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A Rational Seismic Design Method of Wall Framed Buildings Using Reinforcement Quantity Control Method

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ABSTRACT

Improper seismic design of buildings can lead to collapse and severe damage due to natural and unpredictable earthquake loads. Based on a comprehensive analysis of the effect of the quantity of reinforcement of the frame to the plastic hinge formation of the building at wall frame buildings, this paper proposes a rational seismic design method for the wall frame building by means of the reinforcement control method to protect the lives and property of the people and ensure the seismic stability of the building.

Keywords: control method, seismic, wall frame

1 Introduction

The wall frame building is one of the high-rise building structural systems currently many used in construction. In the design of seismic structures of wall frame buildings, it is essential to use vibration mode decomposition response spectrum method (linear dynamic analysis) [1], especially for irregular buildings or high-rise buildings, they perform additional calculations under small earthquake action by time course analysis method and perform elasto-plastic analysis(push-over) to examine whether the displacement of buildings does not exceed under large earthquake action the limit displacement or it does not collapse before the displacement is exceeded [2].

In the design of reinforced concrete structures section, redistribute internal force of until 30% at large internal force place [3], the reinforcement is reinforcing with that value. In occasion increase building to form of wrap structure, a method was investigated of consider the redistribution of the internal force of wall branches and reduction of the internal force [4], by reducing the stiffness of the tie beam because the internal force is concentrated in the wall-tie beam (beam of opening) with a high stiffness.

In several countries of the world, there are research and analysis deeply about plastic deformation and demolition process of reinforced concrete frames, and considered detailed behavior in regard to plastic phenomena and damage of frames by calculating beam finite element formulas using multilayer meth od that subdivide, the distribution state of vertical stress in thickness direction [5].

The result calculated by introduced finite element formula about several objects agree well with experimentation result was showed.

In addition, vibration analysis was carried out on the basis of the Iranian, Turkish and Canadian seismic criteria for small and multi-story buildings with different ductility, and the importance of the definition of plastic hinge properties was clearly confirmed. In here, the result of the push-over analysis using hinges which be defined the numerically of the nonlinear properties of plastic hinges and the basic properties of reinforced concrete elements presented in the applications, the definition of plastic hinge properties is important in the performance evaluation of reinforced concrete frames, especially we obtained conclusion which must use hinge defined on the basis of the material applied to the structure and the details of the reinforcement and the detailed properties of the axial loads [6].

However, it has not been studied that the change in the amount of reinforcement in the frame affects the plastic hinge occurrence and character.

In this paper, it was newly found that the change in the amount of reinforcement in the frame is sensitive to the occurrence course of plastic hinges, and we apply rational seismic design method that controls the plastic hinge occurrence and its characteristics by means of the control method of the amount of reinforcement to economize the reinforcement and ensure the seismic stability of the building.

2 Design By Means of Reinforcement Quantity Control Method

In this paper progress an analysis and diagnosis of a small-scale five-story building for convenience sake.

Figure 1 shows the typical floor plan of the building.

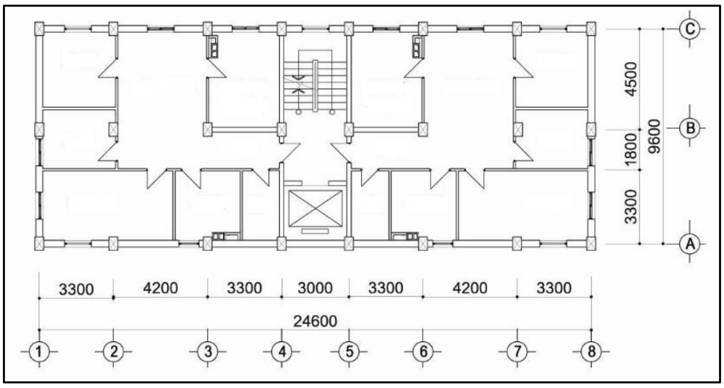

Figure 1 Typical floor plan

Figure 2 shows the arrangement plan of frame for seismic calculation.

