Analysis and application of construction pre-set deformation value of inclined high-rise steel structures

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Abstract. For an inclined high-rise steel structure, for example, the new headquarters of China Central Television (CCTV), if the structural members are manufactured and erected according to the Structural Design Configuration (SDC), it may lead to a considerable deviation between the structural construction completed configuration and the SDC because of its continuously inclined deformation during the installation. And surely it is impossible to connect the cantilever accurately without taking Pre-set Deformation Value (PDV) for structural members during the erection. This paper introduced the concept of the PDV, which includes manufacture pre-set deformation value and erection pre-set deformation value. A new computational method, namely two stage comprehensive iteration method, to determine PDVs of the new CCTV headquarters is proposed. A number of numerical results are obtained which have been used as guidelines for the construction of the new CCTV headquarters.

1. Introduction

The inclined high-rise steel structures are more attractive than ordinary up-straight structures and give a strong visual shock to the public, such as the leaning tower of Pisa in Italy and the Puerta de Europa twin leaning towers in Madrid Spain, and the new headquarters of China Central Television (CCTV) in Beijing, China, as seen in Figure 1. The building consists of two towers leaning 6° off vertical in both directions, a tremendous 14-storey-high cantilever connecting two leaning towers at the top and a 9-storey-high podium at the bottom. During the construction, its two towers are erected firstly step-by-step, its cantilever extending out from the two towers is then erected gradually without using any temporary supports from the ground, and finally the cantilever is connected orthogonally in the sky.

Due to the two inclined towers and the tremendous cantilever that connects them on the top, the continuously added gravity results in additional bending moment and lateral deformation during the construction. It is expected that the variation of the structural deformation is not only related to axial compression of structural members, but also related to lateral displacement of the whole structure. If structural members are manufactured and erected according to the Structural Design Configuration (SDC) provided by structural design, it may lead to a considerable deviation between the structural construction completed configuration and the SDC. Consequently, the buildings in the service period can’t satisfy the design requirements to structural configurations. For the construction of the new CCTV headquarters, there are several requirements to the structural geometric configuration proposed by the architectural and structural design as follows in detail: (1) When the construction is finished and after all dead loads are applied to the structure, such as self-weight of the structure, floor, decoration, glass curtain and so on, the differences between actual and design horizontal coordinates of the nodes
of the two towers are within an acceptable level, and actual vertical coordinates of the nodes on the cantilever after the construction is finished are not lower than their design coordinates, and the gradient of each floor plane is required to be within an acceptable level. (2) The aided structures and equipments, such as the glass curtain, elevators and so on, should be erected successfully during the construction, and they should perform their function completely in the structure service period. Generally speaking, the construction-completed structural configuration is required to meet the SDC. At present, for the structure, taking Pre-set Deformation Value (PDV) for structural members, including manufacture and erection pre-set deformation value, is an effective measure to keep the structural configuration during the construction to approach gradually the SDC.

![Figure 1. The new CCTV headquarters in Beijing.](image)

At present, there are many analytical models developed to simulate the construction of high-rise structures or bridges. Saffarini and Wilson (1983) developed a simulation model of actual behavior of building structures under sequential loads [1]. Choi and Kim (1985) proposed a multistory frame analysis technique for simulating structural construction which can take into account the construction sequence and sequential application of dead weight [2]. Choi and Chung et al. (1992) proposed a simplified approach, termed correction factor method, to solve the problem of erroneous bending moments induced in the members of the building when the sequential nature of construction and of the sequential application of its weight are not adequately counted for [3]. Cruz, Mari, and Roca (1998) present a general step-by-step model for the nonlinear and time-dependent analysis of reinforced concrete, prestressed concrete, and composite steel-concrete planar frame structures [4]. Mari (2000) presented a step-by-step analytical model for the nonlinear and time-dependent analysis of segmentally constructed three dimensional concrete frames [5]. Besides these models, the element birth and death technology based on finite element analysis software can be applied to simulate the construction process of the structures exactly. The technology deactivates or reactivates elements by changing their stiffness, external force and mass matrix to simulate the removal and erection of members. Using this technology, a global structural finite element model can be established at once, and all elements are deactivated, then all elements are reactivated step by step according to the pre-scheduled erection sequence of structural members. In this way the internal force and deformation of the previously erected structure during the construction can be obtained.

