Elastic Joints and its lateral forces Futuristic structural concept

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Abstract: Bridge structures have been supported on flexible and elastomeric bearings for a number of years. In this paper supporting the structure system concerning buildings in every connection on elastomeric bearing will be discussed. The human body structure content elastic joints in its connection. A simulation of this concept can be useful for the buildings concerning earthquakes. Most structures act as transfer elements, receiving certain forces and transferring them to other points. This transfer capability is dependent on the internal strength and stability of the structure. A thin sheet of aluminum may be easily buckled, a block of wood may be easily split along its grain, and a rectangular framework with loose, single-pin joints may be easily collapsed sideways. All of these structures fail because of an inability to maintain internal equilibrium through lack of strength, or because of the lack of some inherent stability, or for both reasons. The complete static equilibrium of a structure requires two separate balances: that of the external forces and that of the internal forces. Externally sufficient reaction components must be developed by the supports. Internally, there must be an inherent capability for stability and sufficient strength to do the work of transferring the applied loads to supports. But what is about a flexible structural system? Can we damage the movement of the system? Are sensors useful for this new structural concept? The idea is to develop a steel structure system with elastic connection. And this system includes a error reader (sensor) response for the linearity of the system. If we have any horizontal force in form earthquakes or wind the sensor give the signal to the stepper motor to correct the error through moving the structure with the tension member. We propose that the humane design is one of the most important principles of sustainability in architecture.

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Introduction

The shape of the structure and the type of connections affects the behavior of the structures under seismic loads. As shown in figure 1, three types of the structures were studied:

1- Flexible structures with bracing.
2- Rigid structures without bracing.
3- Rigid structures with bracing

Flexible structures without bracing couldn't be studied as it is unstable. Three shapes (triangle, square, and hexagonal) with different number of floors were studied under seismic loads using response spectrum functions according to UBC97. Direction X is considering the direction of earthquake force.

Improvement in seismic design

The improvement in seismic safety, since about the time of the San Francisco earthquake in 1906, has been due primarily to acceptance of ever-increasing force levels to which building must be designed. Innovation has been confined to the development and acceptance of economical structural systems that perform reasonably well, accommodate architectural demands such as open exteriors and the absence of interior walls, and enable materials such as steel and reinforced concrete to compete in the marketplace on near-equal terms.

The vocabulary of seismic design is limited. The choices for lateral resistance lie among shear walls, braced frame, and moment-resistant frames. Over the years these have been refined and their details developed, and methods of analysis and modeling have been improved and reduced uncertainly. But the basic approach of constructing a very strong building and attached it securely to the ground has not changed. The approach of arm wrestling with nature is neither clever nor subtle, and it involves considerable compromise.

Although codes have mandated steadily increasing force levels, in a severe earthquake a building, if it were to remain elastic, world still encounter forces several times above its designed capacity. This situation is quite different from that for vertical forces in which safety factors insure that actual forces will not exceed 50% of designed capacity unless a serious mistake has been made. For vertical forces, this is easy to do but to achieve similar performance for seismic forces, the structure would be unacceptably expensive and its architectural impact would be extreme. This discrepancy between seismic demand and capacity is traditionally accommodated by reserve capacity, which includes uncalculated additional strength in the structure and often the contribution of partitions and exterior cladding to the strength and stiffness of the building. In addition, the ability of materials such as steel to dissipate energy by permanent deformation -which is called ductility- greatly reduces the likelihood of total collapse.

Modern building contains extremely sensitive and costly equipment that has become vital in business, commerce, education and health care. Electronically kept records are essential to the proper functioning of our society. These building contents frequently are more costly and valuable than the buildings themselves. Furthermore, hospitals, communication and emergency centers, and police and fire stations must be operational when needed most: immediately after an earthquake.

Conventional construction can cause very high floor accelerations in stiff building and large interstory drifts in flexible structures. These two factors cause difficulties in insuring the safety of the building [2].