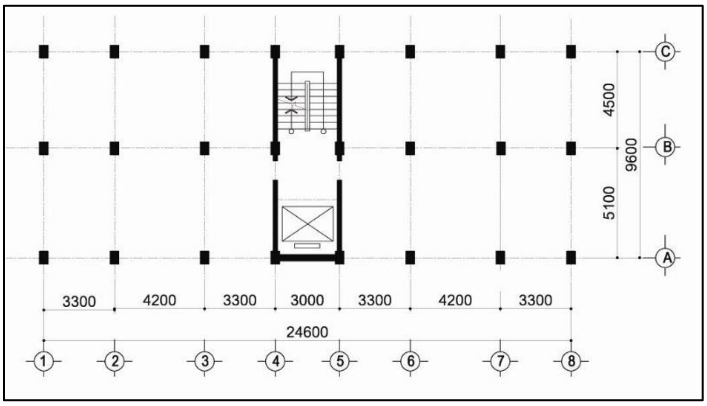

Figure 2 Arrangement plan of frame

Figure 3 shows the analytical model of the structure for seismic calculation.

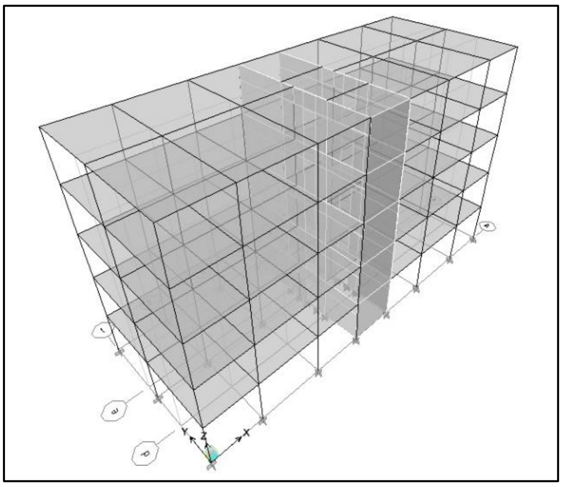

Figure 3 Analytical model of the structure

After the analysis, the columns of all layers were arranged with a symmetrical reinforcement of 3Φ25 mm by the maximum moment at principle of strong column-weak beam, the beams were arranged with 2Φ20 mm of top and bottom reinforcement in beams 9 and 10 connected to the walls of the staircase with the highest moment, and the remaining beams were all reinforced with 2Φ16 mm.

In the past, the design was finished as this.

In the Pushover analysis, when the vertical load is gradually increased, the yielding phenomenon (plastic hinge formation) occurs gradually in the structural elements.

Figure 4 shows the behavior of the structure due to plastic hinge formation in beams and columns.

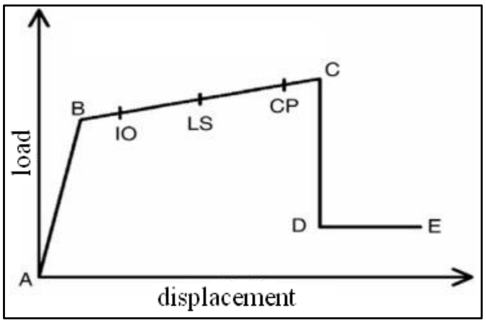

Figure 4 Load-displacement curve

The results of the push-over analysis show that the plastic hinge occurs first in the 1-story corner beam 4 and it, belongs to point B (indication by pink), so the hinge is in an elastic state.

Figure 5 shows the occurrence of the first plastic hinge.

