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Research on Assembling Steel Tower on The Top of Skyscraper by Gradual Erection

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ABSTRACT

The top surface of the hise rise buildings are very small for working space. The findings of this research is to clarify the scientific and technological problems to assemble big steel tower in different shapes on the top of the skyscrapers to the height of dozens of meters safely by using simple mechanical equipment including hoist, hydraulic jack by gradual erection method.

Keywords: gradual erection, steel tower assembly

1 Introduction

Rapid development of the science of construction enables realization of any shape of the building desired by human. Recently, urban construction has been briskly going on worldwide and there appear lots of skyscrapers with large-sized steel towers having symbolic meanings on the top of them. So scientific construction methods for to erect those towers are being investigated and introduced.

Development and modernization of construction machines have been accelerated in the construction field. So it is easily done to construct and dismantle large-sized steel structure, heavy member and equipment. However, still the work by application of the conventional construction machines takes high proportion of construction works [8,16,17].

Only a few professionals in the construction field pay attention to the assembly methods of large steel structures. There are various forms of steel structure assembly in skyscrapers, whose top surface and space are minimal for large-scale works [9-12]. As a result, there needs to be more research on construction methods for erecting large steel tower structures than the general structure. So, there needs to be more synthetic research related to this [8,13,14,15]. Then, in the general substance of the previous research, it can be seen that most conditions are favorable, such as work in the field or a place that describes equipment that can be installed easily [1-8,13,14,15]. Therefore, it is necessary to solve practical problems by building structures that have towers with large steel structure systems in skyscrapers [18-20].

2 Method

2.1 The principles of gradual erection

This method is to complete erection by pulling or pushing up the parts of a structure one by one along the vertical space prepared for its assembly. In other words, it is the method to assemble the parts to into a complete unit. In this method the erection equipment (hoist or hydraulic jack) is installed in a passage space. The first part of the structure is moved up. Then the second part is also moved up and the top of the second part is connected to the bottom part of the first part. The third part is also moved up and connected to the second part. This process is repeated several times to complete the assembly. This method can be classified into assembling parts methods and assembling the whole method according to the connecting method, and pull-up method by hoist and push-up method by hydraulic jack according to equipment.

2.2 Assembly method by using hoist in gradual erection

In this method, the hoist is used as erection equipment. Then, in presenting the method of applying the hoist to assemble the components by pulling them up. Thus, there are four stages in moving parts up, connecting on the assembly floor, raising the structure, and the process in repairing.

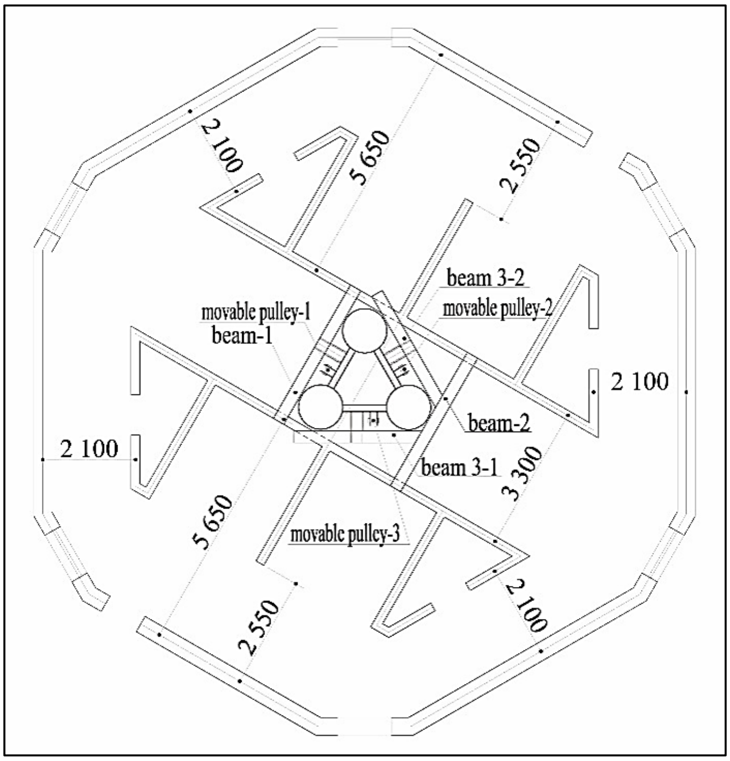

Figure 1 Installation of steel supporter

The vital thing to provide ample space at the position of several stairs at the top of the building is to use a steel structure assembly. Meanwhile, the number of floors that are not built is determined by the specific maximum length for the assembly section and the height of the steel structure. Then, the lowest part of the assembly floor is called the preparation floor and more than one opening is designed in this part of the floor. Next, a suitable floor preparation is designed at the position of the exterior and interior walls. Figure 1 shows the plan for floor preparation and installation of support beams of a steel frame structure.

