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Study on the Fire Resistance of Supports and Hangers in Different Working Condition

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Abstract. In this study, the typical application of supports and hangers in the water supply and drainage system, ventilation and smoke extraction duct system and electric or optical fiber system has been collected and investigated, in order to understand the fire resistance of supports and hangers used for service installation in China, and further optimize the fire testing and evaluating method of these products. A series of fire resistant testing for supports and hangers used in different working condition have been carried out and the effect of bearing load and structure on the fire resistance of supports and hangers has also been discussed in this paper. Moreover, the improved fire resistant testing and evaluating method has been proposed here.

Keywords. Supports and hangers, service installation, fire resistance, fire testing and evaluating method

1. Introduction

Supports and hangers are widely used in the mechanical and electrical engineering installation field, including building water supply and drainage system, ventilation system, air conditioning system, gas supply system, heating system, smoke extraction system, power supply system and so on. According to the external load in the end use, their installed structure and method are different significantly. At present, supports and hangers are always utilized as the single pipe type and the door-shaped type based on the construction characteristics of the products. The single pipe type supports and hangers is used for single water supply/drainage pipe, and the door shaped type supports and hangers is used for ventilation or smoke extraction ducts, cable trays, or their assemblies [1]. Mechanical and electrical engineering installation system contains the penetration items, like pipes, cables, conduits, trays, and ducts, which always penetrate through the walls or floors of building compartment to the adjacent one. Therefore, supports and hangers as the fixing accessories for these penetration items should not only satisfy the requirement of bearing capacity, but also resist the destructive force caused by the earthquake and high temperature attack from fire [2]. Current most related regulations emphasis on the requirements of their installation

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process and mechanical property. However, high temperature from fire could induce the reduction in mechanical property of supports and hangers, and then the destruction of the installation system, which finally results in the spread of flame and smoke to another compartment from the opening formed due to the collapse of the penetration items. Moreover, the destruction of supports and hangers in the fire could also cause the ineffectiveness of the fire facilities, such as the smoke extraction ducts and fans, and then increase the hazard of fire and the difficulty of rescue.

Different application of supports and hangers leads to the difference in the requirement of its fire resistance. But related regulations only provide a universal testing and evaluating method to determine the fire resistance of supports and hangers used in the various field. In China, only GB/T 37267 General technical conditions for seismic support and hanger of buildings provides the fire resistance requirement for supports and hangers as the seismic bracing. It mentions that the fire endurance of the supports and hanger should not be less than 180 min with a constant load of 20.4 kg, and they should keep their integrity under the exposure of fire without breakage or falling of component in the test [2]. This could cause the lack in the accuracy of fire resistance evaluation. And the fire resistance of supports and hangers has been rarely mentioned in some standards and regulations involved to supports and hangers in the developed country. All these result in the ineffectiveness and inaccuracy during supervision in the fire resistance of supports and hangers, which finally reduce the fire safety in the building. Therefore, it is essential to find a comprehensive method to test and evaluate their fire resistance in the actual working condition. In this study, a series of fire resistant testing for supports and hangers used in different working condition have been carried out and the effect of load and structure on the fire resistance of supports and hangers has also been discussed, which aims to provide a reference for the revision of the fire resistant standard of supports and hangers in the future.

2. Experimental

2.1. Sample

2.1.1. Sample with the Specific Load

A load of 20.4 kg was added to the connection of the sample and the pipe during test. In this study, the round object used for simulating the pipes as the concentrated load was added to the single pipe type supports and hangers, which was placed in the pipe clamp. And the rectangle object used for simulating the duct or cable tray as the distributed load was added to the door-shaped type supports and hangers, which was placed on the beam.

2.1.2. Sample with the Actual Load

2.1.2.1. Supports and Hangers for Single Pipe Used in Building Water Supply or Drainage System

According to Provisions of Indoor Supports and Hangers for Pipes (Atlas No. 03s402), the weight of thermal insulation pipe was calculated by adding the dead weight of the pipe, the water weight of the full pipe, the weight of the insulation layer with 60 mm thickness, and the 10% additional weight of the sum of these three items. The weight of uninsulated pipe was calculated by adding the dead weight of the pipe, the water

weight of the full pipe and the 10% additional weight of the sum of the two items. The unit weight of insulation layer was calculated as 100kg/m^3. Table 1 shows the reference weight of the loadbearing capacity of the single pipe type supports and hangers for building water supply or drainage system.