However, the analytical models mentioned above can only be used to compute the internal force and deformation of the structure during the construction. And for the towers inclined alone, it is relatively easy to obtain PDVs by using forward iteration method or backward iteration method, which are generally used in bridge construction analysis (YAN 1999[6], LIANG 2000[7], XIN 2004[8]). But for the new CCTV headquarters, because of the two inclined towers and the loop-connecting cantilever by the L-shaped body in the space, it is much more difficult to obtain the PDVs during their construction process, and corresponding computational method of the PDV is little studied. This paper introduces firstly the concept of the PDV, and then proposed a new computational method, namely two stage comprehensive iteration method, to determine PDVs of the new CCTV headquarters.
number of PDVs are obtained which have been used as construction guidelines for the member manufacture and erection of the new CCTV headquarters. The computation results reach a good agreement with the measured deformation from the actual project, and the construction has been finished without meeting any construction difficulty.

2. PDVs of steel structures during the construction
Theoretically speaking, structural members deform under their gravity loads after they are installed. So the determination of installation coordinates of members to be erected at the next step should consider the deformation of structural members erected previously. In other words, in order to control the structural configuration during the construction and make the completed configuration satisfy with the SDC given by designers, each structural member should be erected in special configuration, namely the member erection configuration which is different from that obtained according to the SDC. In general, the member configuration at the first erection step is called Structural Initial Construction Configuration (SICC).

The PDV, which is used to compensate for structure deformation caused during the construction, includes Manufacture Pre-set Deformation Value (MPDV) and Erection Pre-set Deformation Value (EPDV). As a simple example (Figure 2), the construction of a cantilever steel beam that is divided into three segments to be erected with the denotation of 1-2, 2-3 and 3-4 by using the cantilever erection method step-by-step, is used to illustrate how to take the PDVs for structural members during the construction.

![Erection configurations of members](image)

(a) Erection configuration of member 1  
(b) Erection configuration of member 2  
(c) Erection configuration of member 3  
(d) The SDC construction-finished

**Figure 2.** PDVs consideration of Erection process of a cantilever beam.

(1) Manufacture Pre-set Deformation Value (MPDV) is the difference between the member design length and actual erection length, and it is used to compensate for the axial elongation or compression of members caused during the construction. When PDVs is considered, due to the deformation caused by consecutively added loads during the construction, the member dimensions of actual manufacture is different from that obtained according to the SDC. The length of the member erected at the \( n+1 \)th step should be determined in the structural configuration after the \( n \)th step member is installed and its deformation is produced. For example, if the design lengths of member 1, 2 and 3 are denoted by \( L_{1d} \), \( L_{2d} \) and \( L_{3d} \), and their manufacture lengths are denoted by \( L_{1e} \), \( L_{2e} \) and \( L_{3e} \), then their MPDVs are defined as \( \Delta_1=L_{1e}-L_{1d} \), \( \Delta_2=L_{2e}-L_{2d} \) and \( \Delta_3=L_{3e}-L_{3d} \), as seen in Figure 2.

(2) Erection Pre-set Deformation Value (EPDV) is the difference between the nodal design coordinate and actual erection coordinate of members, and it is used to compensate for the nodal displacement of members during the erection. When PDVs is considered, due to the deformation caused by consecutively added loads during the construction, nodal coordinates of the actual erection members are different from that obtained according to the SDC. Nodal coordinates of the member to be erected at the \( n+1 \)th step should be determined in the structural configuration after the \( n \)th step member is installed and its deformation is produced. For example, if the design coordinates of node 1
and 2 of member 1 are denoted by \((X_{1d}, Y_{1d}, Z_{1d})\) and \((X_{2d}, Y_{2d}, Z_{2d})\), and their erection coordinates are denoted by \((X_{1e}, Y_{1e}, Z_{1e})\) and \((X_{2e}, Y_{2e}, Z_{2e})\), then their EPDVs are defined as 

\[
\begin{align*}
\delta_{1X} &= X_{1e} - X_{1d}, \\
\delta_{1Y} &= Y_{1e} - Y_{1d}, \\
\delta_{1Z} &= Z_{1e} - Z_{1d}, \\
\end{align*}
\]

and 

\[
\begin{align*}
\delta_{2X} &= X_{2e} - X_{2d}, \\
\delta_{2Y} &= Y_{2e} - Y_{2d}, \\
\delta_{2Z} &= Z_{2e} - Z_{2d}, \\
\end{align*}
\]

and similarly EPDVs of other members are obtained, as seen in Figure 2.

