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Seismic Behavior of Wooden Rollers Support in the Great Earthquake of Guilan Province, Iran: a Case Study

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ABSTRACT

Today increasing the performance and buildings' safety (structures) before and after the great earthquakes are so significant. One of the methods to increase and protect buildings against earthquakes is to apply “Seismic Base Isolation” systems. In this method, the maximum base shear decreases, instead of increasing the structure strength. Base isolation systems have different kinds with extensive researches have been done on them. In the current article a new system of seismic base isolation is introduced and investigated in some areas of Guilan province especially around Lahijan, Iran. This system is formed of some wooden rollers which have been placed on the wide foundation in two orthogonal directions and on the four layers. The friction between surfaces of rollers and the wood damperlike behavior is so important in absorbing the earthquake energy and transmitting it to the upper structure. The result of computer analysis according to spectrum analysis reveals that the maximum base shear decreases from about one-third to one-fourth of the maximum earthquake shear.
KEYWORDS: seismic base isolation, wooden roller Support, base Shear.

1. INTRODUCTION

One of the methods to increase and protect buildings against earthquakes is to use of vibrating isolators (Seismic Base Isolation systems). Vibrating isolator is to set up a system in which the structure and its accessories are isolated from the earth destructive seismic movement and, or support. This isolation is obtained at the result of system flexibility growth and also providing appropriate amortization. Vibrating isolators are called foundation isolators because in most cases, they are set up in the bottom part of the structure. Isolation, usually decreases the costs of providing seismic strength to demand level.

The method following in New Zealand is to design for increasing seismic strength with costs decreasing [1]. The considerable point is that in spite of applying different methods for calculating by designers, all methods consider reasonable the displacement of about 50 to 400 millimeters. These amounts are also reasonable to about twice as much if violent earthquake movements would happen. So, it must be considered an earthquake joint for all structures with vibrating isolators to make it possible these types of displacements during earthquake [2].

In the seismic base isolation system, no issues related to ordinary system with clamping base happen. In this manner, the upper structure almost as a rigid body is displaced on the soft isolators. In fact the main part of earthquake movements are absorbed into the isolators' level and as a result the transmitted earthquake movements to the upper structure decrease 5 to 10 times as much the ordinary system with the clamping base. In the present condition, the seismic base isolation system, by controlling the transmission of earthquake movements to the upper structure, protects the structural and nonstructural members cracking especially inside accessories of the structure.

It should be mentioned that the seismic base isolation systems in addition to the new buildings, could be applied for reconstruction and strengthen of the valuable old and ancient buildings, too [3]. Some of buildings in guilan province possesses roller foundation that have advantages such as appropriate bearing in the common condition, loss of buckling and performing as an isolator in the condition of earthquake vibrations than usual foundations [4]. These roller foundations had displacements of about 3 to 7 centimeters on June 21st, 1990, and showed good performance against the mentioned earthquake. Also the buildings with roller foundations had less damages than similar buildings[5].

2. The study of the wooden rollers support of Lahijan

2.1. Introduction of the wooden rollers support of Lahijan

There are signs of beauty and variety in the earliest and smallest rural shelters of guilan province as well as other areas of Iran. Utilized materials in rural homes in Iran are influenced of the geographical environment around them. In the north of Iran (Guilan and Mazandaran), because of so much rainfall, homes have haleb gable roof and are built of wood. However, in the other areas of the country, homes are built with adobe, mud, wood, stone and brick according to the availability and more efficiency of the material with the climate.

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Traditional buildings stand on roller foundations are those have been built on the hillside and at the areas with high humidity. On the basis of humidity factor, these buildings make them isolated from the earth and so, special lightness is seen on them.

It is clear that the foundation is a member of a building for transmitting imposed loads on it (vertical and abutment loads) to the earth. Foundations are designed according to the factors like earth material of the under foundation, glacial depth, and surface waters (precipitation). Building static is prepared with wood. These materials are used in bodies, too. The structure usually is built traditionally by a master carpenter. But it will be done by a master mason in desert architecture. Pictures 1-4 shows these types of wooden rollers support of Lahijan as well.

