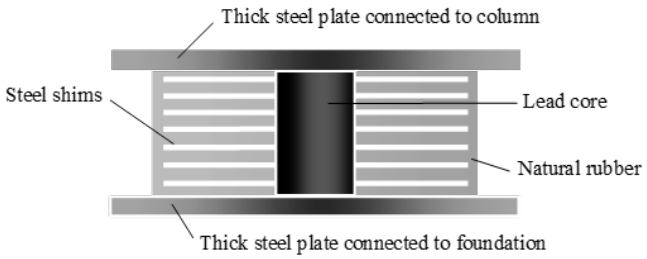


Fig. 5: Bearing base of Lead-plug [10].

4) High-damping rubber bearing; Despite being made entirely of rubber and steel shims, the high-damping rubber bearing has the requisite flexibility and energy-dissipation properties.

5) Friction spherical with concave sliding surface bearing: was created to abbreviate the remove to the centre of the bearing taking after an seismic tremor. Friction pendulum bearings are the name given to this kind of bearing.

Passive energy-Dissipation systems

Passive energy dissipation involves using mechanical devices to distribute the energy that's affecting the structure. These systems are commonly used to minimize structural damage and improve the stability of buildings. The types of systems are as follows [11].

• Tuned mass dampers: may be broken down into their most basic components, which are seen in Fig 6. which include spring (kd), a supplementary mass (md), and dashboard system (cd) that is anchored to the primary building structure. A dynamic vibration absorber is the fundamental component of this system.

• Tuned fluid damper: In this framework, the mass in movement may be a fluid, like water, and the re-establishing constrain is created by gravity. It is shaken by the auxiliary vibration, which too causes the fluid inside the holder to move. By changed the energetic vitality of the liquid stream into warm through the grinding between the holder and fluid stream and perplexity of the fluid stream, retaining vibrational vitality of building structure.

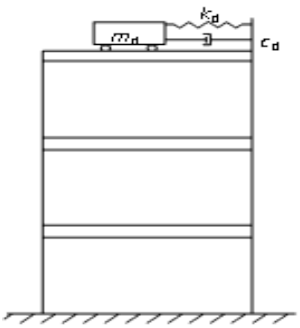


Fig. 6: Installation of the tune-mass damper on a structure [9].

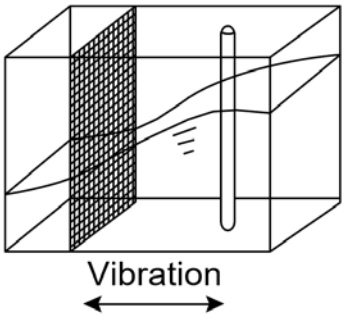


Fig. 7: The technique of tuned-liquid damper [9].

• Friction device: is a commonly used, dependable, cost-effective method of dissipating kinetic energy by converting it to heat see fig 8.

• Metallic device: another efficient method for releasing energy is the inelastic deformation of metallic materials sees fig 9.

• Viscoelastic dampers: use visco-elastic materials with strong damping to disperse energy via shear deformation. Rubber, polymers, and glassy materials are among the examples. Recall that the performance of structures exposed to environmental excitations is improved by the use of solids in the metallic, frictional, and VE dampers. Heavy industries and the military are both familiar with the use of viscous fluid to reduce stress and vibration see fig 10.

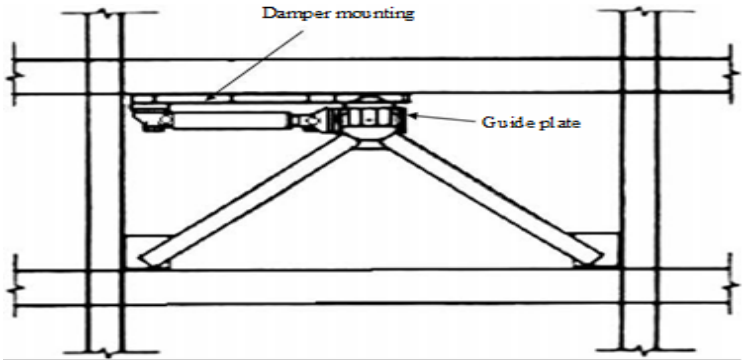


Fig. 8: Installation of friction dampers [11].