Table 1. Reference weight of pipe for water supply and drainage system.

Nominal diameter DN/mm		65	80	100	125	150	200	250	300	350
Wall thickness/mm		3.75	4	4	4	4.5	6	6.5	7.5	9
Calculated length/m	WI	3	3	3	6	6	6	6	6	6
	WOI	6	6	6	6	6	6	6	6	6
Weight/kg	WI	42.3	53.2	75.8	204.0	271.8	465.2	673.8	933.6	1265.4
	WOI	67.8	88.6	129.8	178.8	243.6	430.4	632.4	885.6	1210.8

"WOI" means without insulation
"WI" means with insulation

2.1.2.2. Supports and Hangers for Ventilation or Smoke Extraction System

According to Provisions of Supports and Hangers for Metal and Non-metal Air Ducts (Atlas No. 19k112), the weight of ventilation or smoke extraction duct with insulation was calculated by adding the weight of the metal duct and the weight of the insulation layer. The weight of metal duct was calculated according to the steel plate with a density of 7850 kg/m^3, and the weight of insulation layer was calculated with a density of 70 kg/m^3 and a thickness of 40 mm. The thickness of air duct plate and flange type was selected and calculated according to GB 50243-2016 code of acceptance for construction quality of ventilation and air conditioning works. Table 2 shows the reference weight of supports and hangers for ventilation or smoke extraction duct system [3].

Table 2. Reference weight of rectangular duct for ventilation or smoke extractioning system.

Horizontal width/mm		400	500	630	800	800	1000	1250	1600	2000	2000
Vertical height/mm		300	400	500	600	700	800	800	800	800	1000
Weight of insulation/kg		18.1	22.7	28.0	34.3	36.6	43.5	49.3	57.4	66.7	71.3
Weight of flange/kg		10.9	14.0	17.6	26.7	28.6	34.3	39.1	80.7	94.2	100.9
Calculated length/m		3	3	3	3	3	3	3	3	3	3
Low pressure	Thickness/mm	0.5	0.6	0.6	0.75	0.75	0.75	1.0	1.0	1.0	1.0
	WOI/kg	33.6	49.0	61.6	94.8	101.6	121.9	172.1	236.4	275.8	295.5
	WI/kg	51.7	71.7	89.6	129.1	138.2	165.4	221.4	293.8	342.5	366.8
Middle pressure	Thickness/mm	0.6	0.75	0.75	0.75	0.75	0.75	1.0	1.2	1.2	1.2
	WOI/kg	38.1	57.8	72.6	94.8	101.6	121.9	172.1	267.6	312.2	334.5
	WI/kg	56.2	80.5	100.6	129.1	138.2	165.4	221.4	325.0	378.8	405.8

	Thickness/mm	0.75	1.0	1.0	1.0	1.0	1.0	1.2	1.5	1.5	1.5
High pressure	WOI/kg	45.0	72.4	90.9	117.5	125.9	151.1	198.7	314.3	366.7	392.9
	WI/kg	63.0	95.1	118.9	151.8	162.5	194.6	248.0	371.7	433.3	464.1

"WOI" means without insulation
"WI" means with insulation

2.1.2.3. Supports and Hangers for Cable Tray System

According to Provisions of Seismic Installation of Building Electrical Facilities (Atlas No. 16d707-1), the weight of cable tray is calculated and listed in table 3 [3].

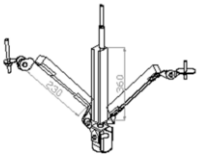
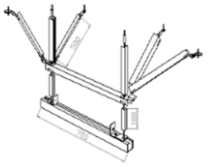
Table 3. Reference weight of cable tray system.

