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Reliability of Fitness Equipment Safety Checking Calculation and Reliability Research of the Electric Retractable Machine Stand Framework to be Reactivated after the Arrest

TianBiao Huang*, Xuan Bao, Houyun Liang

Zhejiang Ocean University Donghai Science and Technology College, Zhejiang, China
**corresponding author*

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Abstract: Humans have a gregarious nature. After the arrest of the COVID-19 epidemic, the will of the people to resume or carry out healthy physical and mental activities will be strengthened. From the view of safety and health of facilities and equipment for collective activities, this paper provides a method of safety checking calculation and simulation based on the telescopic underframe of electric grandstand equipment, which can provide reference for similar facilities and equipment. According to "building structure load code (GB50009-2001)", using ANSYS software to analyze the internal force of structure under external load; According to the Technical Code of cold-formed thin-wall steel structures (GB50018-2002), the strength and stability of the members were Checking. According to the Technical Code of cold-formed thin-wall steel structures (GB50018-2002), which is the national standard of the People's Republic of China, the strength and stability of the members are checked. It could help engineers predict electric grandstand effectively, ensure its load bearing was safe and reliable, and prevent accidents such as the stand gave way all of a sudden. This paper has certain reference value for the safety checking calculation, reliability confirmation, design and production of the same kind of products.

1. Introduction

The whole society to carry out useful cultural and sports activities, to shape a good social image, building a harmonious social environment and other aspects have a very important role. Especially, it is the important content of cultural self-confidence construction and the important means of building cultural self-confidence too.[1] Under the guidance of this background, the common people participate in beneficial cultural and sports activities and improve their own quality, which will gradually become a fashion of common people's life. With China's decisive victory against Covid-19 last year, starting in April last year, resuming production and becoming a major economy with positive economic growth last year, this year has entered a post-epidemic era, mass vaccination is in full swing.[2] by next spring, optimism is that the world will have wiped out the new pneumonia epidemic. Human Society will enter a large-scale of beneficial activities outdoor large-scale activities. But the demand for venues for cultural and sports events is stretched to the limit. 1,2Taking the road of resource-saving and environment-friendly social development, effectively and rationally applying the existing venues, saving the space used for venues, reducing the investment in funds, and increasing the utiliz3ation rate of large-scale cultural, sports or entertainment venues, innovative Development of related mechanical equipment, has become an effective solution to the above "green" development of the shortcut. The grandstand is mainly due to its high flexibility and high value, and the creative concept of multi-functional conversion can meet the requirements of different large-scale cultural, sports or entertainment activities, opening the way for the most challenging public gatherings, so that the limited space as an unlimited application, for the venue chair brought a new concept, its facilities and equipment in the increasingly popular degree. Therefore, engaged in this product design, the production of more and more enterprises. However, due to the uneven level of experience and technology, the lessons were painful: The collapse of the dragon boat stand in Shijing town of Guangzhou, and the collapse of a hospital stand in Ethiopia, which caused many deaths and injuries. The safety of the people is a priority we can not afford to ignore. It is the key to ensure the high safety of the movable stand equipment to make a reliable check of the design of the telescopic bottom bracket.

2. Internal Force Analysis of Electric Prop Bracket Structure

Electrically retractable mechanical movable stand equipment, such as Figure 1, including the bottom bracket; and seats, pedals, stair erector, etc. The working state of the equipment is scientific, according to different crowd and body, there are many different row spacing and different step height to meet the requirements of the audience space and sight. Its expansion and contraction is divided into manual, semi-automatic and electric operation, because of its flexibility, it has a variety of different collection methods, wall-mounted, independent, mobile, wall-na and inverted, and so on.

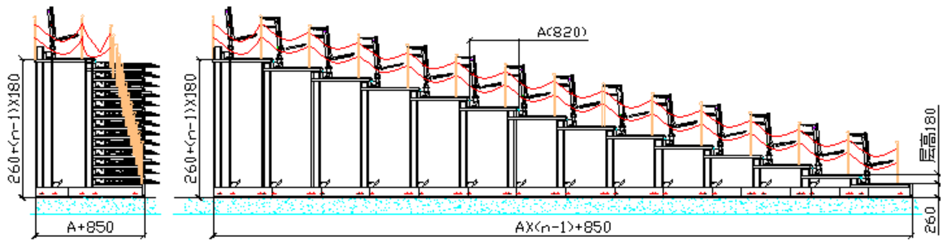


Figure 1: The dopaminergic pathways in the brain

In an electrically retractable mechanical movable stand, any of a series of steps, as shown in Figure 2:

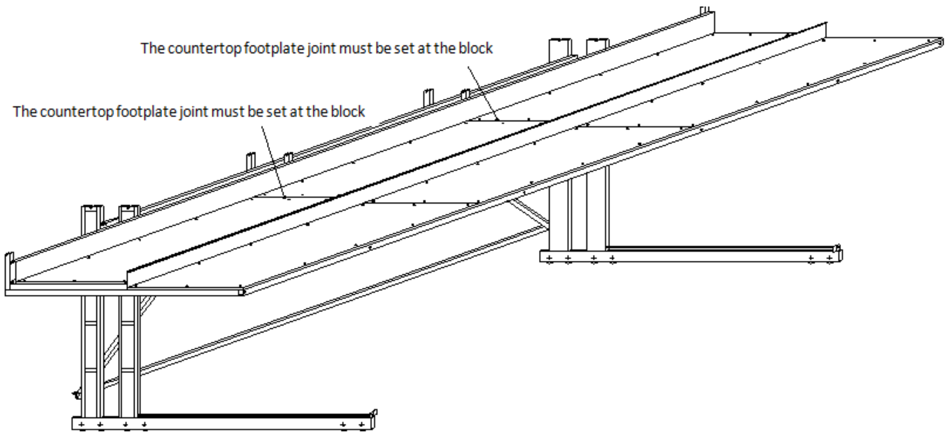


Figure 2: The planked stand

In the electric retractable mechanical movable stand equipment, any one of a row of ladder structure bearing skeleton structure components by a variety of original components as shown in Figure 3

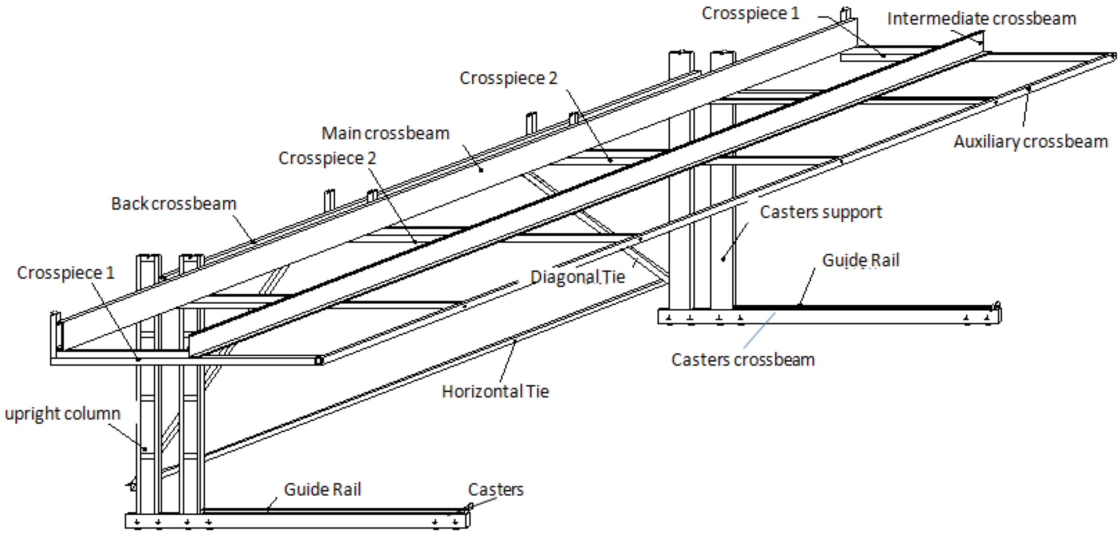
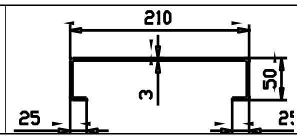
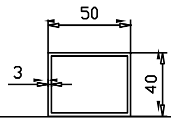
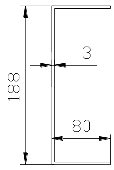
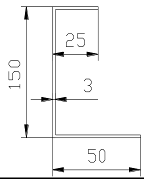
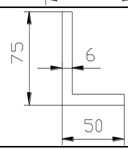
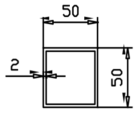
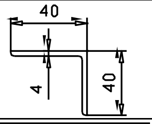
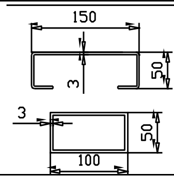
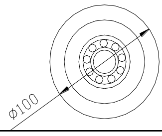
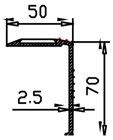