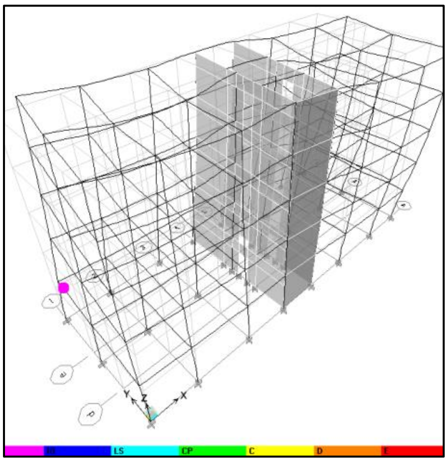

Figure 5 Occurrence of the first plastic hinge

As the vertical load gradually increases, at the second step from the beams of lower story to the beams of upper story the plastic hinge was enlarged, and the plastic hinge of point B occurred at the bottom of the 2.3.6.7 axis 1-story column on the c-axis.

As the third step, the plastic hinge extends further from the beams of lower story to the beams of upper story, and the plastic hinge of point B occurs more at the bottom part of several columns of the 1- story.

As the fourth step, a plastic hinge in the normal use point IO(Immediate Occupancy) point (Indicated by blue) was occurred in beams of 1~ 2 story of one-axis and eight-axis which are corner axes, so that the normal use of the structure is possible, a slight repair of the non-structural member should proceed at this state.

In the fifth and sixth stages, the plastic hinge in the beam continues to expand to the upper layer, and that of the IO point also expands as the upper layer.

In the seventh stage, a plastic hinge at the normal use point of the LS (Life Safety) point (Indicated in blue) occurred in beams of 1~ 2 -story of one-axis and eight-axis which are corner axes, that the structure is safe but repair should proceed.

Afterwards, the plastic hinge of the LS point is enlarged in the next two stages, but the plastic hinge of the CP (Collapse Prevention) point (Indicated in green) does not occur, so the building does not collapse.

Figure 6 shows the occurrence of plastic hinges in the final stage.

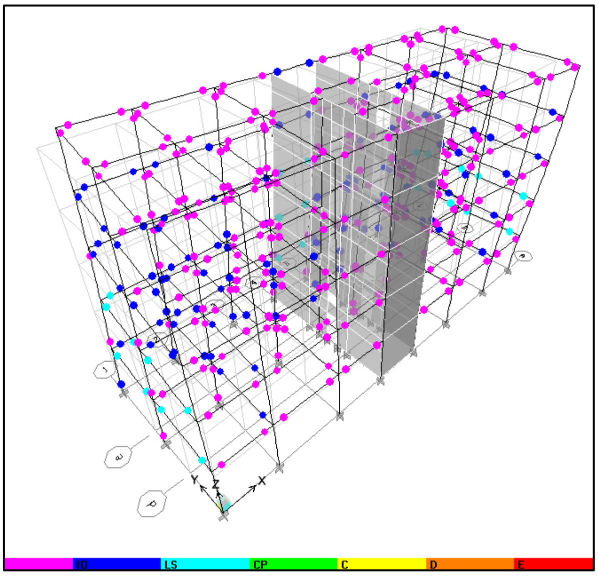

Figure 6 Occurrence of plastic hinges in the final stage

The results of the push-over analysis not only show the occurrence and destruction state of plastic hinges as above, but also be obtained in the form of capacity spectrum curve and demand spectrum curve.

Figure 7 shows the push-over curve.

