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Monitoring and Suggestions for Overhead Accumulative Sliding Construction of Large Span Spatial Steel

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Abstract. The large span spatial steel is used in chop manufactory of the Chengdu integrated circuit manufacturing project. Because of the complex construction conditions, high altitude cumulative slip construction is adopted to ensure the installation quality and construction requirements of the structure. The vertical displacement, bearing synchronicity and key bar stress during the sliding process are monitored in same time. The smooth implementation of the slip construction scheme is guaranteed in that way. In addition, the monitoring data are analyzed, and the reliability of the sliding construction technology is demonstrated, which provides reference for the standardization of the slippage construction of the large span steel roof in China..

1. Preface

In recent years, in order to meet the social and economic requirements, various types of large-span factory buildings have been increasing gradually [1]. In the process of forming, large span steel structure is very easy to occur because of insufficient structural constraints and insufficient stiffness, resulting in structural damage. In addition, the structure of the construction process is very intricate, construction technology and construction method, probability of risk in construction stage is higher than other structures, in the event of accident, its influence and consequence is extremely serious. In the process of the implementation of the project, due to various factors, the quality accidents of steel structure are frequently encountered [2]. There are due to lack of construction monitoring and checking calculation of the weak link in the process of the overall collapse led to the destruction of a component [3], due to the loss of structural stability in the process of the construction led to the overall damage [4], etc. According to the literature [5], large-span steel structure since the birth of all kinds of accidents happened at home and abroad, in the design phase and production installation phase probability is about 80% of the accident, and the construction stage of up to 49.2%. Due to the imperfect analysis method of the construction process, the calculation value of the large span steel roof structure in the construction stage and the forming force state is different from the actual process [6]. Therefore, in order to ensure the stability of the large space structure in the process of the construction structure, the structure of the deformation and stress monitoring is necessary, at the same time ensure the safety of construction and orderly, real-time dynamic tracking and monitoring is necessary [7-8].

Involves a lot of big span engineering at home and abroad using different construction methods, many projects in order to ensure the safety on the construction monitoring, due to different structure forms, monitoring content and method also each are not identical [9-10]. Now slip in steel structure construction in our country, and there is no uniform standard to control quality mostly rely on their own experience to work, there was certain limitation in terms of security. This article to understand lattice core (chengdu) into the period of the construction of the chip factory large span steel roof in high altitude accumulating sliding deformation characteristics of the structure in the construction process, and ensure the stability of the structure and construction safety well, the key link of synchrony stress, slip and vertical deformation of main truss (midspan deflection) for real-time monitoring. When the deformation is too large, the construction party should be warned and timely adjust the security and stability of the guarantee structure. At the same time, analysis of monitoring data, reveals the construction process, especially the slip deformation structure of the real stress state in the construction process, and provide Suggestions to optimize the construction schemes, to provide reliable basis for structure disposal. On the other hand, the field monitoring data can provide the basis for the formulation of relevant construction codes or regulations, and advance the standardization of the construction of large-span steel structure slip construction in China.

2. Project Overview and Slide Construction Process

2.1. Project summary

The project is located on the side of Binhe road, west of Chengdu high-tech zone. A chip plant with another domestic Q345B - h-beam section bar of large span steel roof truss roof, the structure of the total weight of about 5900 t, the longitudinal length of 412.8 meters, single span span 48 m, lower shores of the longitudinal spacing of 9.6 m. The left and right structures are completely symmetrical, which consists of 42 trusses of main trusses. The purline and support rods of the main trusses are arranged by the upper and lower strings to form the overall structure of the roof, which is connected by high strength bolts. The overall effect of the project is shown in figure 1. As the supporting Settings around the chip plant are relatively concentrated, the construction of large-span steel roof construction is restricted by the site, so the construction of high altitude accumulation slip is adopted. The structure of steel structure is symmetrical, as shown in figure 2.