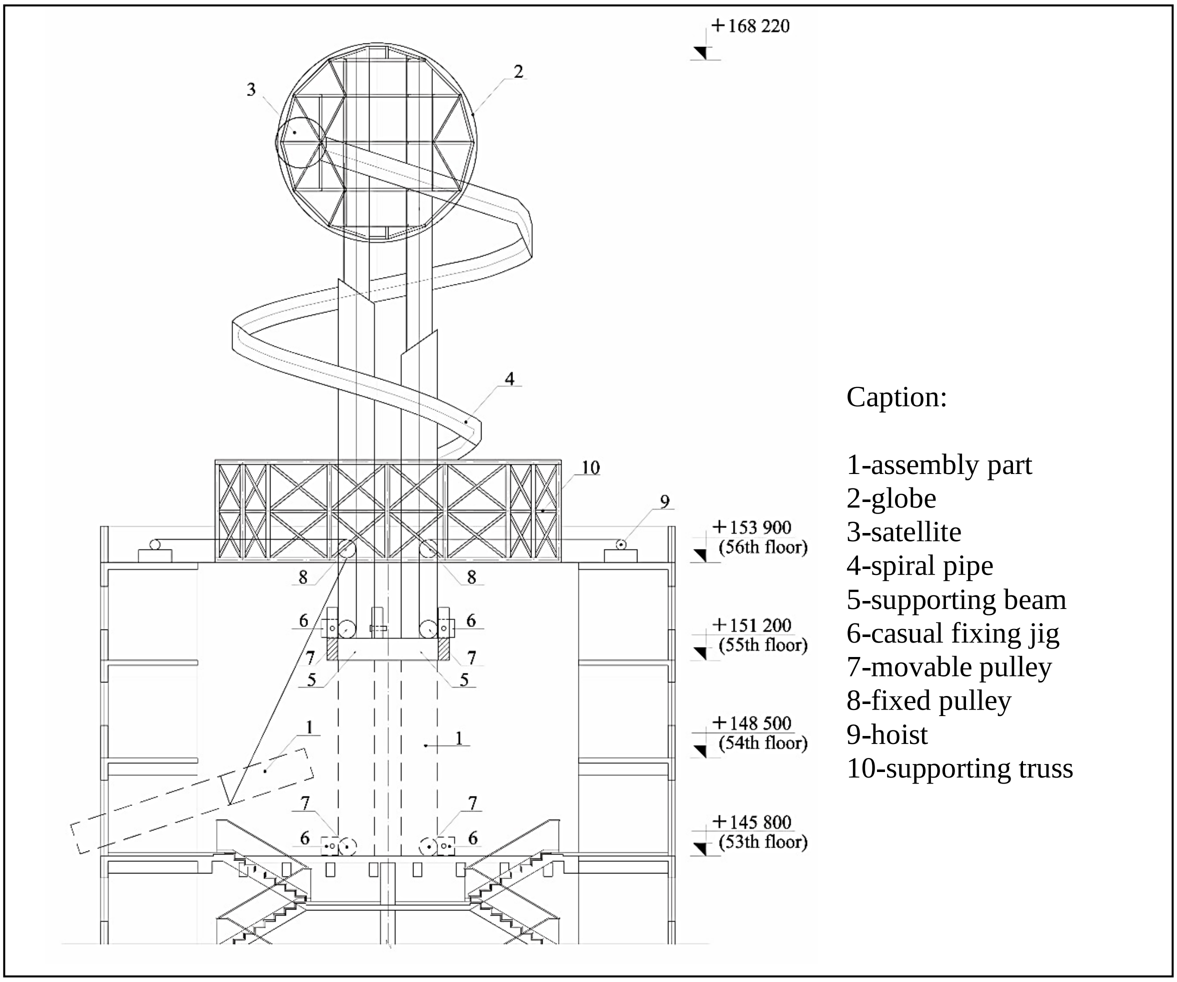

Figure 2 Assembly of steel structure

Initially, space for the stairs of the top three floors (10 450×3 300mm) was left unconstructed to be used as an assembly line. This can be seen in Figure 2 which shows the steel structure assembly process. The figure describes three hoists (capacity-3t, speed-1~3cm/s), three fifth gear moving pulleys (capacity-30t), three fifth gears fixed pulleys (capacity-30t), three first gear auxiliary pulleys (capacity-3t) installed in the attic to provide a primary appointment. Meanwhile, the lifting rope has a diameter of 18.5mm, a length of 274m and a strength of 130kg/mm^2 and a connecting rope of 38mm and a diameter and length of 6 m. Next, two ropes are connected with three rings (capacity-50t). Then, the support beam acts as an I-beam, with a flange 270mm wide and 12mm thick and a web height of 540mm.

In order to ensure the assembly accuracy, square-head screws whose diameter is 80mm are applied to positions adjacent to the structure for assembly and derricks are installed at three edges of supporting truss to assemble decoration tower.