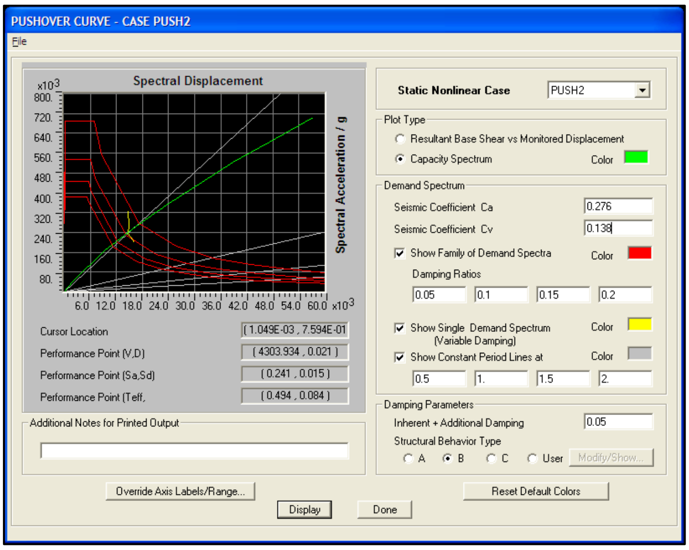

Figure 7 Push-over curve

Since the capacity spectrum curve pass the demand spectrum curve, the seismicity of the building is estimated to be safe. The intersection point of capacity spectrum curve and demand spectrum curve is called the performance point. If the performance point is close to the elastic range, the structure is stable and has good resistance with sufficient strength.

If the performance point is beyond the linear range, due to the seismic load occurring in the structure without remaining sufficient strength, the behavior becomes unstable. The analysis about performance of the structure in terms of performance points can be performed simultaneously with parameters such as maximum base shear force, maximum axial displacement, period, damping coefficient, acceleration spectrum and displacement spectrum.

Now, if the top and bottom reinforcing bars of beams 9 and 10 with the largest moment are replaced by 2Φ16 mm, and the Pushover analysis, is performed then the first plastic hinge occurs in beam 9 connected to the staircase wall with the largest moment.

Figure 8 shows the occurrence of the first plastic hinge in this case.

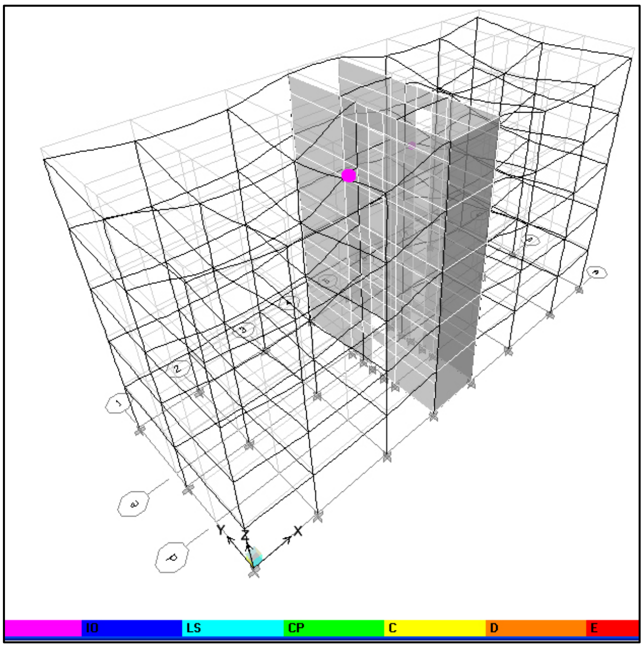

Figure 8 Occurrence of the first plastic hinge

Since this plastic hinge also belongs to point B, the hinge is in an elastic state.

Here, we can ascertain the whole process from the occurrence of plastic hinges to the failure of the structure, and can obtain conclusion that the change of the amount of reinforcement is sensitive to the occurrence of plastic hinges.

Thus, if we control the amount of reinforcement in the frame, we can control the occurrence of plastic hinges, and finally the demolition state of the structure can be controlled by the designer.

The basic key point of the seismic design method by the reinforcement quantity control method is not to finish the design by calculating the reinforcement quantity by the seismic force after seismic analysis, be perform the push-over analysis, and then looking at the occurrence course of the plastic hinges and its characteristic, is the method to find a reasonable design to avoid great damage and sudden collapse in the structure by controlling the reinforcement quantity.

Figure 9 shows the flow diagram of the seismic design method by the reinforcement quantity control method.