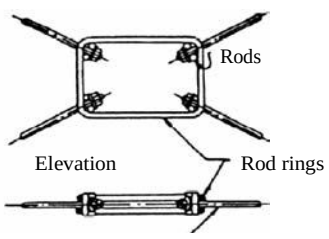


Fig. 9: Metallic yield damper [11].

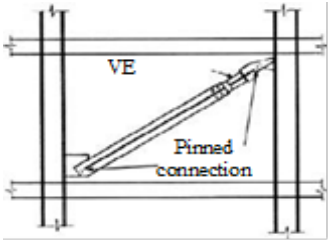


Fig. 10: Installation of viscoelastic damper in diagonal bracing [11].

7.2 Semi-active system

Semi-active systems prove beneficial in reducing and suppressing structural responses to external factors, such as wind-induced vibrations.

• Semi-active damper: Incorporating adaptable elements to enhance efficiency, these dampers utilize sensor and structural data to adjust their behaviour, optimizing energy dissipation. [12].

• Semi-active tuned mass damper: is suggested to manage vibrations caused by wind in tall structures. The tuned mass damper and actuator for this system are mounted on top of the primary structure [13].

• Semi-active tuned liquid damper: is incorporated a conventional of movable baffles into the liquid tank. These baffles' orientation may be changed using an actuator and predetermined algorithms. The fluid tank keeps its unique length when the baffles are put on a level plane [14].

• Dampers for Semi-active Friction: This tool is established by a friction condition in damper, which consists of a firmly fastened friction shaft and structural bracing, see fig 11.

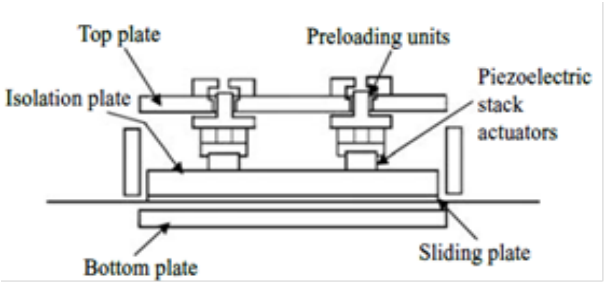


Fig. 11: Schematic friction damper [14].

• Semi-active vibratory dampers: Utilizing a variable orifice valve to modify the stream of a pressure driven damper is an efficient way to create a controlled damping mechanism. Semi-active vibration absorbers, also known as semi-active hydraulic dampers [15].

• Semiactive Stiffness Control Devices: This device is attached to the structure's bracing system. The is made up of a tube connecting the two barrel chambers, a regularly closed solenoid control valve, a double-acting cylinder bar, and a balanced hydraulic cylinder as shown in Fig. 12 [12].

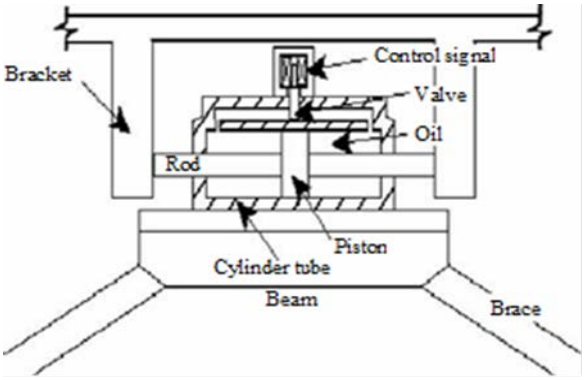


Fig. 12: Semi-active damper system [12].

• Electro-rheological damper: is employed intelligent electrorheological fluids, which are nonconducting viscous fluids (like oil) adsorbed onto dielectric particles dispersed within the fluids. The

dielectric particles of electrorheological fluid is polarizing and aligning and providing flow resistance When electrical field is applied [16].

• Semi-active viscous fluid damper: for structural seismic response management, this device employs a usually looping valve to regulate the intensity of fluid. The energy will be lost through friction that occurred between the piston head's orifices and flow, and bypass loop. The fluid may readily flow through the valve when the aperture is big, and there is less damping [17].