Basic elements of seismic isolation system

There are three basic elements in any practical seismic isolation. These are :

1- Flexible so that the period of vibration of the total system in lengthened sufficiently to reduce the force response.
2- Damper or energy dissipater so that the relative deflections between buildings and ground can be controlled to practical design level ; and
3- Means of providing rigidity und low (service) loads levels such as a wind and minor earthquakes.

Bridge structures have been supported on elastomeric bearings for a number of years, and as a consequence have already been designed with a flexible mount. It is equally possible to support buildings on elastomeric bearings, and numerous examples exit where buildings have been successfully mounted on pads.

This has been done primarily for vertical-vibration isolation rather than seismic protection. Several buildings in Europe and Australia have been built on rubber bearings to isolate them from vertical vibrations from subway system below, and are performing well more than 40 years after construction. By increasing the thickness of the bearing additional flexibility and period shift can be attained.

While the introduction of lateral flexibility may be highly desirable, additional vertical flexibility is not vertical rigidity is maintained by constructing the rubber bearing in layers and sandwiching steel shims between layers. The steel shims, which are bonded to each layer of rubber, constrain lateral deformation of the rubber under vertical load. This results in vertical stiff nesses several hundred times the lateral stiffness and of a similar order of magnitude to conventional building columns.

An elastomeric bearing is not the only mean of introducing flexibility into a structure, but it appears to be the most practical and the one with the widest range of application. Other possible devices include rollers, friction slip plates, capable suspensions, sleeved piles, and rocking (stepping) foundations.

The reduction in force with increasing period (flexibility) is shown schematically in the force-response curve of figure 1. Substantial *reduction in base shear is possible if the period of vibration of the* structure is significantly lengthened.

The reduction in force response illustrated in figure 1 is primarily dependent on the nature of the earthquake ground motion and period of the fixed-base structure. Further, the additional flexibility needed to lengthen the period of the structure will give rise to large relative displacements across the flexible mount.

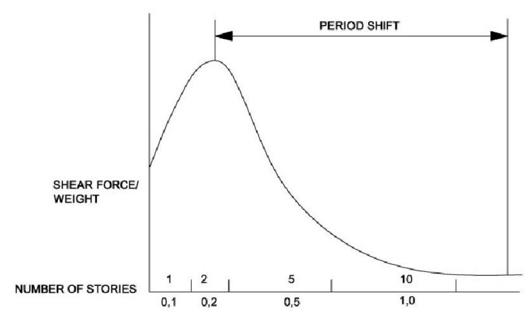

Fig.1 Idealized force responce spectrum

The elastic joint gives the same effect concerning force reduction. The idea is to design a knee like the sphere connection in the space truss. Adding from another structure element like tensions-member and bracing system is very necessary for the stability of this system.

Design objective

In general, the design of economical earthquake-resistant structure should aim at providing the appropriate dynamic and structural characteristics so that acceptable levels of response result under the design earthquake.

Elastic Connection

The new idea is to construct the joints in elastic connection (Fig. 2). The deformation in the structure member is through the continuity of the column. If we are looking to the human body, we will find the elastic joints between the members. The knee is one of these elastic joints.

We would like to have intelligent building that react with the wind and earthquake and after that become its rigidity again.

Fig. 2: Sphere element in the connection to have the motion in any direction

Fig. 3: Tensions member in x, y direction as a bracing elements

Structure type's analysis

The shape of the structure and the type of connections affects the behavior of the structures under seismic loads. As shown in figure 1, three types of the structures were studied,