Figure.1 Overall effect of the project

Figure.2 Scene of partial roof system

2.2. Overview of construction process

Due to the limited construction site conditions of steel roof, the shape of each truss is the same, but the elevation of the support design is not consistent. The concrete column with the axis q-axis, k-axis and e-axis of the support axis has longitudinal concrete connecting beams, which can be placed on the sliding track, and at the same time, the top of the concrete column can be pushed and pulled at the same time.

In the construction process, the slip of the steel truss can only be started after the concrete beam column in the lower part of the steel roof is finished. Therefore, in order to ensure the construction efficiency, the project is divided into three slippage sections for construction, namely 1-10 axis (zone 1), 11-28 axis (zone 2), and 29-43 axis (zone 3). In (1), (2) and (3) between the axis of the erection construction platform, 1 truss segment between lifting and (2) and (3) axis, in the sky into a whole, other trusses are assembled into a whole on the ground, then USES two crawler crane double machine lift hanging to the design elevation (1) and (2) axis, and in place between truss assemble into stable space structure system, finally adopt the way of "shard + cumulative" slip using hydraulic pusher slip the truss structure to the design and installation position, finally will be divided between the connecting beam and support bar installation is complete. 2 area in 44 shaft assembling complete 18 as the starting point through the same way the main truss of the cross, then the whole slip to 11-28 shaft location, after finish the sliding construction of 3 area, structural setting, the make-up residual steel beam, steel structure installation is complete.

3. Monitoring system

3.1. Monitoring content and methods

The steel structure adopts the cumulative slip construction method, which is to set the top thrust point in different positions, and the structure slip is put in place through the external top thrust and the mutual pull pull between the bars. Due to the complexity of slide monitoring condition on site, sliding time is long, the condition of the sliding process occurs, in the process of monitoring, the guarantee does not affect the sliding construction of steel structure under the premise of several working conditions is shown in the table 1 in the process of structure of sliding construction three sliding bearing of synchronicity, A common across the deflection and the key to A and B cross bar stress (deformation) of the monitoring.

Table 1. Sliding conditions

Sliding condition	Condition instruction	Middle span Deflection	synchronicity	A truss stress	B truss stress
condition1	1-2			√	
condition2	1-2-3	√	√	√	
condition3	1-2-3-4-5	√	√	√	√
condition4	1-2-3-4-5-6	√	√	√	√
condition5	1-2-3-4-5-6-7	√	√	√	√

Remark: the working conditions represent the truss truss number of the sliding body, such as the sliding condition of 1-1 -2. A trusses the first trusses in one area, and B is the second one in one area.

(1) The largest roof bottom chord immunity monitoring: monitoring of the roof truss single bottom chord in common across the measuring point location (G, N points), according to the use of total station in the construction process shown in the elevation difference change, calculate the change of immunity of measuring points.

(2) The roof sliding point synchronization monitoring: by observing the total station, the total station (three bearing point) with the sliding distance change measure, measure the slip in the process of synchronization, the site of the three horizontal distance change are consistent, better prove synchronicity, whereas for the poor.

(3) Bar stress monitoring of main control points: slip before construction, key bar stress determined by finite element simulation, combining with the actual construction situation in key nodes arrangement strain gauge for monitoring the stress variation in the bar.

3.2. Monitoring system composition and measuring point layout

In order to grasp the possible problems in construction, the real-time monitoring scheme is used to understand the deformation of the structure at every moment. Decorate a total of two sets of monitoring system, one is the deflection and synchronicity monitoring system, mainly through the erection of observation platform, using the world's highest precision multi-function total station LEICA TCA2003 real-time synchronization and deflection of structure construction process manual monitoring; The other set is the direct response stress change of strain collecting system for the deformation monitoring of the truss.

(1) Synchronization, deflection monitoring system and measuring point layout.

The plan plane layout of the deflection and synchronization monitoring is shown in figure 3, and the synchronism observation point is the upper truss of the upper truss of the first truss on the three axes of E, K and Q. Deflection monitoring is located across the bottom chord in G and N points, basic according to about 1 times/min intervals observation records, and write the data, through the data changes can fully master structure slippage and overall deformation characteristics in the process of construction.