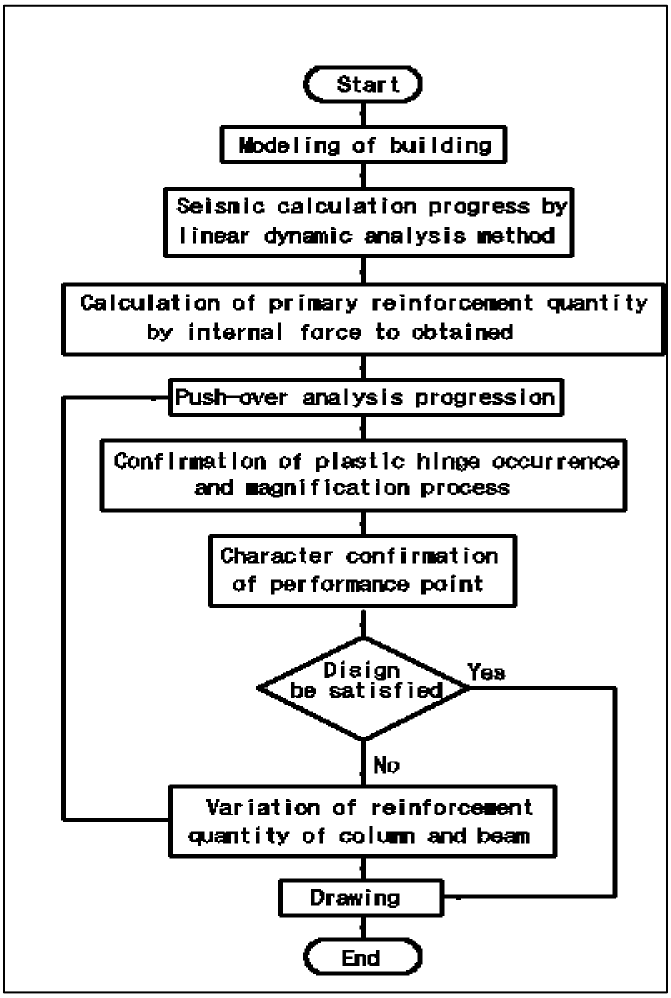

Figure 9 Flow diagram of the seismic design method

In the example project, the replacement of 1 and 2 story column reinforcements from 3 Φ25 mm to 3 Φ28 mm by controlling the amount of primary reinforcements, makes a plastic hinge occur in the third stage, instead of occurring at at point B in the bottom part of the 1 story column in the second stage.

Now, if the reinforcement quantity of 3~5 story column is changed from 3 Φ25 mm to 3Φ20 mm or 3Φ16 mm, the plastic hinge also occurs in the third stage at the bottom part of the 1 story column.

When the five-story column reinforcement quantity is replaced by 3Φ14 mm, the reinforcing bars of this stage are selected as the final reinforcement quantity, since plastic hinges are also generated in the third stage at the bottom part of the one-story column.

Thus, reinforcement quantity control method can achieve a better seismic stability with a 13% reduction in reinforcement in columns than in the original design.

The reinforcement quantity control is reasonable where weak layers, weak parts, or internal force are concentrated, and the column reinforcement is effective to reduce where go up to upwards.

According to the design experience, where in wall-framed buildings, there is occur phenomenon of sudden increase of moment at the beam end in the following cases: (1) Beams connected to a rigid wall; (2) A shopping network is planned on the bottom floor and there is no rigid wall on the 1~2 –stories, there occur rigid wall from the three story, in this case, beams established to columns of the 1~2 -stories and rigid wall of bottom story; (3) At rigid walls with narrow width and high height because induce large forced deformation in the top story frame due to bending deflection in the top story, beams established on top stories in high story buildings, etc.

Therefore, it's rationalistic to control the reinforcement quantity first in such beams.

Reinforcement quantity control method proceed in condition the modeling of the building is completed for seismic analysis, so the process of the reinforcement quantity control and push-over analysis does not consume much work and time.

3 Conclusions

In this paper, see simultaneously the whole process from the occurrence of plastic hinges to the failure of structures, and push-over curve, and parameters such as maximum base shear force, maximum axial displacement, period, damping coefficient, acceleration spectrum and displacement spectrum as characteristics of performance point, by controlling reinforcement quantity can ensure the seismic stability of the building as well as to reduce the quantity of reinforcement.

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