Figure 3 shows modelling in every step of assembling the structure.

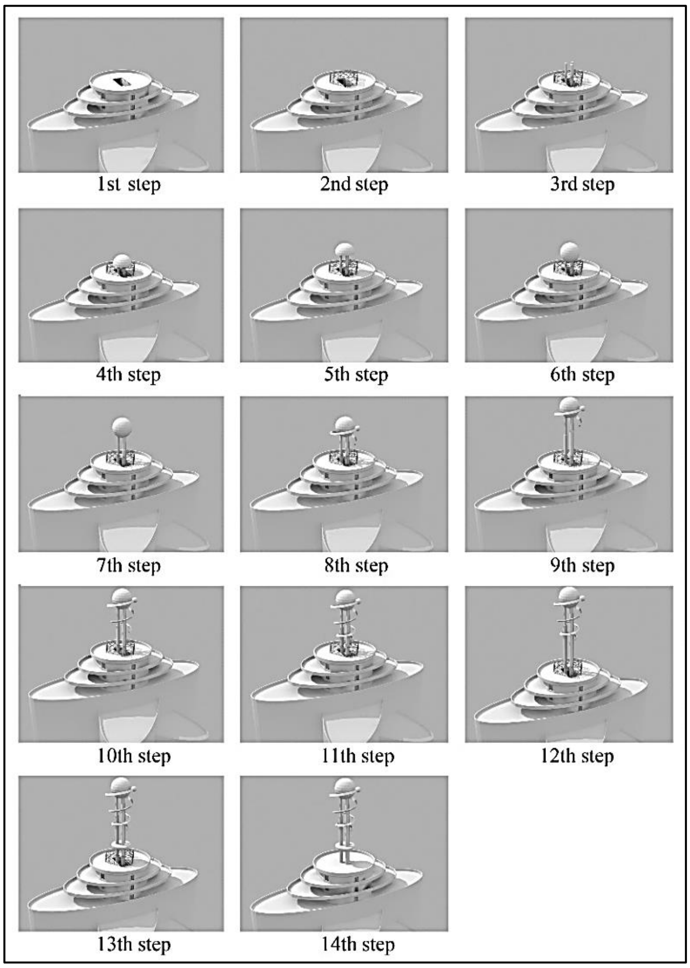

Figure 3 Modelling of tower assembly

2.3 Assembly method by using hydraulic jack in gradual erection

This method is to push up the structure as a whole by using hydraulic jack temporarily installed at the lowest part of preparation floor. In the case of putting down the parts of assembly through the upper part of the assembly floor First, fixing frame for jack is installed on the supporting beam in preparation floor, where the steel structure stay temporarily. Next, the bottom of the first part coming from the upper part of the assembly space is welded to the supporting beam, bottom of the second part is connected to the top of the first part and again, bottom of the third part is connected to the top of the second part. Like this the parts are assembled into a complete unit in the preparation floor. Finally, the structure is pushed up to tis right position as a whole.

