Seismic performance analysis of new frame columns in a story-adding frame structure

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Abstract. With the rapid development of urbanization in China, the old urban buildings in many cities are facing the problem of weakening function. There are broad prospects for floor-adding renovation and expansion of in-service houses. In this paper, based on the background of the actual project, the direct floor-adding scheme is adopted to design the existing buildings after the reliability evaluation. The key point of the floor-adding reconstruction and expansion is whether the new part can be reliably connected with the old structure. In view of this weak link, this paper makes a further study on the seismic performance of new frame column members with different anchorage depth, which provides a certain guiding significance for the design and construction of story-adding reconstruction and expansion.

1. Introduction
At present, the general direction of China's capital construction has entered a period in which new houses go hand in hand with maintenance and renovation of existing houses [1], and the market for the renovation of old houses has great potential and broad prospects. Due to the inadequacy of early urban planning, with the increasing development of urban economy and the continuous promotion of the process of urbanization [2], the city is facing the development of re-planning and design. The treatment of the old urban areas has become a problem that can not be avoided in the development of every city. We should actively face it, treat it scientifically, base on the reality, and carry out the transformation and expansion of the qualified in-service houses is the wise move. In this paper, the weak links of story-adding reconstruction and expansion are studied, and the seismic performance of frame column members with different anchorage depth is studied by ABAQUS.

2. General situation and scheme analysis of story-adding reconstruction of a frame structure
The project is located in the central district of Jinan City, the school was completed in 2009. The floor and roof of the building are cast-in-place reinforced concrete slabs and reinforced concrete frame structures. The filling wall is autoclaved block, and the concrete strength grade is C30. The outer wall is 200 mm thick and the inner wall is 120 mm thick. Now, due to the functional requirements, it is proposed to add an overall floor on the basis of the original comprehensive building, with a height of 3.9m. According to the reliability evaluation of the comprehensive building [3-4] and the bearing capacity of the foundation, it is decided to adopt the scheme of direct floor addition, and to build an overall floor directly on the basis of the existing comprehensive building. The reliable anchorage connection of new and old frame columns is the top priority, and it is the key to ensure that part of the
new load is effectively transferred to the original structure or even the foundation. For the connection of new and old frame columns, the method of chemical drilling and planting steel bar is adopted.

3. Finite element simulation analysis

Anchorage depth of planting steel bar, Condition 1 $h_1=450$ mm (Calculated according to the standard); Condition 2 $h_2=350$mm; Condition 3 $h_3$-The anchoring depth of six steel bars is 450mm, and the anchoring depth of the remaining two steel bars is 350mm.

3.1. Hysteretic curve analysis

In the first several stages of loading, the slope of the overall hysteretic curve [5] of the frame column increases rapidly under various conditions, and the column is in the stage of elastic stress. With the increase of the load, the slope of the hysteretic curve decreases, the overall trend decreases, the plastic deformation occurs, and the residual deformation increases gradually. When the curve load reaches its peak and begins to enter the descending stage, all levels of co-directional loading curves are compared. the slope of the latter is less than that of the previous one, indicating that the stiffness of frame column members has been degraded to varying degrees under repeated loading. After the load reaches a certain value, the corresponding residual deformation will occur after the unloading, that is, the load is zero and the deformation is not equal to zero and increases gradually after each cycle, and the recovery deformation lag occurs.

Compared with the three conditions, it can be seen intuitively: when the horizontal displacement of the top of the frame column is in 60mm, the frame column in condition 1 can continue to bear a certain degree of load, but the frame column in condition 2 tends to be completely destroyed. When bearing forward loading, the peak load of condition 2 is 132.7KN, and that of condition 3 is 133.1KN. When the horizontal displacement of the top of frame column reaches 60 mm, the load bearing capacity of frame column of condition 3 is obviously better than that of condition 2. The anchorage depth of steel bar planting in condition 3 is more complex, which is also a common phenomenon in normal construction. By observing the hysteretic curve of condition 3, it can be seen that the local
trend of the hysteretic curve is messy, and there is no relative law of condition 1 and 2, which is due to the difference in the depth of steel bar planting in the three conditions. From the hysteretic curves of condition 1, condition 2 and condition 3, the seismic energy dissipation performance of condition 1 is the best, followed by condition 3, and condition 2 is the worst.

3.2. Skeleton curve analysis

![Skeleton curve under three conditions](image)

Compared with the skeleton curves of condition 1 and condition 3, in the forward loading stage, the two tend to be consistent; in the reverse loading process, condition 1 is better than condition 3, but there is little difference between the two. From the trend of the skeleton curve, the load bearing capacity and the size of deformation, the working condition 1 is the best, the third is the second, and the second is the worst.

3.3. Strength attenuation analysis

Strength attenuation refers to the phenomenon that the strength of members decreases with the increase of the number of load cycles under cyclic loading. The strength attenuation degree of members can reflect the seismic performance of members, and the bearing capacity degradation coefficient $\lambda$ is usually used to evaluate the strength attenuation of members. Do not calculate the bearing capacity degradation coefficient of frame columns at partial displacement under three conditions, the specific results are shown in Table 1.

| conditions | 6mm | 12mm | 18mm | 24mm | 36mm | 48mm |
|-----------|-----|------|------|------|------|------|
| Condition 1 | 1.07 | 1.04 | 0.95 | 0.96 | 0.98 | 0.95 |
| Condition 2 | 1.05 | 1.00 | 0.96 | 0.95 | 0.94 | 0.87 |
| Condition 3 | 1.06 | 1.02 | 0.96 | 0.97 | 0.98 | 0.91 |

Comparing the data of three working conditions, the strength attenuation of condition 1 is obviously better than that of condition 3, and that of condition 3 is better than that of condition 2, indicating that the sufficient depth of planting steel bar can obviously resist the strength attenuation of frame columns and increase the seismic performance of members.

4. Conclusion

In this paper, the hysteretic curve, skeleton curve and strength attenuation of frame column members with different anchorage depth are studied by ABAQUS. It can be concluded that it is necessary to ensure the sufficient depth of steel bar planting at the joint surface of new and old concrete (condition 1) in order to ensure the seismic performance of the members at the weak layer of the joint surface. If it is particularly difficult to plant steel bars in individual areas, it can be compared with the third condition in the construction environment, and the prescribed depth must be reached in the area where the member reinforcement can reach the required depth of steel bar planting. It is preliminarily
estimated that the anchorage depth in the area accounts for more than 75% of the total number of steel bars planted in the code, which can achieve good results. Then, when the conditions are available, another steel bar is planted around the depth area that can not meet the requirements to bear the load. The planting and anchoring of steel bars similar to the second condition is avoided in the process of construction.

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