

SOFT-STOREY BEHAVIOUR IN AN EARTHQUAKE and SAMPLES OF IZMIT-DUZCE

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ABSTRACT

Due to the considerations of occupancy and architectural appearance, especially in the entrance floor and on one of the intermediate levels, inner sections between columns and outer walls are not constructed in the way they are done in other storeys or rigidity of the single structures in the storeys are different. These sections in the buildings are generally used for sales stores, restaurants, bank branches, installations and lightening. These are labelled as soft storeys in literature. Form the studies and investigation of the quake results, it is observed that partitioning walls and beam fillings enable buildings to gain great rigidity. Although irregularities of soft storey have taken place in many construction codes, it is observed that most of the damage constructions suffered result in this kind of irregularities. In the current study the focus, depending on the investigations on soft storeys conducted in quake regions of Izmit and Duzce, was on the investigation of the effect of a soft storey on the behaviour of a construction. Also solutions were investigated for making the soft storeys in the present constructions and in the ones to be built resistant to quake.

KEYWORDS

Earthquake, soft storeys, column, shear wall, wall, irregularities of structure

INTRODUCTION

Once a general investigation of the results of the quakes that occurred so far is conducted, it can be seen that the biggest damage to human beings has always come from weakness buildings. Thus, the most effective way of protection against quakes is not to build resistant constructions. It is only possible to build a resistant construction if we take quakes into consideration at the stages of design, project, construction, and occupancy. There are essential specifications which should be taken into consideration at these stages. These are short column, strong column-weak beam, and torsion. Soft-storey irregularity is one of these. Short storey is an irregularity which should definitely be taken into consideration if the construction is to be a resistant one. It is only possible to build a quake resistant construction if all these irregularities are considered. If structural irregularities are not taken into consideration, a construction can not be said to be a resistant one no matter the highest quality concrete

is used. Just like an illness in one part of the body affects the whole body, so does an irregularity in a constructions. Because a construction is the whole with its ground and its super structure.

Soft storey is the one of which the rigidity is lower than any other storeys due to the fact that it has not got the walls with the same properties the other ones have. If vertical load bearing structural elements and the partitioning wall continue in all the storeys, there is no soft storey in the construction. Soft storeys are generally present at the entrance floors of the buildings. This situation depends on the constructional properties of the cities and countries. If dwellings and trade centers are at the same building, soft storeys are more common, if not, soft storeys are rare. Since dwellings and trade centers are in the same building in general in Turkey, most of the constructions have soft floors. Because entrance floors of the buildings are used as bank branches, stores, restaurants, offices and the upper storeys are used as dwellings. Since the business stores and the dwellings are not the two sections with the same properties, there exist soft storeys. This aspect of construction in Turkey was observed clearly when we investigate the Izmit-quake results of soft storeys. Nearly 85-90 % of the collapsed and damaged buildings had soft storeys in them (Fig.1).

During an earthquake, more moment and shear strength fall on the columns and walls in the entrance floors than the one in the upper storeys. If the walls that exist in other storeys do not exist in the entrance floor, these columns are forced more those in other storeys. Due to the fact that there is less rigidity in soft storeys, the structure is divided into two sections in terms of structural behaviour; the lower and the upper part of the soft storey. This can be called dangerous storey instead of soft storey Figure1.



Figure 1: Damage of Izmit Earthquake (Adapazarı)

It is not so easy for a country to say that no construction would be constructed having no store and offices in them. In order to do this, it would be better to investigate the precautions to be taken. The measure of the growth in construction technology is to build a construction according to the designated place and possibility of a quake. Since no nation would leave its country because of earthquake, it is necessary for that nation to build quake resistant buildings. Building quake resistant constructions is as important as other struggles. Since earthquakes do not respect for country borders, it is a common menace for humanity. For this reason advances in the field of earthquake studies should be presented to every individual.

This study covers the studies that were conducted in the quake area of Izmit ($M_w=7.4$ and August, 17, 1999) and Duzce ($M_w= 7.2$ and November, 12, 1999). As a result of this investigation and according to the studies in literature, drawbacks of soft storeys and stages of preventing are covered.

QUAKE BEHAVIOUR OF THE CONSTRUCTION WITH SOFT STOREYS

Symmetrical constructions in both plan and height show a better resistance during an earthquake than those that do not have this symmetry. Since the presence of a soft storey which has less rigidity than other storeys spoils the perpendicular symmetry of the construction, and if this fact was not taken into consideration, it causes the construction to be affected by the quake. Because the columns in this part are forced by the quake more than the ones in the other parts of the building. studies conducted suggest that walls increase the rigidity at a certain degree in the construction (1). Turkish Code of Earthquake accepted this ratio as 15 %. That is to say, there is 15 % difference of rigidity between a storey with walls and the one without any walls.