Horizontal width/mm	100	200	300	400	400	500	500	600	600	800	1000
Vertical height/mm	100	100	100	100	150	100	150	100	150	150	150
Load per meter/kg	20	40	60	80	120	100	150	120	180	240	300
Weight calculated length of 3m/kg	60	120	180	40	360	300	450	360	540	720	900
Weight calculated length of 6m/kg	120	240	360	80	720	600	900	720	1080	1440	1800

2.1.3. Testing Samples

Supports and hangers were used with C-shaped channel steel, anchor bolts, screws, nuts, pipe clamps and connectors, which could meet the requirements of GB/T 38053, GB/T 37267 and other national standards of China. Table 4 presents the details and product information of the testing samples with the specific load. Table 5 shows the details and product information of the testing samples with the actual load.

Table 4. Testing samples with the specific load.

Sample	Composition	Structure
1	Composed of C-shaped channel steel with a thickness of 2.5 mm, M10 anchor bolt, M10 threaded rod, M10 nut, U-shaped pipe clamp, and connector with a thickness of 6 mm	
2	Composed of C-shaped channel steel with a thickness of 2.5mm, M12 anchor bolt, M12 threaded rod, M12 nut, and connector with a thickness of 6 mm	

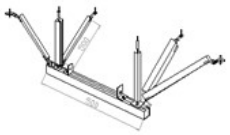
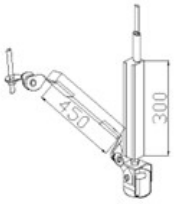
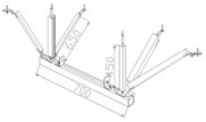
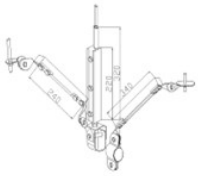
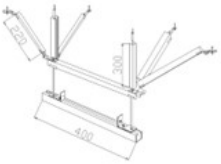
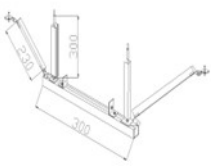
3	Composed of C-shaped channel steel with a thickness of 2.5mm, M12 anchor bolt, M12 threaded rod, M12 nut, and connector with a thickness of 6 mm	

Table 5. Testing samples with the actual load.

Sample	Composition	Structure
4, 7	Composed of C-shaped channel steel with a thickness of 2.0 mm, M10 anchor bolt, M10 threaded rod, M12 screw bolt and nut, U-shaped pipe clamp, and connector with a thickness of 5 mm	
5, 8	Composed of C-shaped steel channel with a thickness of 2.0 mm, M12 anchor bolt, M12 threaded rod, M12 screw bolt and nut, and connector with a thickness of 5 mm	
6, 9	Composed of C-shaped channel steel with a thickness of 2.0 mm, M12 anchor bolt, M12 threaded rod, M12 screw bolt and nut, and connector with a thickness of 5 mm	
10, 13	Composed of C-shaped channel steel with a thickness of 2.0 mm, M10 anchor bolt, M10 threaded rod, M10 screw bolt and nut, U-shaped pipe clamp, and connector with a thickness of 5mm	
11, 14	Composed of C-shaped channel steel with a thickness of 2.0 mm, M12 anchor bolt, M12 threaded rod, M12 screw bolt and nut, and connector with a thickness of 5 mm	

12, 15	Composed of C-shaped channel steel with a thickness of 2.0 mm, M12 anchor bolt, M12 threaded rod, M12 screw bolt and nut, and connector with a thickness of 5 mm	

2.2. Characterization

An improved method has been proposed here to test and evaluate the fire resistance of supports and hangers in the actual working condition, which could make their whole evaluation system more reasonable and comprehensive. Compared to GB/T 37267, the determination of the maximum deformation after the test has been added into the improved evaluation method. The testing sample was heated conformed to the standard time-temperature curve (figure 1) in GB/T 9978.1 [4]. Fire resistance of supports and hangers is determined based on the time of losing their structural stability or loses bearing capacity. In the improved method, the supports and hangers could be considered to lose the structural stability when their components break, fall off, or collapse. And the supports and hangers could be considered to lose the loadbearing capacity when they cannot maintain the bearing capacity continuously, or the maximum deflection exceeds 50mm.