Figure 3: The stand Assembly without planking

To facilitate the verification and Reliability Study of the telescopic mechanical structure of electric stands, it can be simplified as shown in Table 1, which is composed of Materials and specifications and Longitudinal profile of Schematic, the bearing capacity is checked and analyzed

Table 1: Main structural fittings and material specifications for electric stands

Sort number	Structural name	Materials and specifications	Longitudinal profile of Schematic
1	Main crossbeam	210X50X3	
2	Auxiliary crossbeam	50X40X3	
3	Middle beam	188X80(25)X3	
4	Back crossbeam	150X50X25X3	
5	Crosspiece 1	75X50X6	

6	Crosspiece 2	50X50X2	
7	Diagonal Tie	40X40X4	
8	Casters prop stand	210X50X3	
9	Guide Rail	210X50X3	
10	Casters	210X50X3	
11	Countertop deck	210X50X3	
12	Deck Front, left and right pack edge structure	210X50X3	
13	Side Safety Guard rail	210X50X3	

Break the grandstand structure down into two parts; The first part includes: The bearing part of a platform composed of main crossbeam, auxiliary crossbeam, middle beam, back crossbeam, crosspiece 1 and crosspiece 2. The structure is shown in Figure 2 and Figure 3. The lower bracket of the second part bears the axial force and bending moment from the first part, as shown in Figure 4. The platform is supported by fourteen columns as shown in Figure 5. The joints of the columns and the columns constrain the linear displacement in the X, Y, and Z directions and the rotation of the Z axis. When the displacement of the front end of the lug reaches 5 mm, the columns in the front row are subjected to a common force, which constrains the vertical displacement. The distributed live load of the platform was transmitted to main crossbeam q=3.459N/mm, auxiliary crossbeam q=2.124N/mm, middle beam q=4.424N/mm, back crossbeam q=1.167N/mm. The last row of support is the most distance, and the height of the support is the highest, and the stress is the most unfavorable, so the last row of support is selected as the calculation object.[3]