A construction is divided into two parts from the point where there is a soft storey (Fig.2). Of the constructions with equal rigidity between the storeys, the displacement of the peak points at the moment of a quake causes the other building with a soft storey to get damaged because the construction with a soft storey can not show the same rigidity (Fig.2). For example the top point of a ten-storey building with no soft storey performs 3 cm displacement, another building with the same specification but having a soft storey at the entrance floor and with no necessary precaution can show the same displacement 3 cm at this floor. according to this result, a soft storey in upper storeys of the building is not so effective. Quake damages investigated verify this conclusion. U is displacements.

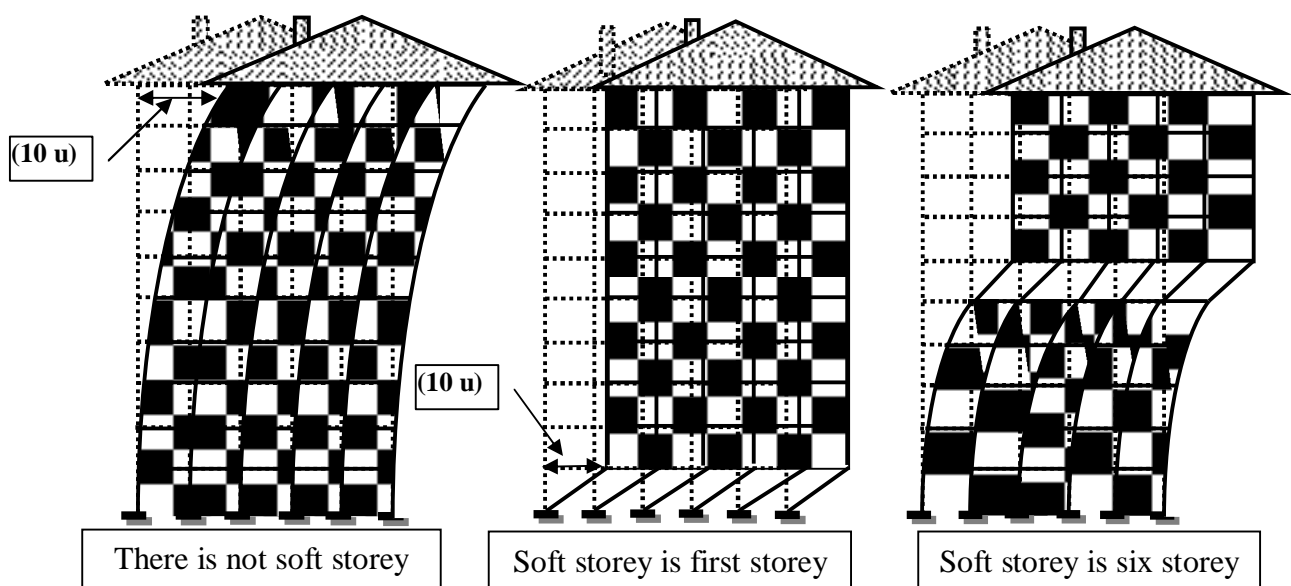


Figure 2: Behaviour of soft storeys to Earthquake

Since soft storeys affect in great extend the behaviour of the buildings during a quake, this fact is given detailed place in Codes of Earthquakes Table1. Despite all this, still most of the constructions damaged suffer from this irregularity (Fig.3-4). As a result of investigation on this and other irregularities, it was observed that Codes of Earthquake are not sufficient, especially in Turkey. For this reason, it comes into forefront that it is necessary for these irregularities to be controlled at the stage of project and construction. It should be known that controlling is one stage in building quake-resistant constructions, and it should be applied.



Figure 3: Damage of Izmit earthquake (Adapazarı)

TABLE 1
SOFT STOREY IRREGULARITIES

COUNTARY	DATE	SOFT STOREY
U.S (UCB)	1994	A
China	1989	A
Eurocode 8	1994	A
ISO 3010	1988	A
Japan	1991	A
Canada	1995	A
NEHRP	1991	A
TÜRKİYE	1997	A
New Zeland	1992	A



Figure 4: Damage to soft storey of Izmit Earthquake (Yalova-Gölcük)

Soft storeys in constructions came into being in two ways:

1. Columns, shears and walls showing difference between storeys (fig.5.a)
2. Rigidity between the storeys of the construction being different, resulting grater displacements (fig.5.b)

At the stage of projecting a structure, certain solutions should be worked out as regards the quake region, importance and the function of the building, and irregularities should be eliminated. it can not be said that storeys being constructed with the same physical properties are not soft storeys. For this two kinds of control should be carried out. The ratio of number of columns, shears, and walls on one storey of the building parallel to the quake to the ones on the other storeys (SS). The ideal ratio is 1 (Eqn.1). But, as it is not always possible to materialise this, this ratio can be taken less than 1. This ratio is taken as 0.80 in Turkish Code of Earthquake. when this ratio is lower, additional precautions should be taken or the design of the building should be reviewed. In case the soft storey irregularities are on the entrance floor, this ratio should be 0.8-0.9, according to the importance of the construction. This ratio being bigger than one brings irregularities to the construction. For this reason, this ratio should be analyzed well at the stage of design. This does not necessarily mean that the construction would not be built with a certain desired appearance or it would not involve stores on the first storey.