7.3 Active Control Scheme

• Active Scheme is a control system utilizing particular hardware, like electro-hydraulic actuators, to apply accurate controlled forces in response to dynamic loads through analysing and make a recording of structural responses [18]. The produced force can mitigate excitation caused by earthquakes, wind, and traffic providing additional damping. Controller devices of active system like dynamic dampers, dynamic bracing, and systems of pulse-generating have been developed by researchers [3].The focus on dynamic control seismic response has grown in recent years for several reasons:

• Improved control efficiency: current scheme may presently work to their complete capability.

• Ground development flexibility: The **scheme** can distinguish ground development and modify its control judgments in like manner.

• Control of selectivity: controller active scheme can be created for a extend of reasons, just, like the security of structure security or social unwinding.

• Applicability to different excitation gadgets: The basic reactivity to wind or seismic movement may be successfully decreased by an exuberant framework.

7.4 Elementary Configuration of Active Systems

The fundamental arrangement of like a scheme is appeared in fig 13., which is consist of by three sorts of components: sensors, a controller, and an actuator with a precise control switch [19].

• Sensor: may well be situated at the base of structure to distinguish outside jolts.

• Controller: It collects sensor information, analyses it, and creates the fitting signals to control the actuator employing an indicated control calculation.

• Actuator: it makes the fitting control strengths.

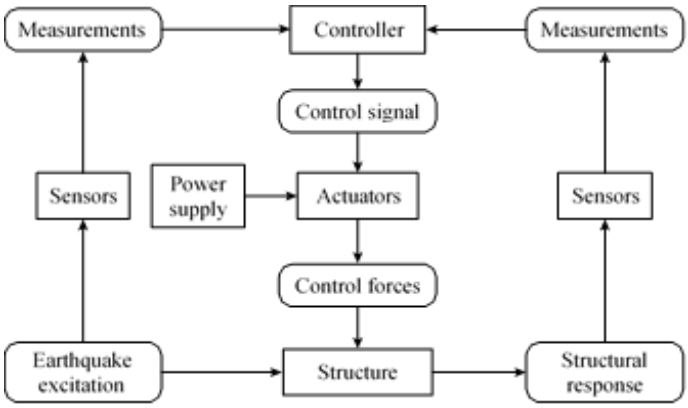


Fig. 13: Fundamental schematic of a dynamic framework for smart structure [19].

7.5 Type of active control system

• Systems with Dynamic Mass Damper: dynamic mass driver is another name for a dynamic mass damper. With the addition of an active control mechanism (actuator), it developed from a tuned mass damper. The system is only useful for controlling the response of structure while govern the first mode, as is the case with wind-induced structural vibration. The goal of active mass driver development is to regulate structural seismic response across a broad frequency range[20].

• Active tendon control systems: An array of pre-stressed tendons is used in active tendon control systems, and electrohydraulic servomechanisms are used to regulate their tension. An example setup of an active control system employing active tendons is shown in Fig 14. Building construction has active tendons inserted in the space between its two levels. The floor below is connected to the actuator cylinder. The tendon's other end is joined to the actuator cylinder, and its other end is attached to the

top floors. In response to an earthquake's excitation, a structure's vibration causes inter-story drift, which impels the actuator piston's relative development to the actuator barrel [21].

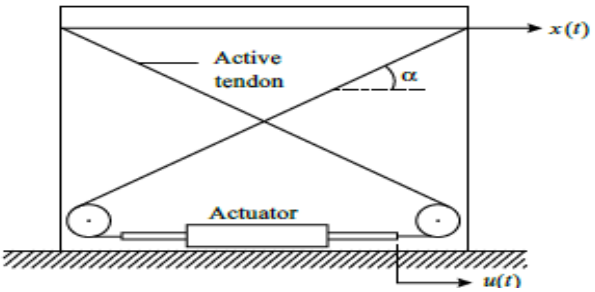


Fig. 14: active tendon system scheme [21].

• An active bracing system: attaches an active control expedient (i.e., an actuator) to a structure using pre-existing structural braces. As with passive dampers, bracing systems come in three varieties: diagonal, K-braces, and X-braces [22]. The invigorating system among two adjacent levels is equipped with hydraulic actuators controlled by a servo valve and capable of producing a significant amount of control force. Fig 15.