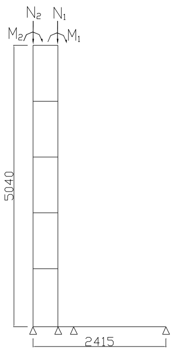


Figure 4: The simplified structure of support bracket

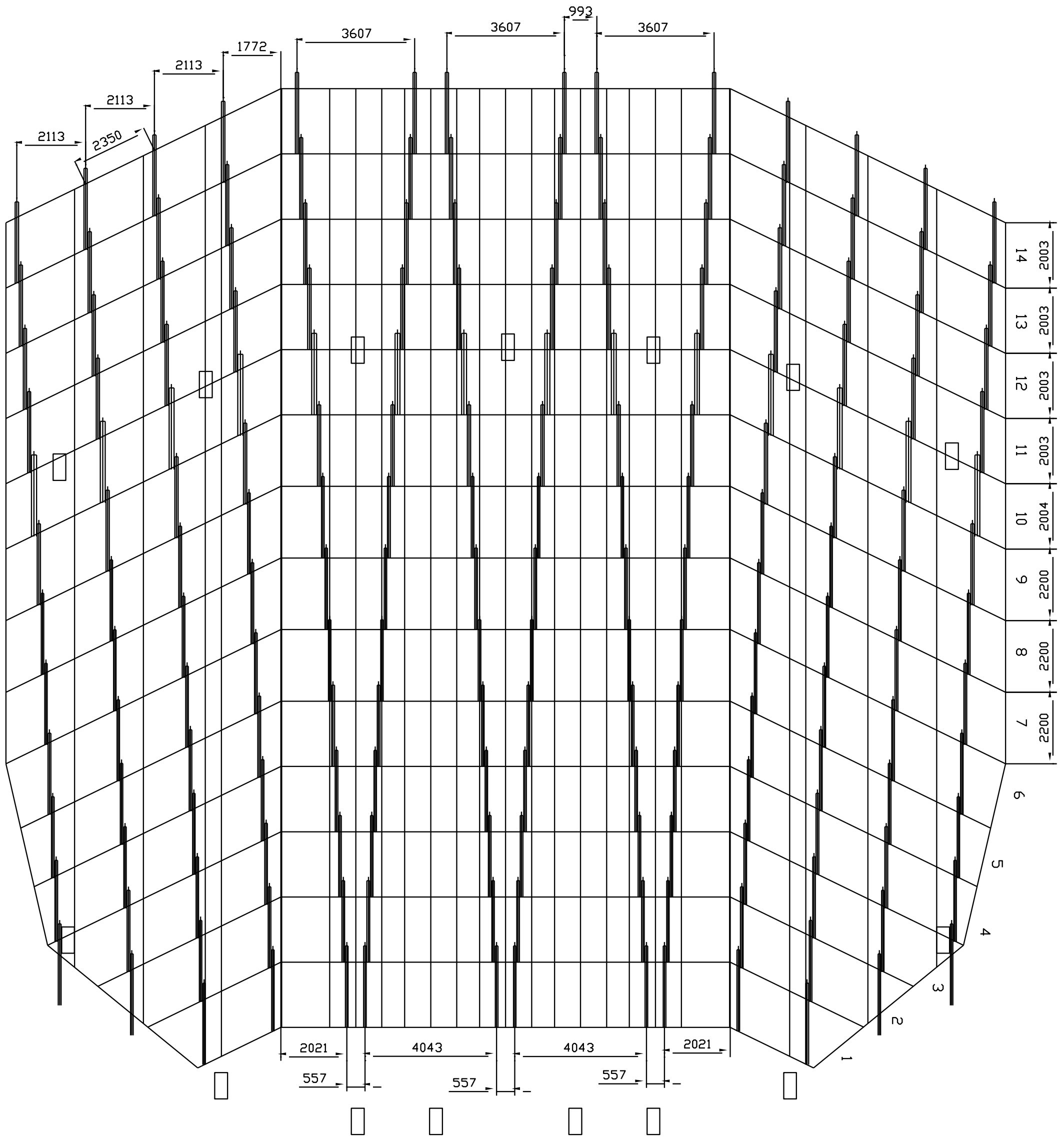


Figure 5: The distribution of support brackets for the grandstand countertops

As mentioned above, the movable stand studied in this paper is a structure consisting of a bracket made of cold-formed thin-walled steel (Q235 steel) , main crossbeam, auxiliary crossbeam, middle beam, back crossbeam,crosspiece1 and crosspiece2, according to "building structure load code (GB50009-2001) " , using ANSYS software to analyze the internal force of structure under external load; According to “the Technical Code of cold-formed thin-wall steel structures (GB50018-2002)”, the strength and stability of the members were analyzed. [4-5] The design value of tensile, compressive and bending strength of Q235 steel is f=205N/mm^2, and the design value of shear strength is f_v=120N/mm^2.

Table 2 lists the main crossbeam of the cross sections of the girders, auxiliary crossbeam, middle beam, back crossbeam, crosspiece1, and crosspiece2. [4-5] The internal force and supporting force of the platform structure under the platform load are analyzed by ANSYS software. The length of each unit is 100mm, and there are 4916 units in the whole structure. The calculation of the internal forces of the platform structure is shown in table 3; The force exerted by the platform on the bracket (the supporting force of the bracket on the platform) is shown in table 4;The internal force of the bracket is calculated as shown in table 5.

Table 2: Main parameters of beam section

Name	A(mm^2)	I_{xx}(mm^4)	I_{yy}(mm^4)	I_{zz}(mm^4)
Main crossbeam	1080	3240	416667	6914000
Auxiliary crossbeam	450	222222	126667	177083
Crosspiece 1	726	9000	411200	147000
Crosspiece 2	600	375000	250000	250000
Back crossbeam	900	2700	375000	3125000
Middle beam	714	2142	26326	2986570