The new CCTV headquarters has two inclined towers and a tremendous cantilever supported by them, and the whole structure is erected step-by-step without using any temporary supports from the ground. Generally speaking, due to the construction completed configuration of the new CCTV headquarters is required to meet the SDC, each structural member should be erected in special configuration where it is deviated slightly from its SDC and higher than its SDC, as seen in Figure 3.

Figure 3. Erection process of the new CCTV headquarters.

3. Computational methods for PDVs of inclined high-rise steel structures

3.1. Forward iteration method (FIM)

The construction of a cantilever steel beam (Figure 4) is selected to illustrate computational principle of the FIM in detail, where the beam is divided into three erection segments by using the cantilever erection method step-by-step without using temporary supports, as shown in Figure 4. It is noted that \(v\) is the SDC required by designers after the beam construction is finished, \(u^{(i)}\) is structural completion displacement away from the initial configuration at the \(i\)th iteration process.

![Figure 4. Computational process of the FIM.](image-url)
Taking the SDC $v$ (Figure 4 (a)) as the construction initial configuration and using a forward analysis, the construction completed deformation $u^{(1)}$ and the corresponding completed configuration $v + u^{(1)}$ can be obtained using element birth and death technology according to the pre-scheduled construction, as seen in Figure 4 (b).

Superimposing oppositely the construction completed deformation $u^{(1)}$ to the SDC $v$, that is to say, superimposing $-u^{(1)}$ to $v$, a new construction initial configuration $v - u^{(1)}$ is obtained. Based on the configuration $v - u^{(1)}$, a new construction completed deformation $u^{(2)}$ is obtained through forward analysis as the process (1). If the structural nonlinear effect can be negligible, the error $u^{(1)} - u^{(2)}$ will be within an acceptable level, then the configuration $v - u^{(1)} + u^{(2)}$ is considered to meet the SDC $v$, and the configuration $v - u^{(1)}$ is just the SICC, as seen in Figure 4 (c).

If the structural nonlinear effect can’t be negligible and the error $u^{(1)} - u^{(2)}$ will be not in an acceptable level, then based on the configuration $v - u^{(2)}$ through forward analysis, a new structural completed configuration $v - u^{(2)} + u^{(3)}$ is obtained, and the error is $u^{(2)} - u^{(3)}$. This process is repeated until the error $u^{(n)} - u^{(n+1)}$ is within an acceptable level, then the configuration $v - u^{(n)}$ is just the final SICC, as seen in Figure 4 (d).

Based on the configuration $v - u^{(n)}$, through forward analysis, the erection configuration, MPDVs and EPDVs of each member at each step can be obtained.

Theoretically speaking, the FIM can be used to calculate the PDV of all structures for any construction method. However, when the structure is too complicated, such as the new CCTV headquarters with a connecting cantilever, it can’t be iterated to correct result because of the too large float or aberrance deformation of the death element on the cantilever.

### 3.2. Two stage comprehensive iteration method (TSCIM)

Unlike a simple cantilever steel beam, the PDV computation of the new CCTV headquarters during the construction is absolutely impossible to be completed while using the FIM because too large float or aberrance deformation of the death element in the loop-connecting cantilever are produced. In order to solve this problem, the PDV computation process is divided into two stages in accordance with the whole construction process of the structure, namely one is the stage before the cantilever is connected and the other is the stage after the cantilever is connected. It is obvious that the two towers deform independently before the cantilever is connected, and the two towers deform compatibly after the cantilever is connected. And deformation trends of the structure at the two stages are essentially different. Therefore, the cantilever connecting state is defined as the middle or critical state during the whole construction process. Based on this consideration, a new method, namely Two Stage Comprehensive Iteration Method (TSCIM), is proposed for the computation of PDVs of the new CCTV headquarters in this study.

The basic idea of the TSCIM for CCTV headquarters is as follows (Figures 5-7): (1) In accordance with the requirements of SDC, the cantilever connecting state can be determined only by using forward iteration method as described above. (2) Then according to the cantilever connecting state the construction initial state can be obtained only by using forward iteration method as well. According to the cantilever connecting state and the construction initial state, the final erection configuration and PDVs of all structural members can be obtained similarly and easily. Generally speaking, the calculation process of the PDVs is the inverse process of the actual construction process, as seen in Figure 5. The sketch map and its corresponding finite element model of the critical states of the new CCTV headquarters during the construction can be seen in Figures 6 and 7 respectively.
Figure 5. Calculation process of the PDVs.

