Influences of Construction of Balcony Structural Column on Internal Force of Frame Structure

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Abstract. Balcony structural column is constructed as a secondary structure traditionally. Not only the construction process is complicated, but also the construction quality is erratic, which results in a large number of repairs and costs. On the other hand, the concurrent method that balcony structural column and main structure are constructed as a whole structure is more convenient for operation and benefit for the construction quality. Therefore, influences of construction technique of balcony structural column on the internal force of frame structure deserve investigation and analysis. Through comparative analysis of Construction Process and selection of a frame structure model calculation and analysis, balcony structural column and main structure are constructed as a whole structure of the useful results. Through analysis, find out synchronous construction is more conducive to improve project construction quality, more convenient construction operation.

Keywords: Balcony structural column; Construction technique; Frame structure; Calculation of internal force.

1. Introduction
O.S.AlAjarmeh[1] many experimental studies have been conducted to investigate the behavior of hollow concrete structural columns under different loading conditions. And yet, hollow structural column and the use of structural column is different. Non-bearing concrete structures in frame, shear wall and frame-shear wall construction are called secondary structures, which are components usually constructed after demoulding of the main frame concrete or parts attached in the masonry project for aseismic design such as structural columns. According to CODE FOR DESIGN OF MASONRY STRUCTURE GB 50003-2011, constructional columns should be set when there is no frame column at the corner of wall. Balcony structural column is one of constructional columns constructed as a secondary structure traditionally, which needs another casting after demoulding of the main structure. At present, the cost of construction of structural columns is high and the quality is erratic.[2]. Because of the narrow construction area of balcony, there is a high security risk for the workers to conduct secondary construction. On the contrary, the method that balcony structural column and main structure are constructed as a whole structure can not only simplify the construction process but also ensure the construction quality. Also, the construction pollutants can be reduced effectively to achieve an environment-orientated construction with significant social benefits [3]. Therefore, influences of construction technique of balcony structural column on the internal force of frame structure deserve investigation and analysis.
2. Construction Process
The traditional concrete constructional column is constructed according to the principle of secondary structure, which does not increase the load and change the stress state of the structure. The main structure of the frame is constructed first, and the constructional column is constructed after the deformation and settlement of the main structure is stabilized[4]. In the construction of frame structure, the steel bar of Constructional column can be embedded or planted, and then connected. Constructional column concrete of frame structure adopts layered casting schedule. The treatment method of forming a flexible connection between the bottom of the beam and the frame beam is that the constructional column of each floor must be left a certain distance (5 ~ 10mm) with upper balcony beam bottom when concrete is poured. The flexible filling connection adopts elastic materials such as foamed rubber.

The integral cast-in-place Constructional column refers to synchronous pouring construction for Constructional column and main structure, synchronous setting-up formwork for the constructional column and the external cantilever beam plate of the main balcony, and synchronous installing Steel Bar of the Constructional column. The elastic material such as foam plate is placed at the base of the column to set up a flexible cushion, and this will not form a rigid fulcrum on the cantilever free end. The 500mm steel bar reserved of the constructional column connected with the lapped reinforced skeleton of the Constructional column [5]. The formwork of the Constructional column and the beam-slab member of the main structure are designed and strengthened synchronously to ensure that the formwork does not rise and the slurry does not leak when the concrete is poured into the constructional column. When pouring concrete synchronously, pay attention to the accuracy of the reserved position of column reinforcement, and the deviation found should be corrected in time. When the concrete strength of the main structure reaches the design strength, the formwork of the balcony constructional column shall be removed together with the top formwork of the balcony beam plate component [6].

In the construction of Constructional column, to adopt fixed reinforcement can obviously reduce the occurrence rate of problems in masonry construction, to ensure the construction quality of masonry structure, to save cost, to reduce rework and treatment cost. The fixed short reinforcement which are used in Stereotyped pull reinforcement is wasted material, which can make full use of the wasted material produced by the processing of steel bar and meets the requirements of re-use the green construction waste material, and saves the cost and bring the economic benefit [7-10].