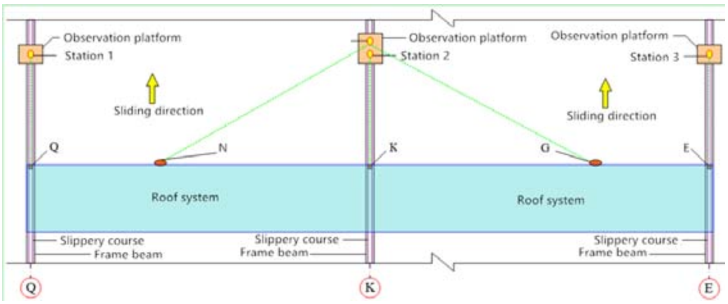

Figure 3. Layout plan of deflection and synchronization monitoring

(2) Strain monitoring system.

Strain gauge measurement with resistance strain gauge is a kind of conventional strain test method, which is mature and widely used, which can realize digital and computer processing of measurement results. Both A and B trusses adopt A strain collection system and work independently. The connection of a strain collection system is shown in figure 4. Using the test and analysis system of DH3821 static strain produced by Donghua Testing Technology Co., Ltd., the strain test software DHDAS dynamic signal analysis and acquisition system is used to obtain the strain data directly. The data bit $\mu\varepsilon$ shown.

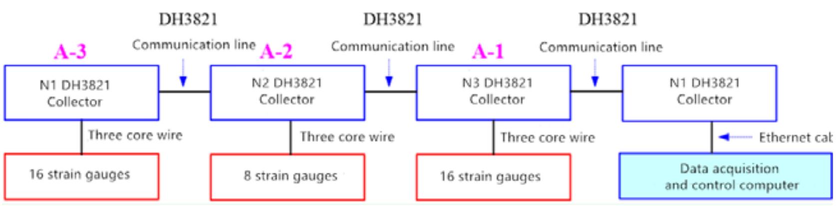

Figure 4. A strain acquisition system

Through the finite element analysis to choose to monitor the stress larger bar decorate, considering the construction site conditions, the main truss is longer, through the partition number, lastly, stress monitoring is shown in figure 5 and table 2. A and B shows the key bar stress monitoring location, the same bar USES is h-beam, each bar are arranged two strain gauge, on the front of the bar on the back (A) and (B) to monitor, as shown in figure 6.

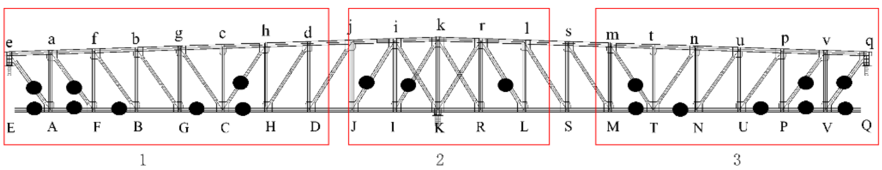

Figure 5. Main truss structure diagram

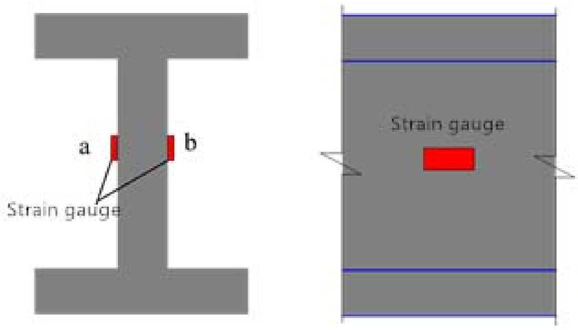

Figure 6. Strain gauge pasting method of truss

Table 2. Layout of stress monitoring points

Number of measuring points	Description of measuring points	Number of measuring points	Description of measuring points	Number of measuring points	Description of measuring points	Number of measuring points	Description of measuring points
11	eA	16	FB	23	rL	35	TN
12	aF	17	GC	31	mT	36	UP
13	Ch	18	CH	32	Pv	37	PV
14	EA	21	Ji	33	Vq	38	VQ
15	AF	22	Ik	34	MT		