1- Flexible structures with bracing.
2- Rigid structures without bracing.
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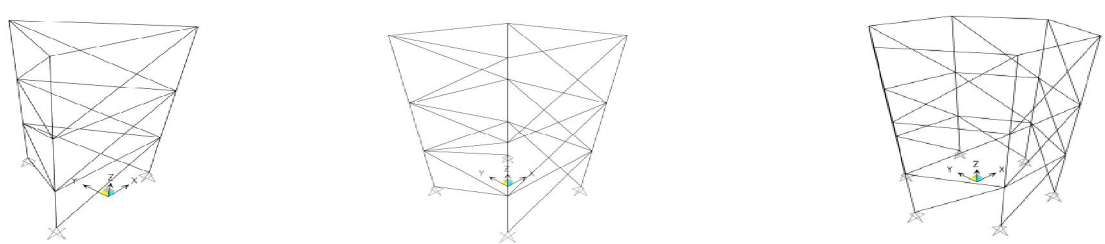
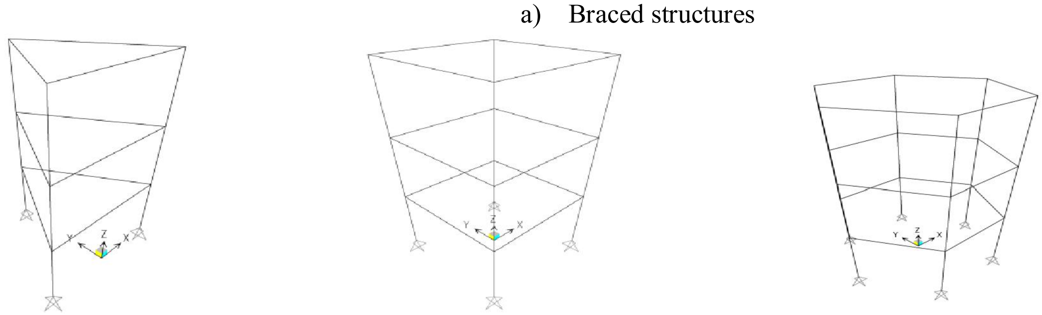
Flexible structures without bracing couldn't be studied as they are unstable. Three shapes (triangle, square, and Hexagonal) with different number of floors were studied under seismic loads using response spectrum functions according to UBC97. Direction X is considering the direction of earthquake force.



a) Braced structures



b) Unbraced structures

Fig. 4. Structures systems

Table 1. Triangle Flexible structures with bracing

Number of stories	Force in X-direction		Buckling factor	Total weight, ton
	Δ_x, m	Δ_y, m		
3rd	0.0052	0.0002	533.694072	4.5939
6th	0.0176	0.0031	1198.912452	7.7366
9th	0.0301	0.0006	398.170491	13.7816
12th	0.0511	0.001	411.679044	18.3755

Table 2. Square Flexible structures with bracing

Number of stories	Force in X-direction		Buckling factor	Total weight, ton
	Δ_x, m	Δ_y, m		
3rd	0.0019	0.0005	390.113842	5.3648
6th	0.0092	0.0006	229.161924	10.7297
9th	0.0186	0.0017	63.908978	16.0945
12th	0.0317	0.0033	60.603253	21.4593

Table 3. Hexagonal Flexible structures with bracing

Number of stories	Force in X-direction		Buckling factor	Total weight, ton
	Δ_x, m	Δ_y, m		
3rd	0.0014	0.0001	2046.83696	6.629
6th	0.0078	0.0007	344.86742	13.258
9th	0.0154	0.0011	98.144866	19.8871
12th	0.0261	0.0017	37.669339	26.5161

Table 4. Rigid structures without bracing

Number of stories	Force in X-direction		Buckling factor	Total weight, ton
	Δ_x, m	Δ_y, m		
Triangle with 3rd floor	0.0318	0.0115	6.4456	2.6523
Square with 3rd floor	0.0393	0.0000	1.762517	3.1238
Hexagonal with 3rd floor	0.0141	0.0000	35.144981	3.8832

Table 5. Rigid structures with bracing

Number of stories	Force in X-direction		Buckling factor	Total weight, ton
	Δ_x, m	Δ_y, m		
Triangle with 3rd floor	0.0049	0.001	54.354133	4.5939
Square with 3rd floor	0.0019	0.0004	2.270767	5.3648
Hexagonal with 3rd floor	0.0013	0.0004	331.853476	6.629

The shapes of the structures affects both the sway ratio and the required mass of the structure as illustrated in Figure 5, it has been found that the hexagonal shape is better than the square shape and the Hexagonal shape is better than the triangle shape. Although the mass of the structure has been increased in the triangular shape by 20% for square and 50% for hexagonal, the sway ratio has been decreased by 50% for square shapes and 40% for hexagonal.