This method can be widely used to assemble large steel tower structures. However, in the event of assembly, the space needs to be more significant to mount the equipment for installation, which also includes a hoist and additional support elements. In addition, there are four stages in setting up the parts, to complete the assembly, and to raise the structure and repair. Then, for assembly work, two ladders in the middle of the building were left unbuilt for use as a roof erection line. Meanwhile, the assembly work plan is described in Figure 4.

Furthermore, support beams are installed along the installation line to raise the tower. Then, it was followed up with the installation of box-shaped support beams with a length of 3,000 mm, a width of 150 mm, a height of 250 mm, and a thickness of 10 mm. Furthermore, when the elevator cab is constructed, an opening (200×300 ㎜) is made in the proper position for the installation of the frame in order to jack up and install the support beams. Meanwhile, a hydraulic jack is used for erection.

Hydraulic jack (capacity 20t) is fixed on the frame and oil cask (50ℓ), operation panel (with non-return and safety valve), motor (22KW, three phases, four polar, 1 760 rounds/min) are located. Working pressure is 100 atmospheric pressure. Individual parts cut in proper size are lifted and put down in the prepared assembly space by crane and welded on the supporting beam.

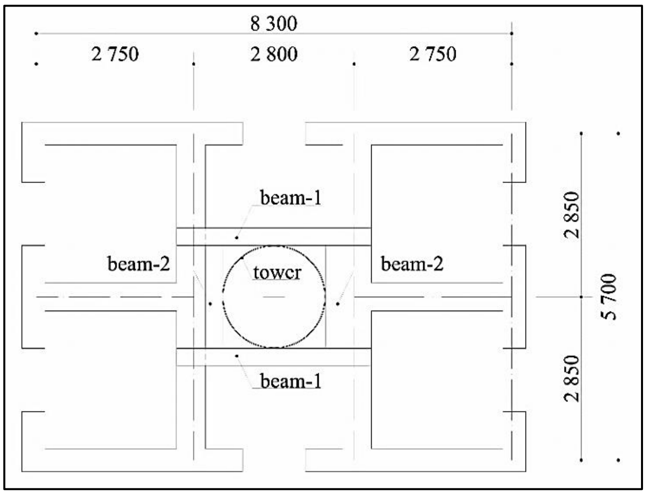

Figure 4 Method to push up supporting beam

In the same way the second part is lowered and welded, the third part is also connected next to it. This repeated process leads to a completion of the tower in the assembly passage. Before raising tower, it must be checked that the resultant center of the jack meets with central axis of tower structure.

At first, the tower is moved upwards for 1 350mm and a guiding frame is dismantled. And supporting beam with jack is fixed temporarily. Next, jack is removed and the bottom structure is pushed upward and reassembled at the position where supporting beam was located.

Hydraulic jack is used again to push up the tower body and fix temporarily (Figure 5). Jack frame is pulled up by controlling non-return valve and fixed. Again the tower body is moved up. The operation is repeated until the tower reaches to its position.