Table 3: Calculation result of internal force of platform

Name/Position	Maximum moment (KN-m)		Maximum Shear (KN)		Maximum Torque (KN-m)	
	Middle	Side	Middle	Side	Middle	Side
Main crossbeam	8.51	4.97	18.3	11.3	0.0031	0.00
Auxiliary crossbeam	0.32	0.34	1.42	1.58	0.70	0.55
Crosspiece 1(front)	1.07	1.37	1.21	1.59	0.0008	0.007
Crosspiece 1(Back)	1.43	1.86	3.04	2.33	0.009	0.11
Crosspiece 2	1.18	1.29	2.33	1.35	0.14	0.20
Back crossbeam	1.18	—	2.22	—	0.0014	—
Middle beam	2.06	0.99	4.10	2.86	0.0014	0.00

Table 4: Force of the platform on the support

Position	N_1(KN)	N_{12}(KN)	M_1(KN-m)	M_2(KN-m)
Middle	29.411	-1.127	1.608	0.000416
Side	14.920	0	1.909	0

Table 5: Calculation result of internal force of support

Name /Position	Upright column		Back crossbeam	
	Maximum moment (KN-m)	Maximum Shear (KN)	Maximum moment (KN-m)	Maximum Shear (KN)
Middle	0.435	32.8	2.120	7.270
Side	0.352	22.1	1.909	7.159

3. Check and Analysis of Bearing Capacity

3.1. Verification and Analysis of the Bearing Capacity of Main Crossbeam

The main crossbeam uses210×50×25×3 steel Type C. The beam is a flexural member with a maximum bending moment of Mmax=8.51KN-m, a maximum shear force of Vmax=18.3 KN, and a double-moment of B=0.

According to GB50018-2002 5.3.23[4-5]

Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 129\ N/mm^2 < f = 205\ N/mm^2 \tag{1}$$

$$\tau = \frac{V_{\max} S}{It} = 44\ N/mm^2 < 120\ N/mm^2 \tag{2}$$

Stability:

$$\frac{M_{\max}}{\varphi_{bx} W_{ex}} + \frac{B}{W_{\omega}} = 154\ N/mm^2 < f = 205\ N/mm^2 \tag{3}$$

So the main crossbeam meets the force requirements.

3.2. Calculation and Analysis of Carrying Capacity of Auxiliary Crossbeam

The Auxiliary crossbeam uses 40×50×2.5 square tubes. The front beam is a bending member with the maximum bending moment Mmax=0.34KN-m, the maximum shear force Vmax=1.58KN, and the double moment B=0.

According to GB50018-2002 5.3.23[4-5]

Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 48\ N/mm^2 < f = 205\ N/mm^2 \tag{4}$$

$$\tau = \frac{V_{\max} S}{It} = 9\ N/mm^2 < 120\ N/mm^2 \tag{5}$$

Stability:

$$\frac{M_{\max}}{\varphi_{bx} W_{ex}} + \frac{B}{W_{\omega}} = 48\ N/mm^2 < f = 205\ N/mm^2 \tag{6}$$

So the auxiliary crossbeam meets the force requirements.

3.3. Calculation and Analysis of Carrying Capacity of Crosspiece 1

The front part of the crosspiece 1 is 75×50×6 angle steel with a 40×5 flat steel plate. Maximum bending moment Mmax=1.37KN-m, maximum shear force Vmax=1.59 KN, maximum torque Tmax=0.007 KN-m. The internal force of the pick-up file is smaller, the length is shorter, and is connected with the paving board, which can guarantee the overall stability of the pick-up file.

According to GB50018-2002 5.3.23[4-5]

Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 208\ N/mm^2 > f = 205\ N/mm^2 \tag{7}$$

$$\tau = \frac{V_{\max} S}{It} = 8N/mm^2 < 120\ N/mm^2 \tag{8}$$

The strength of crosspiece 1 does not meet the force requirement.

The latter part of the crosspiece 1 is made of 75×50×6 angle steel and 50×50×3 square pipes. Maximum bending moment Mmax=1.86KN-m, maximum shear force Vmax=3.04 KN, maximum Torque Tmax=0.11 KN-m. 5The internal force of the pick-up file is smaller, the length is shorter, and is connected with the paving board, which can guarantee the overall stability of the pick-up file.

According to GB50018-2002 5.3.23[4-5]
Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 44\ N/mm^2 > f = 205\ N/mm^2 \tag{9}$$

$$\tau = \frac{V_{\max} S}{It} = 8N/mm^2 < 120\ N/mm^2 \tag{10}$$

So crosspiece 1 meets the force requirement.