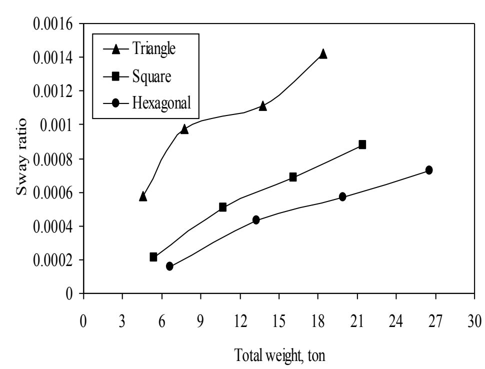


Fig. 5. Effect of the shape of the structure on the sway ratio and total weight shapes

The structure has been studied for a constant number of stories to illustrate the effect of both the shape and the system of the structure on the displacement and buckling load factor. From figures 6 and 7, it has been noticed that, the flexible structures with bracing has almost the same displacement compared with rigid structure with bracing. On the other hand, it has relatively a bigger buckling load factor. This means that we can have efficient structures using flexible structures with sufficient bracing for the stability requirement. In addition to the previous, we can see that the hexagonal shape has the best behavior in the stability and the deformations. Meanwhile, the rigid structures without bracing are not preferred for its large deformations and very low values of the buckling load factor

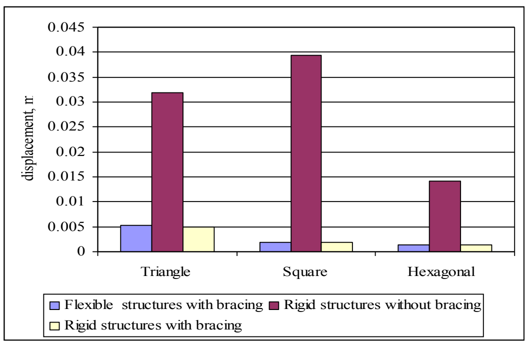


Fig. 6.Displacement – Type of structure

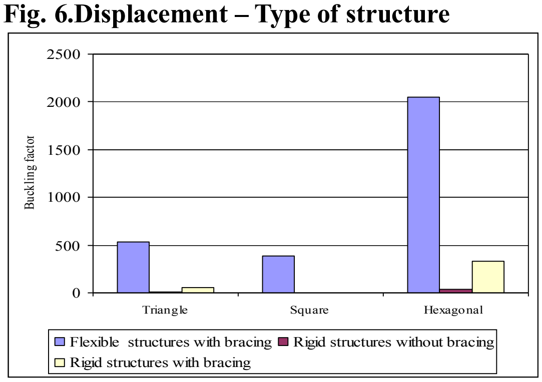


Fig. 7. Buckling factor – Type of structure

The lateral displacement as percent of displacement in earthquake direction was changed according to the shape of the structure, for example for hexagonal structures this percent ranged between 6 to 9% but for triangle structures this percent ranged between 2 to 18% as illustrated in figure 8.

The effect of number of stories on the buckling load factor is illustrated in figure 9. From this figure, it can be noticed that increasing in number of stories attends to increasing in a horizontal displacement. In additional, hexagonal structure has lower buckling load factor at same number of stories than square and triangle structures.

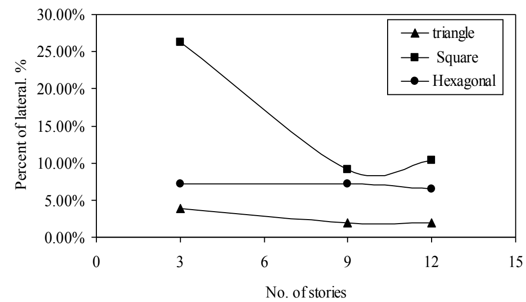


Fig. 8. Effect of number of stories of building on percent of lateral displacement