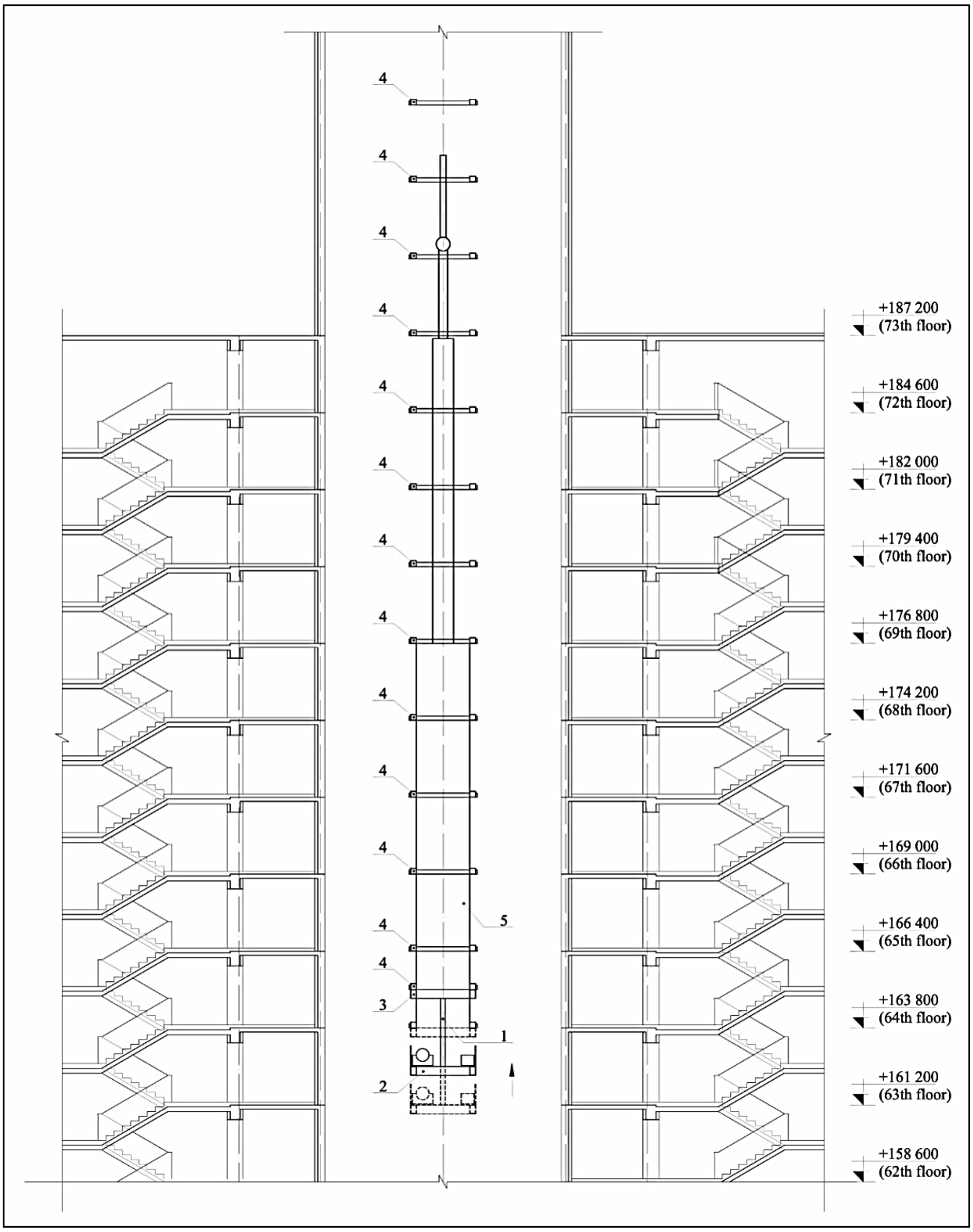

Figure 5 Raising of tower body (1) hydraulic jack, (2) frame for jack, (3) supporting beam, (4) guiding frame, (5) tower body

3 Result and Discussion

3.1 Working state of large-sized steel decoration tower on skyscraper

he seismic analysis of a skyscraper with a large steel structure is described in Figure 6, which shows the modeling calculation for finite element analysis. Then, in the seismic analysis stage based on the response spectrum, there is a first vibration cycle of -2.3910 seconds, a second vibration cycle of -2.3898 seconds, which is then followed up by a third vibration cycle -1.8055s, and a fourth vibration cycle -0.6748s. Figure 6 shows the stereo calculation model confirmed by Table 1 for analyzing forces in steel structures, and Table 2 represents the displacement analysis at the top. Table 1. Internal force of the structure by load combination, X direction; Y direction; Column; Height; Shear force and Moment.

Tabel 1. Internal force Value

column1 height(m)	Direction,X				Direction,Y			
	shearing force, (kN)		moment, (kN·m)		shearing force, (kN)		moment, (kN·m)	
	axis, x	axis, y	axis, x	axis, y	axis, x	axis, y	axis, x	axis, y
0.0	106.75	31.15	87.68	439.10	35.90	20.07	131.01	160.24
3.8	104.66	31.15	87.95	135.31	59.78	26.05	134.99	83.27
4.7	98.36	17.60	74.95	50.94	11.59	19.18	114.74	32.91
6.7	134.38	18.18	35.89	113.48	79.71	20.75	65.20	53.29
8.3	134.05	18.18	30.01	37.22	10.71	18.19	57.95	9.51
10.4	1.76	25.66	1.54	91.63	12.02	17.53	23.06	34.75
11.3	75.47	5.08	3.63	126.66	48.56	9.58	32.73	50.40
12.1	83.66	12.99	-0.49	55.01	50.11	20.10	26.26	5.02
13.0	34.02	31.74	27.25	106.68	14.79	34.60	63.18	44.85
14.1	33.45	31.74	16.00	72.62	16.76	18.85	41.69	29.45
16.8	31.89	8.33	0.27	10.71	16.76	17.62	4.26	1.46
17.5	37.83	10.37	-6.05	9.40	19.83	21.99	-11.68	11.15
20.9	12.96	-2.86	11.03	-1.55	12.96	-2.86	11.03	-1.55
23.7	6.12	9.31	1.41	-11.00	6.12	9.31	1.41	-11.00