Comparison of the two construction processes is shown in figure 1.

![Figure 1. Comparison chart of construction process flow.](image)
3. Calculation of Internal Force

3.1. Computational Model

To select the cantilevered balcony with no constructional column and with constructional column, and the balcony with constructional column is divided into two cases: primary structural treatment and secondary structural treatment. In order to facilitate the comparative analysis, the 10-story frame structure is chosen as the mechanical calculation model, the first floor height of 4.2 meters, the standard floor height of 3 meters, 1.5 meters cantilevered balcony, 6 meters within the span. C30 concrete is used in the frame structure. The elastic modulus, section size and load information of the concrete are given in Table 1.

| Specimen | B [m] | H [m] | L [m] | E [Pa] | I [m²] | A [m²] | EI [N·m²] | EA [N] | Concentrated Force [N] | Line Load [N/m] |
|----------|------|------|------|------|------|------|--------|------|----------------|-------------|
| Frame column | 0.40 | 0.5 | 3 | 3.0E+1 | 0.00416 | 0.20 | 1.25E+0 | 6.00E+0 | 75000 |   |
| Frame beam | 0.30 | 0.5 | 0 | 3.0E+1 | 0.00312 | 0.15 | 9.38E+0 | 4.50E+0 | 0 | 18750 |
| Cantilever beam | 0.30 | 0.5 | 0 | 3.0E+1 | 0.00312 | 0.15 | 9.38E+0 | 4.50E+0 | 0 | 18750 |
| Structural column | 0.24 | 0.2 | 4 | 3 | 3.0E+1 | 0.00027 | 0.05 | 8.29E+0 | 1.73E+0 | 21600 | 0 |

In the table 1, B, H and L represent the cross-sectional dimension width, height and length of the member. E represents the elastic modulus of the concrete member, I represents the area moment inertia, A represents the cross-sectional area.

3.2. Computational Diagram

In order to facilitate the comparative analysis, two kinds of constructional column construction are set. 1. Traditional cast-in-place structural column and 2. Integral cast-in-place structural column. The traditional constructional column is constructed according to secondary structure treatment, and the column top and the bottom of the cantilever beam are calculated according to the hinge joint. Integral cast-in-place Constructional column refers to pouring the balcony constructional column and the main structure at the same time, which is constructed according to one-time structure. The top and top of the constructional column are calculated according to the rigid connection, and the base of the constructional column is treated as the flexible connection. As shown in figure 2.
4. Comparative Analysis of Results

According to the static load method and the traditional constructional column and cast-in-place constructional column, the axial, shear force and bending moment of the frame structure are calculated. This paper mainly compares and analyzes the internal forces of the joint position of the constructional column in the balcony.

To select the internal force data output of the balcony column, the 41-49 units correspond to the two-stories column and the ten-stories column respectively. See tables 2 and 3.

Table 2. Internal force data of traditional constructional column (Internal force at rod end)  

| Unit Code | Axial Diagram [KN] | Shear Diagram [KN] | Moment Diagram [KN.m] | Axial Diagram [KN] | Shear Diagram [KN] | Moment Diagram [KN.m] |
|-----------|---------------------|--------------------|-----------------------|---------------------|--------------------|-----------------------|
| 41        | -74.6876120         | 3.29033907         | -9.87101721           | -74.6876120         | 3.29033907         | 0.00000000            |
| 42        | -110.173112         | 2.01740601         | -6.05221804           | -110.173112         | 2.01740601         | 0.00000000            |
| 43        | -122.692198         | 1.27574431         | -3.82723292           | -122.692198         | 1.27574431         | 0.00000000            |
| 44        | -120.808574         | 0.78049052         | -2.3417155            | -120.808574         | 0.78049052         | 0.00000000            |
| 45        | -108.638675         | 0.42615476         | -1.27846427           | -108.638675         | 0.42615476         | 0.00000000            |
| 46        | -89.1277140         | 0.17198166         | -0.51594497           | -89.1277140         | 0.17198166         | 0.00000000            |
| 47        | -64.3616039         | -0.00915257        | 0.02745770            | -64.3616039         | -0.00915257        | 0.00000000            |
| 48        | -36.2767075         | -0.13551049        | 0.40653147            | -36.2767075         | -0.13551049        | 0.00000000            |
| 49        | -2.78509857         | -0.97792309        | 1.49773511            | -2.78509857         | -0.97792309        | -1.43603416           |
Table 3. Internal Force data of cast-in-place Constructional column (Internal force at rod end) (Multiplier = 1).