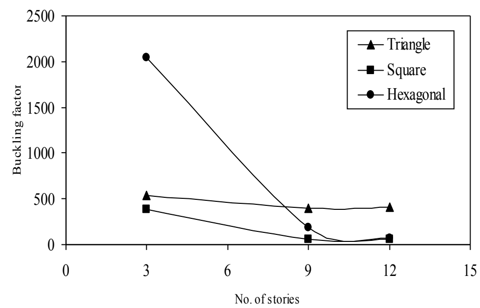


Fig. 9. Effect of number of stories of building on buckling factorComparing between knee and Slab connection

The knee is essentially made up of four bones. The **femur**, which is the large bone in your thigh, attaches by ligaments and a capsule to your **tibia**. Just below and next to the tibia is the **fibula**, which runs parallel to the tibia. The **patella** or what we call the knee cap, rides on the knee joint as the knee bends.

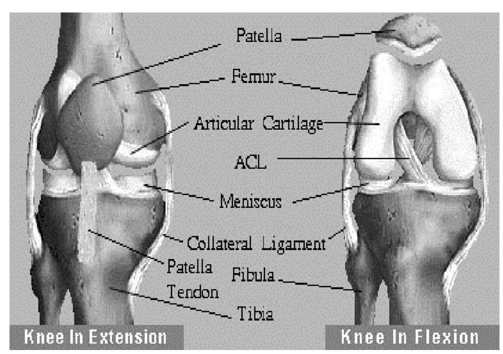


Fig10: Right Knee [6]

When the knee moves, it does not just bend and straighten, or, as it is medically termed, flex and extend. There is also a slight rotational component in this motion. This component was recognized only within the last 50 years, which may be part of the reason people have so many unknown injuries. The knee muscles which go across the knee joint are the quadriceps and the hamstrings. The quadriceps muscles are on the front of the knee, and the hamstrings are on the back of the knee. The ligaments are equally important in the knee joint because they hold the joint together. Problems with ligaments are common. In review, the bones support the knee and provide the rigid structure of the joint, the muscles move the joint, and the ligaments stabilize the joint for a computer animation of basic knee motion.

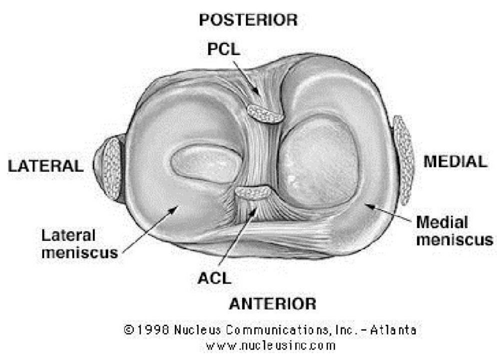


Fig11: Cross Sectional View of Right Knee [6]

The knee joint also has a structure made of cartilage, which is called the meniscus or meniscal cartilage. The meniscus is a C-shaped piece of tissue which fits into the joint between the tibia and the femur. It helps to protect the joint and allows the bones to slide freely on each other. There is also a bursa around the knee joint. A bursa is a little fluid sac that helps the muscles and tendons slide freely as the knee moves.

To function well, a person needs to have strong and flexible muscles. In addition, the medical cartilage, auricular cartilage and ligaments must be smooth and strong. Problems occur when any of these parts of the knee joint are damaged or irritated.