Taking necessary precaution, this ratio should be brought to the desired level. Otherwise, the construction could undergo damage due to these irregularities. Total ratio of irregularity as the total of ΣA_c = total area of cross sections of shear and column at one storey taken in the parallel direction to the quake and ΣA_w = total area of beam fillings (spaces of doors and windows excluded) at any storey taken in the parallel direction to the quake (SS) is calculated as follows:

$$SS = \frac{(\sum S)_i}{(\sum S)_{i+1}} \quad (SS = SA_c + 0.15 SA_w) \quad (1)$$

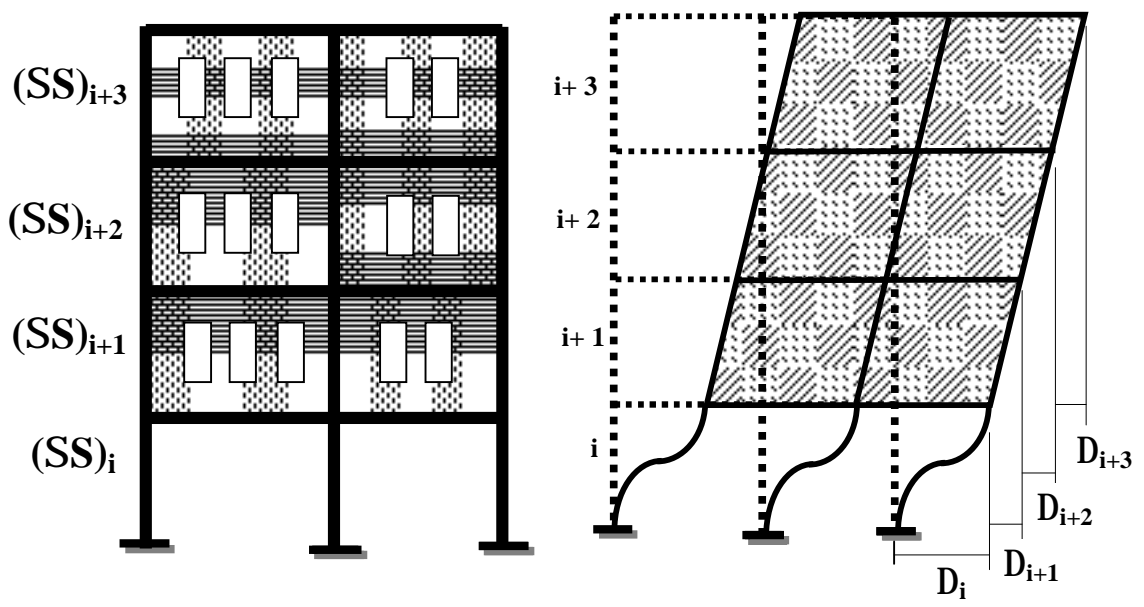


Figure 5: Soft storeys

According to the results of the studies, the maximum displacement of the structure is approximately 0.0035 the height of the construction Tezcan (1998). What is important as regards the storeys is the displacement of the storeys in relation to each other (Eqn.2). The ratio R will automatically provide the displacement of the construction when displacement ratio between the storeys is restricted. What is important in a structure is the ratio of displacement between the storeys. Displacement of the whole construction is important as regards its pounding with the other. Displacement differences between storeys being equal among all the storeys is important in that the whole building works as a whole during a quake. Otherwise, the building undergoes damage at storeys where the displacement is different than the others (R). These are also considered as soft floors. What is ideal is that the construction should perform a great displacement as a plastic building. Because the amount of energy a construction absorbs during a quake is proportional to the property of the construction to perform displacement. Most of the studies undertaken in the field of civil engineering is in this direction. Δ_1 is the average transition of the storey I and Δ_{i+1} is the average transition of the storey i+1, so the irregularity of the soft storey is as follows:

$$R = \frac{\Delta_i}{\Delta_{i+1}} \quad (2)$$

Being $R=1$ shows that the construction is ductile and there is no difference between the storeys, that is the construction is elastic. But in practice, a construction can not be expected to show such a behaviour. Because concrete is brittle material. for this reason, this ratio can not be taken greater than 1.5. If the ratio of SS was well determined, it would be easier to obtain the ratio of R.