Picture 1. General façade of a traditional building on the basis of Lahijan's wooden rollers foundations

Picture 2. General façade of a traditional building on the basis of Lahijan's wooden rollers foundations

Picture 3. Façade of wooden rollers foundations

Picture 4. Façade of wooden rollers foundations

As it was mentioned, one of the reasons for these types of footing is the good strength of buildings that had been built on them. The other reason was how to put or arrange wood in footing that had significant importance. In this way, after distributed foundation is poured as lime mortar, some boulders stand as start for wooden footing, and 5 to 7 of tree stocks in almost circular cross section shape stand on them which is called 'rite'. Then 3 thinner circular wood called 'zy' stand vertically over rites. Next, 3 boards with about featheredged cross section called 'katale' stand over 'zies' vertically. And finally a featheredged cross section wood called 'Fiyoke' stands on 'katales' vertically. Pay attention to figure 1.

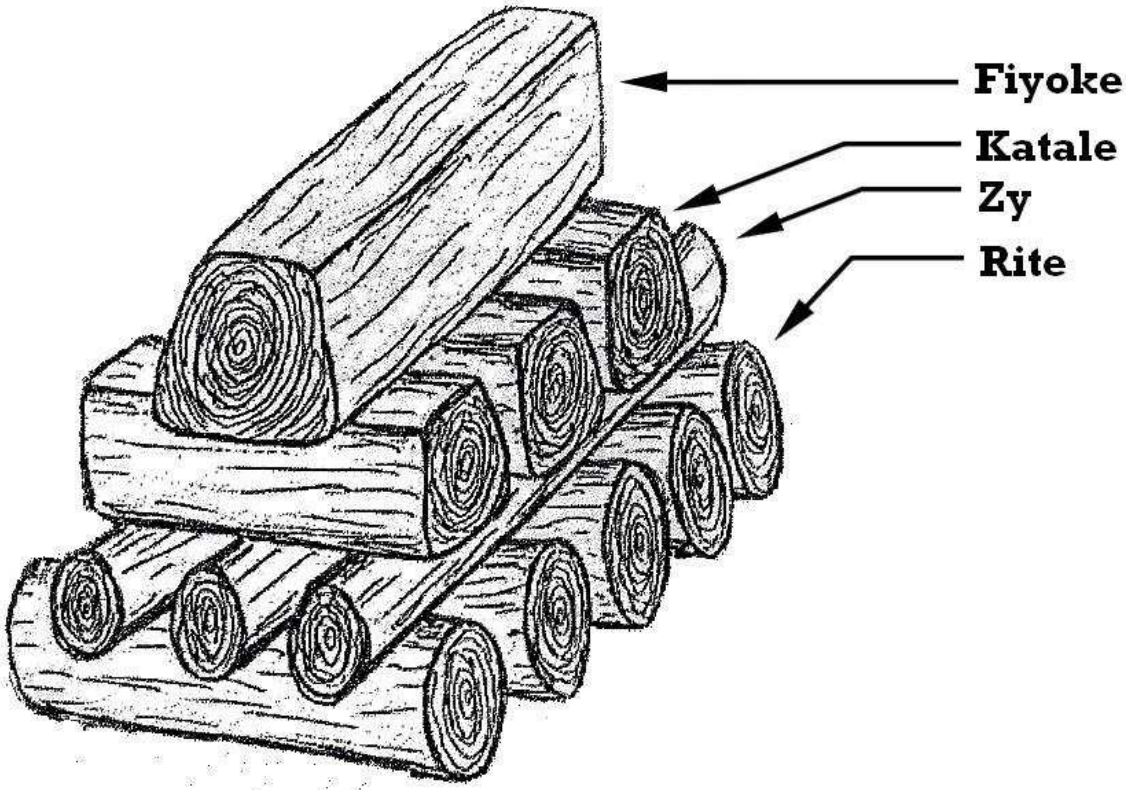

Fig. 1. Details of Lahijan's wooden roller support

After building some of the footings according to the building need, the main structure of the building is built in the way, some wooden beams as ceiling joint stand on Fiyoke featheredged cross section wood as mentioned before. After these ceiling joint, auxiliary beams of wood with lower cross section stand, and finally the first floor of the building is built and the structure of the building will continue at this way to the end.