| Rod end 1 | Rod end 2 |
|-----------|-----------|
| Unit Code | Axial Diagram [KN] | Shear Diagram [KN] | Moment Diagram [KN.m] | Axial Diagram [KN] | Shear Diagram [KN] | Moment Diagram [KN.m] |
| 41        | -73.4132600 | 8.57190508 | -14.4842848 | 8.57190508 | 11.2314304 |
| 42        | -113.698402 | 4.53175621 | -7.71933834 | -113.698402 | 5.87593027 |
| 43        | -127.426313 | 2.71032730 | -4.71675961 | -127.426313 | 3.4122229 |
| 44        | -125.592832 | 1.49926906 | -2.71206975 | -125.592832 | 1.78573742 |
| 45        | -112.923411 | 0.64623813 | -1.29694488 | -112.923411 | 0.64176952 |
| 46        | -92.6089875 | 0.04269271 | -0.29442538 | -92.6089875 | -0.16634725 |
| 47        | -66.865889 | -0.37282426 | 0.40433931 | -66.865889 | -0.71413347 |
| 48        | -37.6146716 | -0.72634899 | 0.96028680 | -37.6146716 | -1.21876018 |
| 49        | -3.02362251 | -0.96877566 | 1.46836429 | -3.02362251 | -1.43796268 |

Figure 3 Comparison of internal forces between traditional secondary pouring and integral cast-in-place pouring of balcony structural column.

As can be seen from Fig. 3, to a certain extent, the state force of the component in the whole cast-in-place process is slightly larger than that in the traditional secondary casting process, while the shear force and bending moment are obviously different. Therefore, when the constructional column and the main structure are whole poured synchronous, the column root steel bar needs to do the flexible connection treatment.

5. Conclusion

To add a constructional column at the end of the cantilever beam will increase the shear force of the cantilever beam at the root, and will have a small effect on the internal force of other members. This needs to recheck the calculation of shear reinforcement of cantilever beams from the source of structural design.

In the case of constructional column on the structure, the calculated results of cast-in-place construction method have little effect on the internal force of the structure. The axial force of the Balcony Column has little change, so it does not have the effect of accumulating internal force from top to bottom.
Therefore, the change of construction method will not have an adverse effect on the original structure with reinforced concrete constructional columns. The two-dimensional computational model has some limitations.

The way of pouring the balcony column and the main structure at the same time is more convenient for construction operation. The constructional column and the main structure are constructed together can be used to cast the constructional column effectively by conveying equipment of the main structure concrete. The construction can reinforce Rachel effectively, enhance the overall stability of the structure, use scaffold operating platform effectively which has been set up for the main structure, enhance the construction safety and reduce the project cost. When the constructional column and the main structure are cast simultaneously, it is necessary to make flexible connection to the reinforcement of the column root. The synchronous construction can utilize the construction technology of the main structure construction team, accelerate the construction progress, ensure the construction quality, effectively avoid the staggered construction of the secondary structure process, effectively control the pollutants generated by the secondary construction, achieve the green construction, and bring significant economic and social benefits. In the future, the construction measures can be further improved.

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