PREVENTING SOFT STOREY IRREGULARITIES

In constructions where it is necessary to build a soft storey, lateral rigidity of this particular storey should be brought to the rigidity level of the other storeys. To be able to do this, the number of columns and shear walls should be increased. Because of this increase, longitudinal and lateral reinforcement should also be increased. These raise the cost of the construction. Soft storey is an irregularity which affects the behaviour of a construction during a quake and also increases the construction costs. For this reason, soft storeys should be avoided as much as possible. In case it is necessary, by the controls to be performed as a result of calculation made, irregularities can be eliminated as follows:

1. Building additional walls (Fig.6.a)
2. Increasing the rigidity of the columns and the shear walls on the soft storey (Fig.6.b)
3. Regulating the dimensions of the columns and shear walls by longitudinal and lateral reinforcement so that the soft floor would show a ductile behaviour (Fig.6.c)
4. Preventing cracking by placing the wall at a certain distance from columns and walls that are on the soft storey (Fig.6.d)

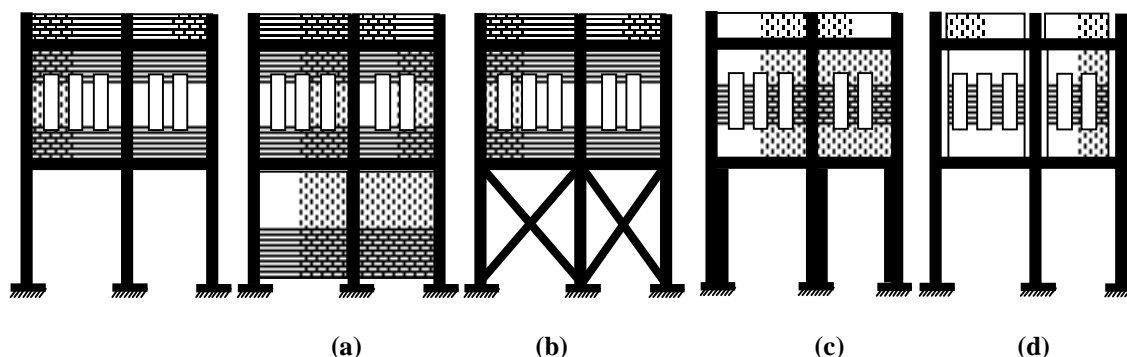


Figure 6: Methods of preventing soft storey irregularities

Now that we can not leave the already present buildings, we should turn them into resisting ones according to the new Code of Earthquake. since the codes and regulations are changed as a result of technological advances and examination of the quake results, those constructions which are considered resistant according to the previous regulations can be weakness according to the new regulations. To be able to do this, present irregularities should be eliminated. Upon investigation in the quake region, it was observed that constructions built in accordance with the previous Code of Earthquake (1975) underwent greater damage, and those built in accordance with the new Code (1998) underwent less damage, and some did not even undergo any damage. to bring the present buildings into resistant state of being, proper one of the following method is applied:

1. Increasing the lateral rigidity of this storey by putting up additional walls between single structural elements on the soft storey
2. Increasing the lateral rigidity of this storey by placing steel diagonals between the columns and shear walls

3. Putting flexible material between columns and walls on the storey atop the soft storey thus preventing it to work together with the soft storey
4. Increasing the rigidity of the soft storey by reinforcing the columns of the soft storey.

CONCLUSION

1. Since the behaviour of the soft storey is very different during a quake, the construction undergoes damage and it increases costs. For this reason, in regions where the risk of quake is high, we should not produce soft storeys, if necessary, quake controls should be done starting from design stage through the stage of occupancy.
2. Present soft storeys should be examined and if necessary, should be reinforced.
3. Ratios of soft storey irregularities should be taken as $SS > 0.8-9$ and $R > 1.5$.
4. Soft storey irregularities should be applicable in Regulations (Codes of Earthquake) and should be explained so that it would have the power of sanction.
5. Results of previous quakes, as in other subjects, should be examined in detail so that they would shed light to future studies.

References

1. Specification for Structures to be Built in Disaster Areas (1998). Ministry of Public Works and Settlement Government of Republic of Turkey (Turkish)
2. Tezcan, S.S., (1998). "The Design of High Strength Building Against The Earthquake Same Notice of Architecture", Turkish Earthquake Foundation (TDV), KT/ 98-24, pp 34-40.
3. (1997) Turkish Earthquake Resistant Design Code for Buildings
4. Earthquake Resistant Regulation- A World List (1992). International Association for Earthquake Engineering, Tokyo