2.2. Analysis of a traditional building on the basis of roller foundations

Firstly model a traditional building, and with supposition of the upper structure of any kinds of materials such as wood, concrete, and steel; consider it as a metal frame structure and use roller and spring instead of the wooden rollers in models.

After calculating the weight of each floor:
W= total building weight = 43700+28570+7830=80100kg≃80000kg
V= 4000kg base shear force

Now by supposition of the friction between wooden rollers is coulomb friction, and by attention to the pointed issue, the researcher models and analyzes the mentioned traditional building. The relationship between force and structure displacement is as follows:
F= $k\Delta$
mm for building with amortization400 $\Delta = 50 \sim$
Δ= 1000 mm for building without amortization

Above structural analysis has been done with different displacements, periods, and drifts, and inside force were recorded at different manners. At first the mentioned traditional building was considered and analyzed without roller and by using of clamping support as the name of Str.00 file. Then the mentioned traditional building was considered and analyzed with roller and spring (Base Isolation) and displacements between 5 to 40 cm and as the names of Str.1 to Str.05 files. The results of analysis recorded bending moment of beam 19, axial force of column 2, axial force of brace 50, periods and correspondent hardnesses with displacements and also drifts. Table 1 shows the results of analysis. For better perception, diagrams 1-5 were drawn according to the obtained results.

Table 1. Analysis results of the traditional building

File's name	Spring hardness(kg/m)	Period(Sec)	Force of column2 (kg.m)	Moment of beam 19(kg.m)	Force of brace 50 (kg)	Drift of the first floor(mm)	Drift of the second floor(mm)
Str.00	-	0.13	4426	49.73	4926	1.00	0.80
Str.01	1667	7.54	586	11.88	731	0.20	0.10
Str.02	3333	5.33	704	14.26	877	0.20	0.10
Str.03	4444	4.62	797	16.13	953	0.30	0.10
Str.04	6667	3.77	963	19.50	1201	0.30	0.20
Str.05	13333	2.67	1181	23.88	1471	0.40	0.20