Table 2. Represents displacement analysis of Building and steel structure, cm

section	support, column member	Direction, X		Direction,Y	
		axis, x	axis, y	axis, x	axis, y
Building	support 1	3.17	2.38	2.40	3.17
	support 2	3.17	2.38	2.40	3.17
	support 3	3.17	2.38	2.40	3.17
Steel structure	column 1	10.74	3.55	4.22	7.52
	column 2	10.74	3.39	4.22	7.46
	column 3	10.60	3.47	4.13	7.49

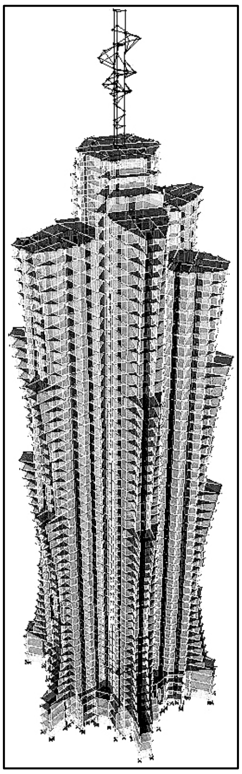

Figure 6 Stereo calculation modelling of building and steel structure

Analysis shows maximum displacement at the upper part of the building is 3.17cm in X and Y direction and the one at the upper part of steel structure is 10.74cm in X direction and 7.52cm in Y direction.

Thus, the real displacement of steel structure is as follows.

X direction: 10.74-3.17=7.57cm

Y direction: 7.52-3.17=4.35cm

Allowed displacement is as follows when the steel tower is 24 meters high and displacement of the upper part of building is 7.57cm.

$$\frac{L}{100} = \frac{2\ 400cm}{100} = 24cm > 7.57cm$$

Safety condition for the vibration of steel structure is verified as follows.

$$\frac{L}{150 \sim 300} = \frac{2\ 400cm}{150 \sim 300} = 8 \sim 15cm > 7.57cm$$

So the steel structure is enough in stiffness.

There is no big difference in vibration cycle under seismic load in both cases of the building only and building with steel structure. Horizontal displacement of the upper part of the building is 3.17cm in the building with steel tower and 3.11cm in the building without steel tower. So the difference is 1.89%.

This explanation shows that the steel structure has little effect on the building. To produce calculations as described in table 3.

Table 3. Calculation result

section	Vibration cycle(s)				Horizontal displacement(cm)	
	first	second	third	fourth	the upper partof the building	the upper part ofthe steel structure
Fixed steel structure(wind)						2.30
Fixed steel structure(earthquake)	0.5735	0.5441	0.2538	0.1861		0.33
Fixed steel structure on building	2.3910	2.3898	1.8055	0.6748	3.17	10.74
Only building	2.3896	2.3884	1.8055	0.6743	3.11	

Displacement of the upper part of building is 10.74cm when steel structure is erected on the building and when diameter of the steel pipe is 1 000mm and the thickness is 10mm, calculation is verified based on internal force analysis. Seismic analysis shows that maximum axial direction force is 633.93kN, maximum shear force is 134.38kN and maximum moment is 439.1kN·m. Section of the column is fully satisfied and the position to cut for assembly should be determined under the consideration of internal force state.

4 Conclusion

Staged erection is a reasonable and logical way to erect large steel frieze towers for skyscrapers. The advantage of this method is that it is easy to install the hoist and hydraulic jack used to build the tower. Then another advantage of this method is the ease of use of the hoist and jack. In addition, this equipment is straightforward in operation and construction for building construction.

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