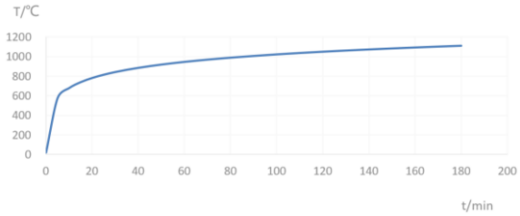


Figure 1. The standard time-temperature curve in GB/T 9978.1.

3. Results and Discussions

3.1. Fire Resistance of Supports and Hangers with the Specific Load

Table 6 shows the fire resistance of supports and hangers used as the seismic bracing with the specific load. It can be seen that the fire resistant rating of Sample 1, 2 and 3 with a specific load of 20.4 kg is more than 180 min, and all the samples could maintain basically integrity without any significant deformation, indicating that these supports and hangers samples could meet the fire resistant requirement from GB/T 36237

Table 6. Fire resistance of supports and hangers with the specific load.

Sample	Supports and hangers	Load/kg	Load mode	Fire resistance	Application
1	For single pipe	20.4	Concentrated load	>180min	DN65~DN125 pipe for water supply
2	For duct	20.4	Distributed load	>180min	Rectangular duct with horizontal width of cross-section less than 500mm
3	For cable tray	20.4	Distributed load	>180min	Cable tray with horizontal width of cross-section less than 500mm

3.2. Fire Resistance of Supports and Hangers with the Actual Load

Table 7 presents the fire resistance of supports and hangers with the actual load. It shows that the fire resistance of supports and hangers with actual loads depends on their application greatly.

Table 7. Fire resistance of supports and hangers with the actual load.

Sample	Supports and hangers	Load/kg	load mode	Fire resistance	Application
4	For single pipe	20	Concentrated load	>180min	DN65~DN125 pipe for water supply, calculated according to the weight of pipe less than DN65
5	For duct	30	Concentrated load	50min, Beam deformation exceeds 50mm	Rectangular duct with horizontal width of cross-section less than 500mm, calculated according to the weight of duct with no insulation and a cross-section of 400mm×300mm.
6	For cable tray	100	Concentrated load	30min, Beam deformation exceeds 50mm	Cable tray with horizontal width of cross-section less than 500mm, calculated according to the weight of cable tray with a width of 200mm.
7	For single pipe	50	Concentrated load	>180min	DN65~DN125 pipe for water supply, calculated according to the weight of DN80
8	For duct	80	Distributed load	>180min	Rectangular duct with horizontal width of cross-section less than 500mm, calculated according to the weight of duct with insulation and a cross-section of 500mm×400mm.
9	For cable tray	100	Distributed load	55min, Collapse of supports and hangers	Cable tray with horizontal width of cross-section less than 500mm, calculated according to the weight of cable tray with a width of 200mm.
10	For single pipe	50	Concentrated load	26min, Collapse of supports and hangers	DN65~DN125 pipe for water supply, calculated according to the weight of DN80

11	For duct	40	Concentrated load	>180min	calculated according to the weight of high pressure duct with no insulation and a cross-section of 500mm×400mm.
12	For cable tray	100	Concentrated load	120 min, Beam deformation exceeds 50mm	calculated according to the weight of cable tray with a cross-section width less than 200mm.
13	For single pipe	40	Concentrated load	65 min, Collapse of supports and hangers	DN65~DN125 pipe for water supply, calculated according to the weight of DN65
14	For duct	60	Distributed load	>180min	Calculated according to the weight of high pressure duct with insulation and a cross-section of 400mm×300mm.
15	For cable tray	60	Distributed load	145 min, Collapse of supports and hangers	calculated according to the weight of cable tray with a cross-section width less than 100mm.

3.2.1. Effect of Bearing Load on Fire Resistance of Supports and Hangers

Bearing load of supports and hangers depends on their application significantly. Figure 2 presents the fire resistance of supports and hangers with different bearing load and loading mode. It can be seen that the higher the bearing load for supports and hangers, the lower their fire resistant rating based on comparison of Sample 10 and Sample13, which have the same single pipe type construction with concentrated load, comparison of Sample 5 and Sample 6, which have the same door shaped type construction with concentrated load in the middle of the span of the channel beam, comparison of Sample 8 and Sample 9, which have the same door shaped type construction with distributed load. This could be attributed to the deformation and destruction of supports and hangers at the high temperature range due to the addition of the high bearing loading. It can be inferred that the bearing load plays a key role in the reduction in the fire resistance of supports and hangers.