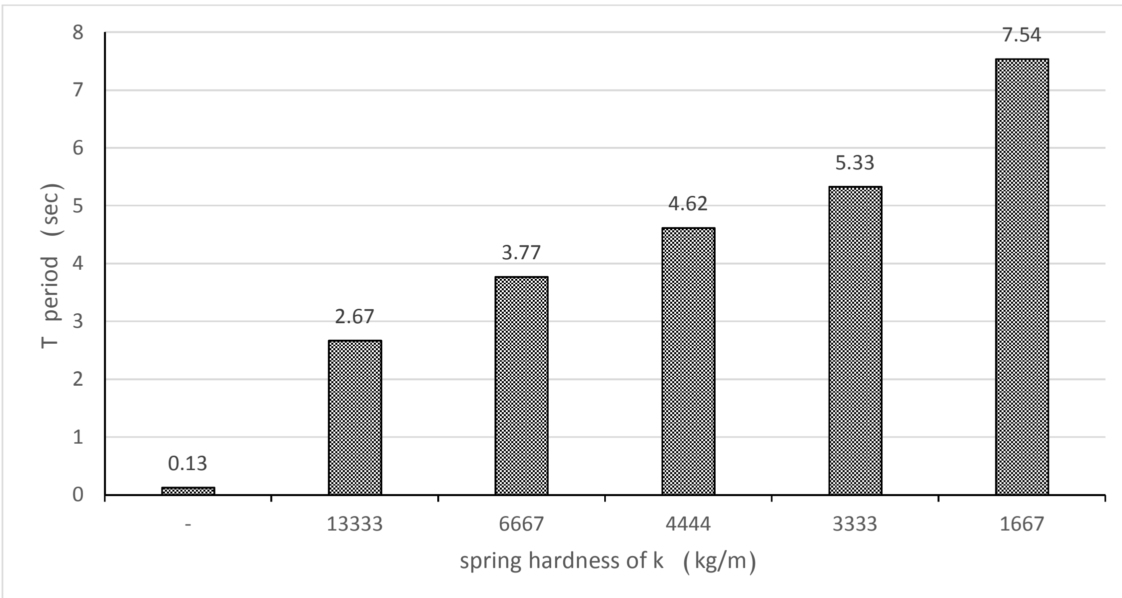

Diagram 1. Period changes on the basis of isolator spring hardness

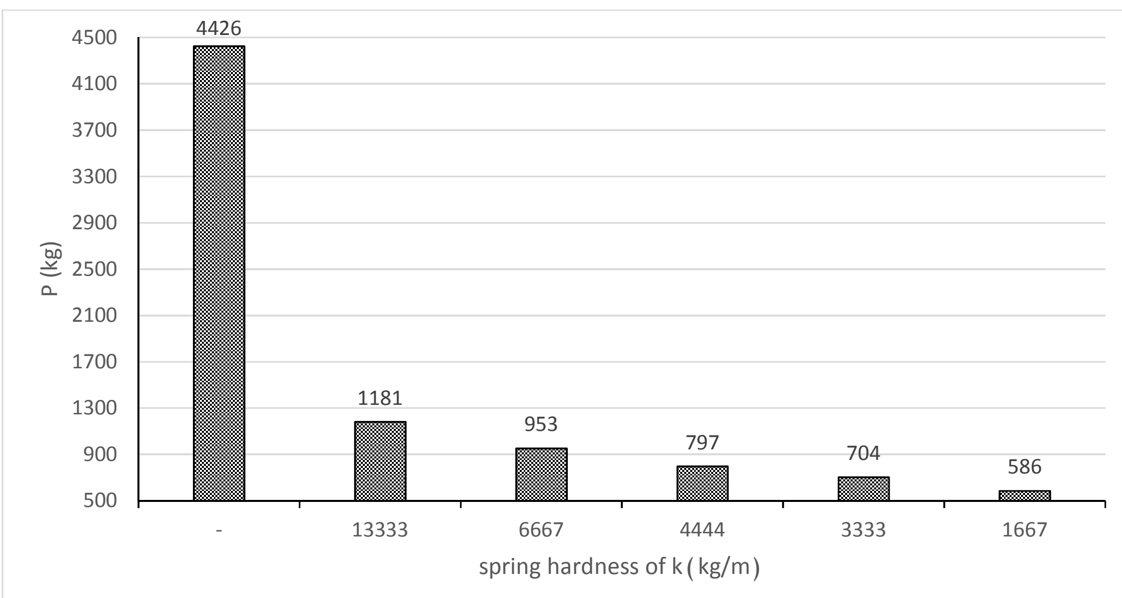

Diagram 2. Axial force changes of column 2 on the basis of changes in isolator spring hardness