4. Monitoring results and analysis.

4.1. Synchronization monitoring results and analysis

In the whole process of sliding, the synchronization slip problem of each thrust point is the key point of engineering construction. The sliding synchronicity of bearing can intuitively reflect the whole roof system during the process of accumulating sliding construction overall deformation, through on-site real-time observation records can carry on the control of construction, in an emergency can also be learned through the amount of sliding bearing. By table 1 shows that the scene of the synchronicity observed mainly in four operating conditions, considering the site condition of slip is intermittent construction condition, to count number as the abscissa, three support maximum differential slip as the ordinate to overall understand the construction process of synchronization, the result is shown in figure 7. Statistical analysis is made on the slip difference of the supports under various working conditions, and the results are shown in table 3.

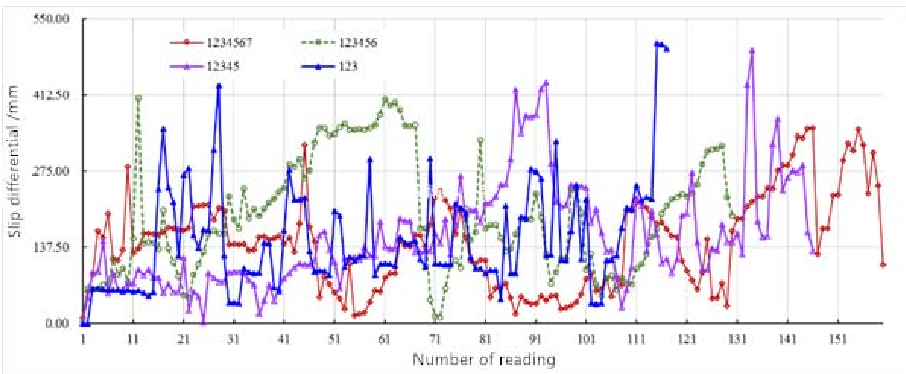

Figure 7. The maximum slip difference curve under different working conditions.

Table 3. Statistics of slip difference in each working condition.

statistical results(mm)	condition2	condition3	condition4	condition5
Maximum slip	504	505	407	352
Mean slip difference	153.0	149.9	189.5	143.6
Slip difference concentration interval	[71,142]	[69,138]	[149,222]	[232,262]

As shown in Figure 8, the overall trend is that with the increase of the number of slippage, the maximum slip difference of the sliding process is gradually improved. Can be found in the process of real-time monitoring, in the process of slip due to various field suddenly accident (such as bearing sudden subsidence in the process of sliding, sliding process encountered obstacles, track different roughness, etc.) will make the scene of the slip is poor at some point increases gradually. Through monitoring and warning, the construction party adjusts the current slip to ensure that the slip is in a relatively stable state. As can be seen from table 3, in general, the slip difference in most slip periods is not more than 250mm. Considering the large span of the whole roof, the overall stiffness is relatively low, and the ability to adapt to the non-synchronization is strong, so the stress caused by the large unsynchronized displacement value is basically within the acceptable range. At some point, the unsynchronized displacement value is nearly 50cm, and most of the time is more than 30mm mentioned in some literatures [10-11].

4.2. *Deflection monitoring results and analysis.*

In the process of slip, the truss can be changed with a certain span, but because the main force in the slip process is from the longitudinal horizontal direction, the influence on the span deflection is limited. Truss structure in the process of considering the slip out-of-plane bending or shear deformation and torsion deformation, warping deformation, plus a variety of reasons in the process of sliding roof vibration, these are to have more or less influence on the midspan deflection, lastly, the vertical gravity loads deflection of the location of the largest in the truss span deflection monitoring in the process of slip. The monitoring object is a truss truss in the outermost layer of displacement slip, considering the possible deflection effect of the sliding motion of different working conditions on the structure. In addition, the abscissa denotes the condition 1 due to special circumstances the count number, other conditions with several time as the abscissa, a common midspan deflection as shown in figure 8 (a) (b) (c) (d).