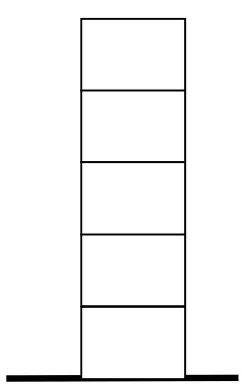
Equilibrium of structures

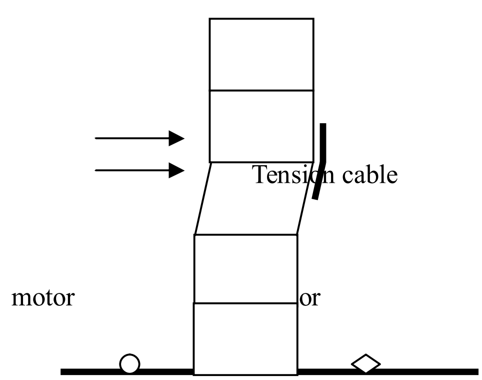
Most structures act as transfer elements, receiving certain forces and transferring them to other points. This transfer capability is dependent on the internal strength and stability of the structure. A thin sheet of aluminum may be easily buckled, a block of wood may be easily split along its grain, and a rectangular framework with loose, single-pin joints may be easily collapsed sideways. All of these structures fail because of an inability to maintain internal equilibrium through lack of strength, or because of the lack of some inherent stability, or for both reasons.

The complete static equilibrium of a structure requires two separate balances: that of the external forces and that of the internal forces. Externally sufficient reaction components must be developed by the supports. Internally, there must be an inherent capability for stability and sufficient strength to do work of transferring the applied loads to supports.

For internal stability, the structure must be formed, arranged, and fastened together to develop the necessary resistance. The aluminum sheet was too thin for its size, the wood block had weak shear planes, and frame lacked the necessary arrangement of members or type of joints. All three could be altered to make them more functional. The aluminum sheet can be braced with stiffening ribs, solid-sawn wood block can be replaced with a laminated piece with alternate plies having their grain directions perpendicular to each other, and the frame can be stabilized by adding a diagonal member.

There are three possible conditions for external stability. If support conditions are insufficient in type or number, the structure is externally unstable. If support conditions are just adequate, the structure is stable. If the supports provide an excess of the necessary conditions, the structure is probably stable, but may be indeterminate – not necessarily a bad quality, just a problem for achieving a simple investigation of structural behavior.

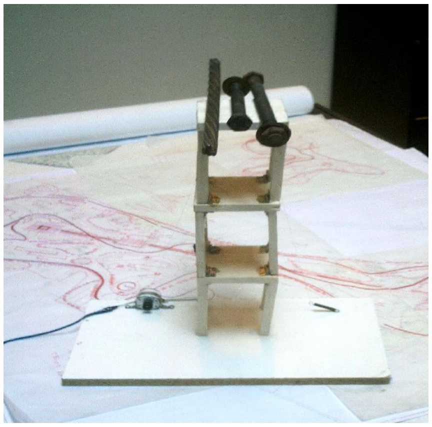




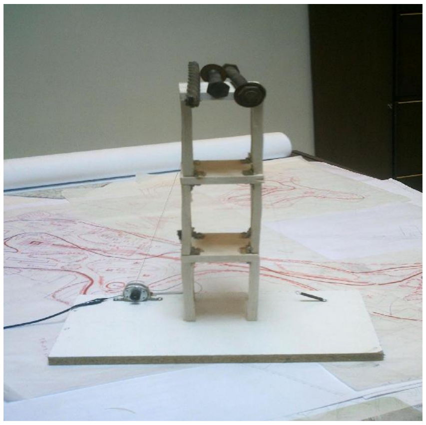
Elastic sensor added structure Concept

The idea is to develop a steel structure system with elastic connection. And this system include a error reader (sensor) response for the linearity of the system. If we have any horizontal force in form earthquakes or wind the sensor give the signal to the stepper motor to correct the error through moving the structure with the tension member.

We mad an experiment for this concept with a small model. The next step is to build this structure in the reality with two floors.



Before reacting the motor



after reacting the motor

The second Point is that the shape of the building plays a role by its reactions.

The third point is that experiment show us that an elastic connection with error reader (sensor), which response for the linearity of the system, and motor, the can correct the system. If we have any horizontal force in form earthquakes or wind the sensor give the signal to the stepper motor to correct the error through moving the structure with supporting of the tension member.

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Conclusion

In this paper it has been noticed that, the flexible structures with bracing has almost the same buckling load factor. This means that we can have efficient structures using flexible structures with sufficient bracing for the stability requirement. The main point is that finally we have buildings without rise through improving the seismic design. This knee connection or elastic joints is very intelligent as it can react with the movement of the earth.

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