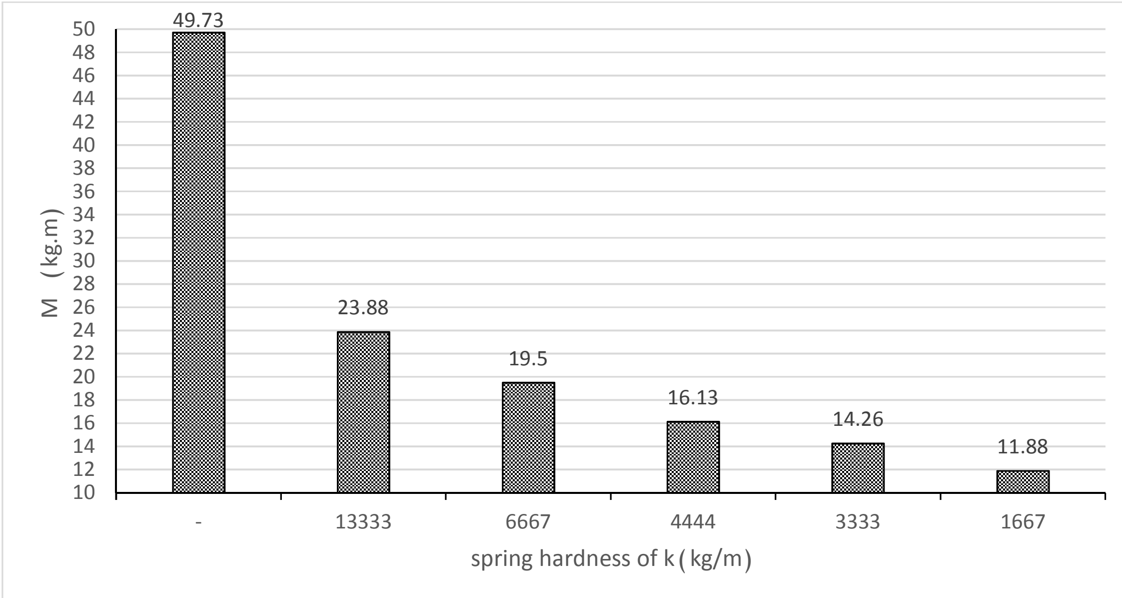

Diagram 3. Bending moment changes of beam 19 on the basis of changes in isolator spring hardness

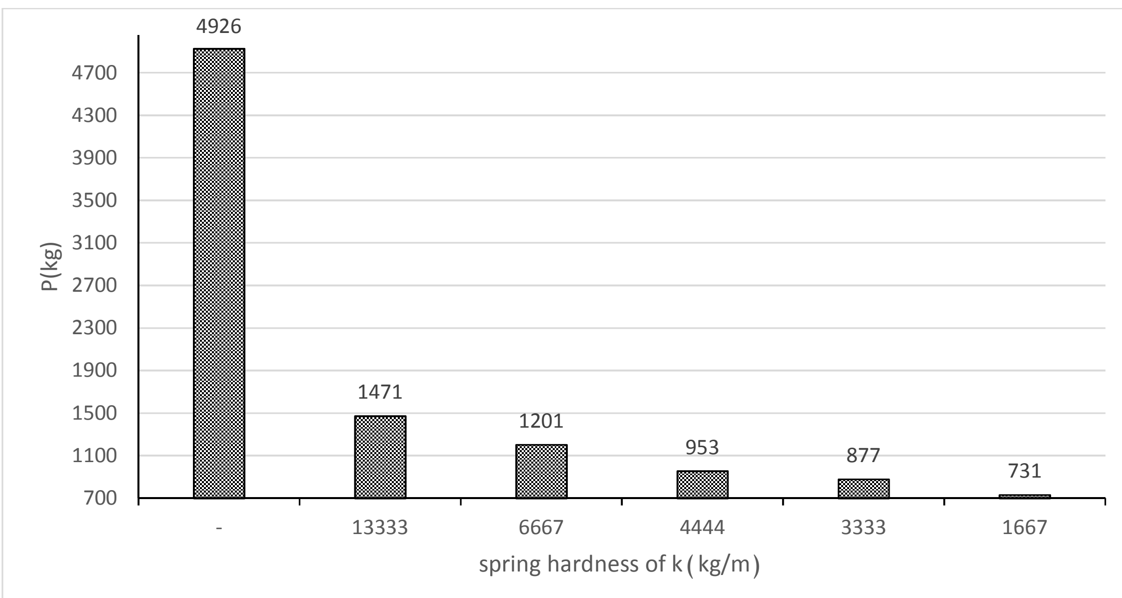

Diagram 4. Axial force changes of brace 50 on the basis of changes in isolator spring hardness