3.4. Calculation and Analysis of Carrying Capacity of Crosspiece 2

The Crosspiece 2 uses 50×50×3 hollow square tube. maximum bending moment $M_{\max}$=1.29KN-m, maximum shear force $V_{\max}$=2.33 KN, maximum torque$T_{\max}$=0.20KN-m. The internal force of the crosspiece is smaller, the length is shorter, and is connected with the paving board, which can guarantee the overall stability of the Crosspiece 2.

According to GB50018-2002 5.3.2[4-5]
Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 129\ N/mm^2 > f = 205\ N/mm^2 \tag{11}$$

$$\tau = \frac{V_{\max} S}{It} = 12N/mm^2 < 120\ N/mm^2 \tag{12}$$

So crosspiece 2 meets the force requirement.

3.5. Calculation and Analysis of Carrying Capacity of Back Crossbeam

The back crossbeam uses 150×50×25×3 type C. The rear beam is bending member with the maximum bending moment Mmax=1.18KN-m, the maximum shear force Vmax=2.22 KN, and the double moment B=0.

According to GB50018-2002 5.3.23[4-5]
Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 28\ N/mm^2 < f = 205\ N/mm^2 \tag{13}$$

$$\tau = \frac{V_{\max} S}{It} = 7N/mm^2 < 120\ N/mm^2 \tag{14}$$

Stability:

$$\frac{M_{\max}}{\varphi_{bx} W_{ex}} + \frac{B}{W_{\omega}} = 39\ N/mm^2 < f = 205\ N/mm^2 \tag{15}$$

So the back crossbeam meets the force requirement.

3.6. Calculation and Analysis of Carrying Capacity of Middle Beam

Middle beam uses 188×80(25)×3 type channel steel. The middle Beam is a bending member, so it does not need to be checked for its stability. The middle Beam has a board on the compression flange and is firmly connected with the compression flange. Maximum bending moment Mmax=2.06KN-m, maximum shear force Vmax=4.10 KN, double moment B=0.

According to GB50018-2002 5.3.23[4-5]

Intensity:

$$\sigma = \frac{M}{W_{enX}} + \frac{B}{W_{\omega}} = 64\ N/mm^2 < f = 205\ N/mm^2 \tag{16}$$

$$\tau = \frac{V_{\max} S}{It} = 11 N/mm^2 < 120\ N/mm^2 \tag{17}$$

So the middle beam meets the force requirement.

3.7. Calculation and Analysis of Upright Column Capacity

Upright column uses a 100×50×3 rectangular steel tube. The bracket is a bending member N=32.8KN, M=0.453KN-m, which can bear both axial force and bending moment.

According to GB50018-2002 5.5.1 and 5.5.53[4-5]

Intensity:

$$\sigma = \frac{N}{A_{en}} + \frac{M_X}{W_{enX}} + \frac{M_Y}{W_{enY}} = 61\ N/mm^2 < f = 205\ N/mm^2 \tag{18}$$

In-plane stability:

$$\frac{N}{\varphi A_e} + \frac{\beta_m M_x}{(1 - \frac{N}{N'_{EX}}\varphi) W_e} = 68\ N/mm^2 < f = 205\ N/mm^2 \tag{19}$$

Out-plane stability:

$$\frac{N}{\varphi_y A_e} + \frac{\eta M_x}{\varphi_{bx} W_{ex}} = 121\ N/mm^2 < f = 205\ N/mm^2 \tag{20}$$

So the Upright column meets the force requirement.

4. Conclusions

The electric grandstand in this paper shall use the following materials to fully meet the requirements of force.

a. 210×50×25×3 type c section steel is used in Main crossbeam, 40×50×2.5 square pipe is used in the front part of the crosspiece 1, 75×50×6 angle steel is used in the latter part of the crosspiece 75×50×6 angle steel and 50×50×3 square pipe is used in rear half part of shift, 50×50×3 Hollow Square pipe is used in crosshead, 150×50×25×3 type c section steel is used in middle beam and 180×80(25)×3 type channel steel is used in middle beam. It is recommended to be closely connected with the paving board to prevent the torsion deformation of the bar.

b. stand two columns with 100×50×3 rectangular steel tubes, to meet the force requirements.

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