Figure 6. Sketch map of the critical states.

(a) The cantilever connecting state  
(b) The design state

Figure 7. The construction finite element model of the new CCTV headquarters.

(a) Analysis process at stage one  
(b) Analysis process at stage two

Figure 8. Analysis process of the TSCIM for the PDV.

The computational process of the TSCIM for PDVs of the new CCTV headquarters in detail is as follows:

- According to the design parameters and pre-scheduled construction scheme of the building, a finite element model simulating its full construction process can be established where the
model is divided into two large construction stages. That is to say, all structural members in
the model can be divided into two groups during the construction, and one group is erected
before the cantilever is connected and the other group is erected after the cantilever is
connected, and accordingly the all loads applied during the construction can be divided into
two parts. Then all structural members are deactivated and all loads are set to zero by using
element birth and death technology.

- The analysis process at stage one is as follows in detail: (a) Based on the SDC \( v \), the all
  elements which are to be erected before the cantilever is connected are reactivated, and only
  their stiffness matrices are retained but their mass and load matrices are set to zero, as well as
  all elements which are to be erected after the cantilever is connected are deactivated. (b)
  According to the pre-scheduled construction scheme, the members after the cantilever is
  connected are erected and the relevant loads are applied step-by-step by using element birth
  and death technology through the forward construction simulating analysis, as shown in
  Figure 4, the construction completed deformation \( \mathbf{u}^{(1)} \) can be obtained. (c) A new structural
  configuration \( v - \mathbf{u}^{(1)} \) can be obtained after superimposing oppositely \( \mathbf{u}^{(1)} \) to \( v \). Based on this
  configuration, the members after the cantilever is connected are erected and the relevant loads
  are applied step-by-step as the process (b), the structure will deform and coincide with \( v \) if the
  structural nonlinear effect can be negligible, then the configuration \( v - \mathbf{u}^{(1)} \) as the cantilever
  connecting state can be obtained. (d) If the structural nonlinear effect can’t be negligible, the
  process (c) is repeated until the error \( \mathbf{u}^{(1)} - \mathbf{u}^{(0)} \) is within an acceptable level, then the
  configuration \( v - \mathbf{u}^{(1)} + \mathbf{u}^{(0)} \) will coincide with \( v \) and the configuration \( v - \mathbf{u}^{(1)} \) is just the
cantilever connecting configuration, as seen in Figure 8 (a).

- The analysis process at stage two is as follows in detail: (a) Based on the configuration
  \( v - \mathbf{u}_{1}^{(1)} \) of the cantilever connecting state, all elements of the whole structure are deactivated.
  (b) The members to be erected before the cantilever is connected are erected and the relevant
  loads are applied step-by-step by using element birth and death technology through the
  forward construction simulating analysis, as shown in Figure 4, the deformation \( \mathbf{u}_{2}^{(1)} \) can be
  obtained when the cantilever is connecting. (c) A new structural configuration \( v - \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} \)
  can be obtained after superimposing oppositely the deformation \( \mathbf{u}_{2}^{(1)} \) to the configuration
  \( v - \mathbf{u}_{1}^{(1)} \). Based on this configuration, the members to be erected before the catilever is
  connected are erected and the relevant loads are applied step-by-step as the process (b), the
  structure will deform and coincide with the configuration \( v - \mathbf{u}_{1}^{(1)} \) if the structural nonlinear
  effect can be negligible, then the configuration \( v - \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} \) as the structural construction
  initial state can be obtained. (d) If the structural nonlinear effect can’t be negligible, the
  process (c) is repeated until the error \( \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} \) is within an acceptable level, then the
  configuration \( v - \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} + \mathbf{u}^{(0)} \) will coincide with the configuration \( v - \mathbf{u}_{1}^{(1)} \), and the
  configuration \( v - \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} \) is just the SICC, as seen in Figure 8 (b).