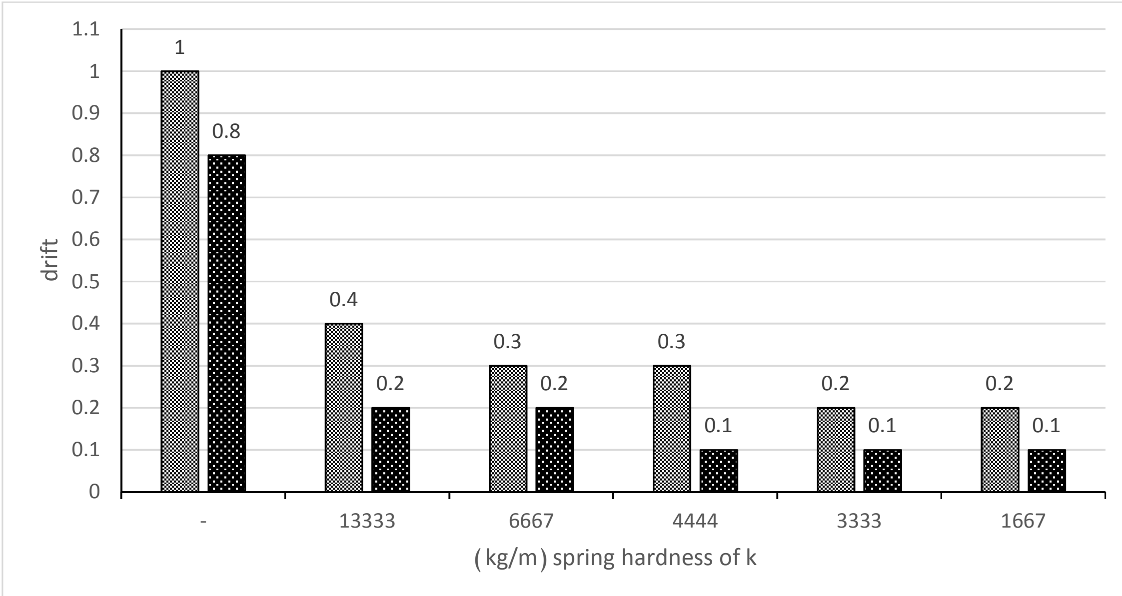

Diagram 5. Drift changes on the first and second floor on the basis of changes in isolator spring hardness

3. **Conclusions**

By comparison between the mentioned table and diagrams, it could be seen if the hardness of isolator springs are between 13333 to 1667 kg/m, so,

1- Bending moment of beam 19 decreases from half to quarter.
2- Axial force of brace 50 decreases from one-third to one- sixth.
3- Axial force of column 2 decreases from one-third to one-eighth.
4- Drift decreases from one-third to one-fifth.

It is suggested that the abbreviation LWRS is used for Lahijan's Wooden Roller Support. It could be concluded that in the isolated buildings, cost of the upper structure is so much less than the common buildings, because forces and moments in the upper structure of the isolated buildings by roller supports are about one-third to one-fourth of forces and moments in the structure of the common buildings.

According to the provided matters, this would be an economic conservation in building industry, and because the cost of preparation and constructing the roller supports (LWRS) is so much lower than elastic isolators, rubber isolators, and friction pendulum or the other types. So, it has economic justification in this area, too. But, roller support or on the other words, roller isolator(LWRS) in addition to significant decreasing in the construction costs of the upper structure, it could be provided easily and with the lowest cost. Therefore, it could be concluded that:

- Traditional buildings stand on the common roller foundation in guilan province and especially in Lahijan is a kind of Base Isolation showed good performance in the great earthquake of guilan.
- Seismic isolator system is an applied method for decreasing financial and body dangers during the earthquake, and LWRS system is not an exception.
- The results of numeral analysis approves the efficiency of the current system in decreasing transmitted acceleration to the structure and its drift.
- By using of the present system (LWRS) and similar ones (with other materials), it is possible to build strong buildings against earthquake by available facilities; or make strong the old buildings by this way.
- It is possible to apply the current system (LWRS) for seismic isolation of rural buildings all over the country and urban buildings up to 4 floors if villagers and people who want to use it get some primary trainings.

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