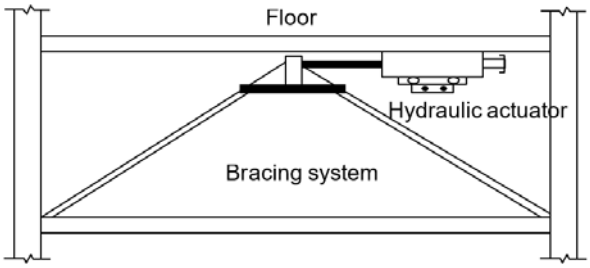


Fig. 15: Scheme of bracing system and control devices [26].

• Pulse generating system: Instead of a hydraulic actuator, a pulse generating system employs a pulse generator. Pneumatic mechanisms are used by pulse generators to create an active control force. Unlike hydraulic actuators, which use high-pressure fluid, such devices produce a pulse-type actuation force using compressed air. Pulse generators may be installed at various places across a structure to create a smart structure system[23].

7.6 Hybrid control system

A blended of combines dynamic and inactive control advances. A cross breed framework combines the benefits of both techniques whereas too making strides the restrictions of each technique autonomously. Be that as it may, the frameworks cross, the confinements of all frameworks (detached, dynamic, and semi-active), whereas accomplishing the aabilities of the dynamic framework and the unwavering quality of the detached framework, the sort of the framework is as takes after [24].

• Hybrid mass dampers: are combining detached tuned mass dampers with an dynamic control actuator or with an dynamic mass driver. The characteristic movement of the tuned mass damper is generally capable for the vibration-suppression capacity of the crossover framework. The actuator produces a controlled drive that controls the mass damper, expanding the device's viability and strength to alter the structure's energetic properties [25].

• Hybrid base-isolation framework: Furthermore, a base-isolation framework with an dynamic control framework coordinates has been proposed [26]. This framework comprises of a base-isolation framework between the establishment and the superstructure [15].

• Hybrid bracing control system: also known as a hybrid damper-actuator invigorating control, installed on the structure via K-braces, as illustrated in Fig 16. The device of hybrid which consisted of a damper, actuator, and control device that placed on one floor of the building structure due to diverse control objectives and financial concerns. This system has the ability in reducing earthquake structural response more than a passive system, and it requisites force fewer than an active system to keep a governor devices[26].

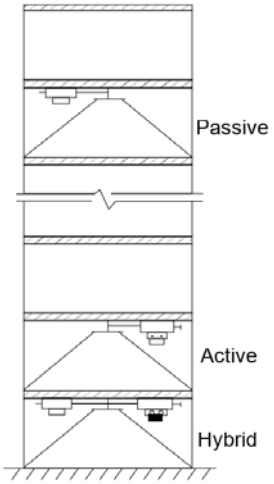


Fig. 16: Hybrid bracing control system [26].

8 Conclusions

• The adaptive schemes used throughout the whole structure serve more than just the lifespan of the building. Therefore, designers should consider these systems as functional components that can adapt and perform effectively through each level of process design.

• In this era of revolutionary innovation, advance of modern building structures needs massively for versatile scheme to have the capacity to foresee the altering of the environment.

• The semi-active systems are more reliable and developed compared to passive systems. However, semi-active dampers perform to be a viable technique for structural excitation response management of building structures, meanwhile they incorporate the benefits in cooperation systems (active and passive systems) with less costly with respect to passive systems.

• The building structure with passive systems is not adequately adaptive to environmental change because the system doesn't utilize external power to become capable of response and sense excitation. Meanwhile, Semi-active systems (incorporated systems) give the building structure ability to adaption to the atmosphere changes, but they can only act within the limited capability of the system (passive system) devices on which they are established. However, using a special device in the innovative active system like electro-hydraulic actuators can produce extra force damping to reduce excitation of the structure under earthquake, wind, and traffic forces.

• The significance of a hybrid system is the gains of techniques of together systems (active and passive systems), so using a passive system can be reduced the huge external power required for an active system (actuator and sensors) to resist the excitation of wind and earthquake loads. Also, improves the restrictions of each technique alone.

Acknowledgement

The author would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad – Iraq for its support in the display work.

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