- Through the two analysis stages mentioned above, the structural construction initial state and
  the cantilever connecting state can be obtained. Then erection configuration, MPDVs and
  EPDVs of the members at each construction step can be obtained. That is to say, the members
  at the first construction step are erected according to the configuration \( v - \mathbf{u}_{1}^{(1)} - \mathbf{u}_{2}^{(1)} \), and
  when the cantilever is at the connecting state the structural configuration will be \( v - \mathbf{u}_{1}^{(1)} \), and
  the construction completed configuration of the whole structure will be the SDC \( v \).
4. PDVs for the new CCTV headquarters

4.1. Finite element model for construction simulation

In this paper, the TSCIM is applied to calculate PDVs of the new CCTV headquarters. A finite element model for the construction simulation is established as seen in Figure 7, and its global coordinates is shown in Figure 9. The assumptions for the construction simulating analysis are as follows: (a) The sizes and properties of the steel members and reinforced concrete floors established in the analytical model are taken according to their design drawings. And the steel reinforced concrete columns are equivalent to steel columns based on the design axial and bending stiffness for calculation simplification. (b) The foundation of the structure is assumed to be infinite rigid. (c) Every two adjacent stories along the tower height are taken as one construction step. In this way, there are totally 53 construction steps in the whole construction process, especially where the cantilever is connected at step 35. (d) The loads applied at each step are determined at current construction step, include the self-weight of actual structure, floor, decoration, glass curtain and so on.

To illustrate nodal displacements, MPDVs and EPDVs clearly, some arisises on the structure and some aris nodes are numbered, as seen in Figures 10 and 11 respectively. And design coordinates of the nodes and their erection steps during the construction analysis are given in table 1.

4.2. Some nodal displacements during the construction

For the two inclined towers of the new CCTV headquarters, due to its self-weight and the additional bending moment, the columns near the leaning-ward side will experience a larger compressive deformation than columns in the other side, while the columns against the leaning-ward side will perhaps have an elongation deformation if the axial tension caused by additional bending moment is greater than the axial compression due to structural gravity.

Through analyzing some nodal displacements of arisises 1, 2, 3 and 4 on tower 1 during the construction after the nodes are erected, as shown in Figure 12, some conclusions can be obtained as follows: (a) X displacements of most nodes increase continuously during the whole construction

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**Table 1.** Nodal design coordinates and erection steps.

| Nodal number | Coordinates in the SDC (m) | Erection step | Floor | Nodal number | Coordinates in the SDC (m) | Erection step | Floor |
|--------------|----------------------------|---------------|-------|--------------|----------------------------|---------------|-------|
|              | X  | Y   | Z     |     |              | X  | Y   | Z     |     |
| Node 1       | 79.089 | -79.089 | 5.1 | 2   | F02          | Node 7 | -79.089 | -36.891 | 5.1 | 2   | F02          |
| Node 2       | -69.519 | -69.519 | 96.15 | 12  | F22          | Node 8 | -69.519 | -31.53 | 96.15 | 12  | F22          |
| Node 3       | -58.998 | -58.998 | 196.25 | 24  | F45          | Node 9 | -58.998 | -21.009 | 196.25 | 24  | F45          |
| Node 4       | -21.1 | -79.089 | 5.1 | 2   | F02          | Node 10 | -21.1 | -36.891 | 5.1 | 2   | F02          |
| Node 5       | -11.53 | -69.519 | 96.15 | 12  | F22          | Node 11 | -11.53 | -31.53 | 96.15 | 12  | F22          |
| Node 6       | -1.009 | -58.998 | 196.25 | 24  | F45          | Node 12 | -1.009 | -21.009 | 196.25 | 24  | F45          |
process. (b) Y displacements of all nodes increase continuously before the cantilever is connected and decrease continuously after the cantilever is connected. (c) Absolute values of Z displacements of all nodes on arrises 1 and 3 increase continuously before the cantilever is connected and decrease continuously after the cantilever is connected, but absolute values of Z displacements of all nodes on arrises 2 and 4 increase continuously. (d) Arris nodal displacements of tower 2 are basically the same as that of tower 1 mentioned above.

[Figures 1 and 2 showing nodal displacements during construction]

**Figure 12.** Some nodal displacements during the construction.

**Figure 13.** Displacements of node 25.

Because of the special structure of the new CCTV headquarters, the deformation of the cantilever is composed of the deformation produced by its self-weight and that caused by the deformation of two inclined towers due to the load added continuously. After node 25 located at the bottom of the cantilever structure (Figure 11) is erected, absolute values of its X, Y and Z displacements increase continuously with the construction sequence (Figure 13). That is to say, in order to make the cantilever...
deform to its SDC when the whole building is completed, it should be erected at the position higher than its position in the SDC.