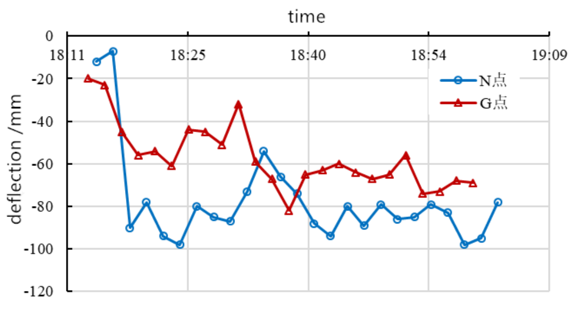

Figure 8(a). Deflection in the working condition 2.

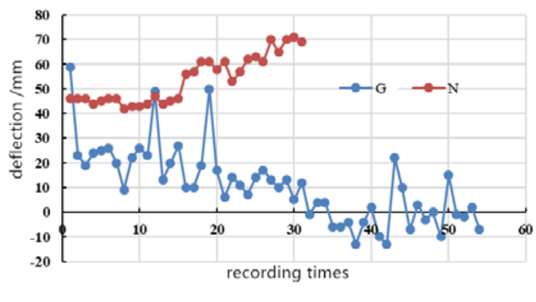

Figure 8(b). Deflection in working condition3.

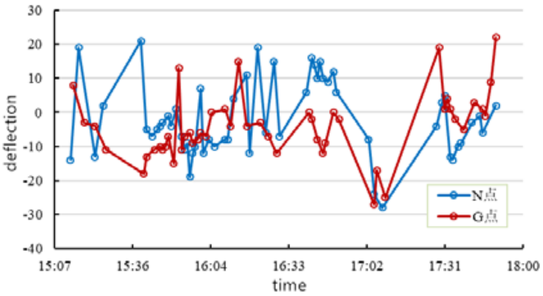

Figure 8(c). Deflection in the working condition 4.

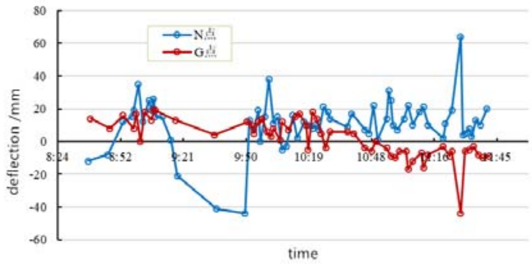

Figure 8(d). Deflection in working condition 5.

Due to complicated structure in the process of the slip stress, bearing place besides itself weight, and the external force pushing device, and in every time slip brake is in an upward and the process of ascension with vibration, and in the construction process is the relative deflection of the structure under surveillance, so you can see in figure 10 has deflection has the positive situation. According to the total monitoring data, the change value of the vertical deflection value of the structure is not more than 10cm, which is 1/480 of the span. It is believed that the vertical deformation of the structure of the large span steel roof truss system in the construction process of high altitude slip will not be affected greatly, and the limit value of the structure deflection should not exceed the construction time.

4.3. Stress monitoring results and analysis of rod parts.

In this paper, the stress analysis of the main bar in the construction of steel structure is carried out, which mainly shows the stress of the main truss in the process of high altitude accumulation slip. The slipper of the support in the sliding process is the welding connection with the main truss, which can be regarded as a permanent support. In working condition of the whole construction process, because the structure is the h-beam, overall it is a very flexible structure, and because of the influence of the slip process are not synchronized, lead to structure by force or pressure. Engineering focuses on the stress changes of its biggest bar and moving down time different due to different working conditions, and site construction conditions is complex, many factors affect the strain test result in the process of monitoring, after the data collection and analysis, get the working condition of A and B shows the maximum stress as shown in table 4.