4.3. Some member MPDVs during the construction

Some member MPDVs of the two towers during the construction are given in Figures 14 and 15. Through analyzing member MPDVs, some conclusions can be obtained as follows: (a) MPDVs of the columns in the inclined inside of tower 1 is larger than that in the inclined outside of tower 1 at the same storey. (b) MPDVs of all columns decrease continuously along the height of the tower basically. (c) Member MPDVs of tower 2 are basically the same as that of tower 1 mentioned above.

4.4. Some nodal EPDVs during the construction

Some nodal EPDVs of the two towers during the construction are given in Figures 16 and 17, in which “1-X” stands for the nodal EPDV at X coordinate of arris 1 along the tower height and so on. Through analyzing nodal EPDVs, some conclusions can be obtained as follows: (a) Nodal EPDVs at X and Y coordinates in the same storey of each tower are equal to each other basically, and nodal EPDVs at Z coordinate near the leaning-ward side of the tower are greater than that against the leaning-ward side. (b) For tower 1, absolute values of nodal EPDVs at X coordinate increase continuously along the tower height, and absolute values of nodal EPDVs at Y coordinate increase continuously at the lower stories and decrease continuously at the higher stories, and most of nodal EPDVs at Z coordinate increase continuously. (c) For tower 2, nodal EPDVs at Y coordinate increase continuously along the tower height, and nodal EPDVs at X coordinate increase continuously at the lower stories and decrease continuously at the higher stories, and most of nodal EPDVs at Z coordinate increase continuously.

Figure 14. Some member MPDVs of tower 1. 

Figure 15. Some member MPDVs of tower 2.

Figure 16. Some nodal EPDVs of tower 1. 

Figure 17. Some nodal EPDVs of tower 2.
Some nodal EPDVs of two arrises at the bottom of the cantilever during the construction are given in Figure 18, in which “9-X” stands for nodal EPDV at X coordinate of arris 9, and node 1 on the arris is located in the position near the tower, and node 10 is the intersecting point of the two arrises and so on. Some conclusions can be obtained as follows: (a) For arris 9, nodal EPDVs at X coordinate near the tower are greater than that near the intersecting point, but nodal EPDVs at Y and Z coordinate near the intersecting point are greater than that near the tower. (b) Nodal EPDVs of arris 10 are basically the same as that of arris 9 mentioned above.

4.5. Comparison and application of PDVs
The construction of the new CCTV headquarters has been finished. The theoretically predicted PDVs in this study have been applied to manufacture and erect the members of the new CCTV headquarters during the construction. In order to verify the theoretically predicted displacements and PDVs, actual measured displacements of the structure are monitored continuously during the construction and the comparison between them is made. And theoretical predicted and actual measured displacements of some nodes on floors 20, 24 and 28 are compared in Figure 19 where “T-UX” and “A-UX” stand for nodal theoretical predicted and actual measured X displacements during the construction and so on. It is found that when nodal displacements are enough small the measured displacements are influenced significantly due to the temperature and the measurement deviation that have not been considered in the theoretical analysis. Correspondingly there is relatively big difference between them. However, their trends are basically identical when the displacements become enough big.

Figure 18. Some nodal EPDVs of the cantilever.
5. Conclusions

- For the new CCTV headquarters, it is an effective measure to take the PDV for structural members to control the structural configuration during the construction. Otherwise, due to the continuously added gravity and additional bending moment, it may lead to a considerable deviation between the structural construction completed configuration and the SDC without taking the PDVs.

- Based on the analysis for the FIM where it may be iterated to incorrect result because of the too large float or aberrance deformation of the death elemen when the structure is too complicated, a new computational method of the PDVs, namely the TSCIM, is proposed, and especially it can be used effectively to compute the PDVs of the new CCTV headquarter with a tremendous loop cantilever.

- By using the TSCIM, a finite element model for structure construction simulation of the new CCTV headquarters is established for determining its PDVs. A lot of numerical results are presented which have been used as guidelines for the construction of the new CCTV headquarters. The comparison between the theoretical predicted and actually measured displacements show their identical trends and agreements basically.

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