Table 4. The force diagram of the rod parts in each working condition

Results(Mpa)		Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
A	Maximum stress	-22.6	-13.8	21.9	27.0	38.0
	Position	GC	AF	PV	FB	VQ
B	Maximum stress	-	-	21.6	-16.5	16.7
	Position	-	-	CH	CH	EA

Structure due to the complexity of the stress, in the process of sliding roof system in the process of the sliding bearing is very complex, in addition to the vertical direction of under gravity load, bearing reaction force, also withstand the pusher device level to the jacking force, sliding boots and the friction between bearing and sliding boots mechanical bite, out of sync with bearing displacement, and the influence of the vibration caused by various reasons in the process of sliding, so bars in tension or compression. The table 4 shows that in the process of the whole slip, although due to start, brake, rail, vibration stress of each point changes unceasingly, all stress strain monitoring stations are not more than 40 mpa, and the probability is low, the influence of visible on the internal forces of the main truss rods in the acceptable range. Due to the large number of monitoring poles, each working condition is different, but in general, the stress change of the bar is a certain rule, and some stress changes are selected to be explained, as shown in figure 9.

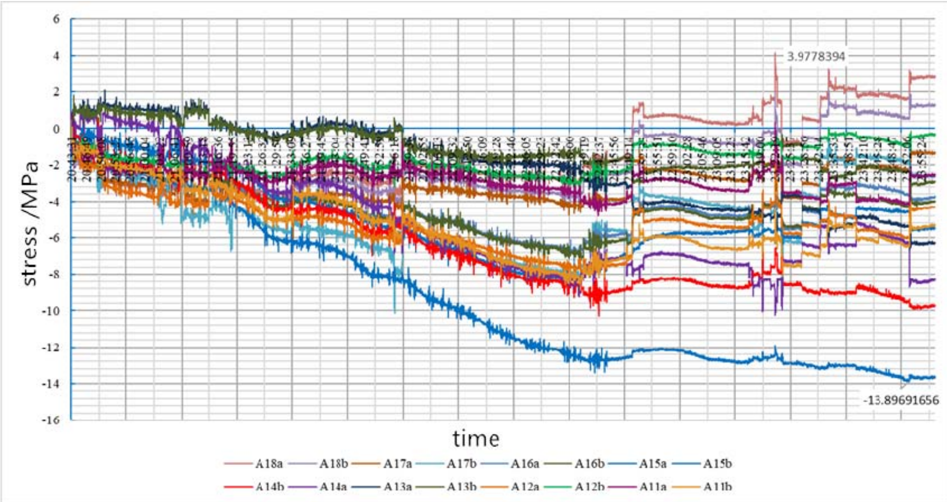

Figure 9 (a). The stress changes of the rod parts of 2A.

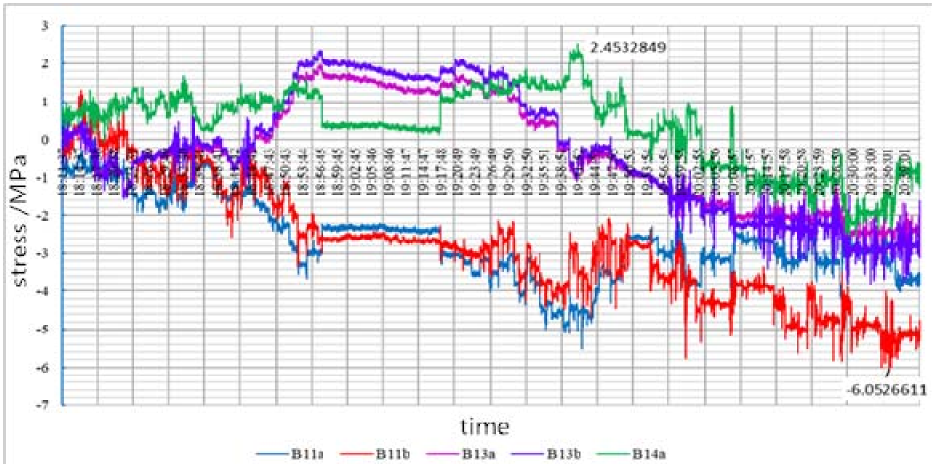

Figure 9 (b). The stress changes of the rod parts of 3B.

It can be seen from Figure 9 that stress changes are very regular in all working conditions. Slip before the main truss plane under its own gravity and install the assembly stress produced in structure, the effect of out-of-plane mainly comes from the purlin, connecting beam and supporting general arrangement, the latter's influence is very limited, and at the same cross section of the bar when the position of the sun (a surface) and just basic near surface (b) stress. In addition, during the whole process of slippage, the structural stress was not greatly affected when the non-synchronization occurred, and most of the time did not exceed 10Mpa. On the other hand, when the structure begins to slip and the stress changes in the plane caused by the unsynchronized displacement of the slip, the stress changes of a and b are different. On one side, due to the tension of the bending moment, the stress on the other side is caused by the stress of bending moment, and the stress on the two sides of the rod is gradually separated, but the overall trend is the same. In addition, when structure appear larger disturbance, such as to overcome the static friction force began to slip, the stress of the bar will be corresponding mutations, due to the slip is intermittent, also included in the construction process by shock and vibration, so the mutation occurs in the whole process.

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5. Slip construction proposal.

In recent years, many long-span steel structure in construction during the construction period of unrestrained accelerate and a decline in the quality of the steel structure installation personnel, led to the collapse of the steel structure installation engineering accidents increased [11-12]. In addition, sliding construction smoothly or not relationship with the integrity of the whole structure and the safety of the later use process, a large number of accidents [13] suggests that many structure after put into use, because the construction process of damage accumulation causes the destruction of structures in the latter period. And construction process of smooth or not is affected by many factors, this article through to the large span steel structure construction process of monitoring, combined with the scene of the accident, the change of the analysis of monitoring data, put forward the following Suggestions to sliding construction process.

(1) Improve the quality of the slide rail profiles (strength, stiffness and roughness), strictly control the height of rail section of the joint in the range of the allowable deviation 1 mm to ensure that the orbit below secondary grouting and padded leveling and achieve the necessary strength requirement rear can implement slip, smooth implementation to ensure that the sliding process.

(2) The sliding boots is the roof of the key parts of the vertical load to slide rail, sliding boots quality fit and unfit quality will affect the sliding boots and uniform distribution of slide rail contact surface compressive stress level, using strong integrity, power transmission path clear, smooth floor and surrounding an arc sliding boots.

(3) In computer synchronous control system, the maximum pushing force of hydraulic crawler each set (can be calculated in advance slide pusher duty counterforce each pusher point), when pushing force exceeds the set value, automatic hydraulic crawler to overflow discharge, to prevent pushing some uneven load distribution on serious damage to the steel structure.

(4) Strengthen the synchronization monitoring of the sliding process, and try to ensure that the non-synchronous value in the slip process is not more than 30cm. In other literatures, the unsynchronized displacement difference is not more than 30mm, which is too simple and arbitrary. The value of the deviation limit value of the unsynchronized displacement should consider the span of the sliding structure and the stiffness of the structure itself.

6. Conclusion

In order to ensure the project adopts high accumulating sliding construction of safety, in the process of the main structure in the sliding bearing of slippage and vertical displacement (deflection), stress the real-time monitoring of key link, intuitive understanding each moment changes of the structure. The monitoring results are analyzed and the following conclusions are formed.

(1) The deflection changes in the process of slippage, but because the stress of the construction process is mainly from the horizontal direction, it has little effect on the deflection and meets the requirements of vertical deformation.

(2) The placement of the ejector is located in the three supports, so the sliding volume of the support is consistent with the stability of the whole project. From the perspective of the whole construction process, the non-synchronization occurs during the whole process of slippage, not exceeding 25cm in most slip periods, and the maximum slip difference is nearly 50cm, but the duration is short. It is found that the large slip difference can affect the stress of the structure, but the change is not more than 40Mpa.

(3) In the process of monitoring, due to the site conditions, only on the internal forces of the structure of the body of the truss were monitored, and connects the main truss form the overall stress variation in the general arrangement purlin in construction process is not clear. The influence of the slip difference on the structure is very large, and the monitoring of the stress of the structure is a point to be studied in the future.

(4) By analyzing and monitoring the data, some Suggestions are put forward on the equipment and sliding method of construction slip construction, and some Suggestions are put forward for the standardization of sliding construction in China.

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