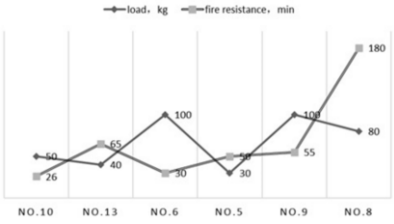


Figure 2. Fire resistance of supports and hangers with different load.

3.2.2. Effect of Loading Mode on Fire Resistance of Supports and Hangers

Single pipe type supports and hangers mainly bear centric load, while door shaped type samples could bear either concentrated load or distributed load. Figure 3 shows the fire resistance of supports and hangers with different loading mode. Comparisons between Sample 5 and Sample 8, Sample 6 and Sample 9, Sample 12 and Sample 15 have been made in this study. The result indicates that the fire resistant rating of the sample with concentrated load is lower than that of the sample with distributed load. It could be concluded that the loading mode also plays an important role on the fire resistance of supports and hangers.

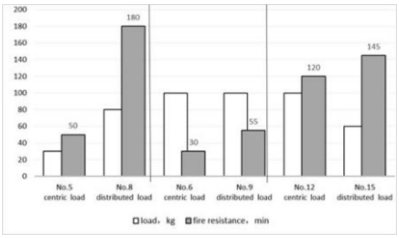


Figure 3. Fire resistance of supports and hangers with different loading mode.

3.2.3. Effect of Moment from Door Shaped Type Supports and Hangers on the Fire Resistance

Channel beam has been used to support the door shaped type supports, and its length is always related to the bearing load. Fire resistance of supports and hangers with different moment has been presented in figure 4 Comparison of Sample 5 and Sample 11 used for duct, Sample 6 and Sample 12 used for cable tray has been made here. It shows that the lower moment from door shaped type supports and hangers is, the higher the fire resistant rating is. And the length of channel beam, the bearing load and the loading point has an important influence on the moment from supports and hangers.

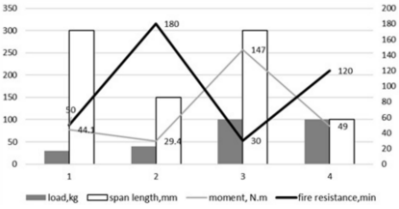


Figure 4. Fire resistance of supports and hangers with different moment.

3.2.4. Other Factors Affecting the Fire Resistance of Supports and Hangers

Different supports and hangers possess different mechanical properties when exposed to fire or high temperature. Besides the factors mentioned above, there are some other factors affecting the fire resistance of samples, such as the connection with the foundation, the loading direction, the installation fastness of components, the number and distribution of loading points, and so on. For instance, fire resistant rating of Sample 4 and Sample 7 could reach more than 180 min, while Sample 10 has a lower rating of 26 min. Therefore, supports and hangers should be constructed strictly during installation in accordance with the related requirement of relevant technical specifications, in order to inhibit the reduction in their fire resistance during the actual application.

Based on the improved testing and evaluating method for supports and hangers in combination with these results and related phenomena, it shows that the loss in the bearing capacity of supports and hangers always associates with the separation of the junction from supports and hangers and the serious deformation of channel beam at the high temperature range.

- Separation of the junction from supports and hangers. Samples are always constructed with clamp, threaded rod, trapeze rod, trapeze frame, channel through saddle nut, bolt, channel connector, drilled plate and so on. And the

reduction in the mechanical properties of these elements made from steel, such as yield point, tensile strength, bending resistance and elastic modulus could be observed significantly due to high temperature (up to 600 ℃), which could finally result in the separation of the junction and then the collapse of supports and hangers (Sample 10 and Sample 13).

- Serious deformation of channel beam. Channel beam, composed of steel, from door-shaped type samples directly bears the load. At the high temperature range, deformation and bending could be observed from the beam of the samples due to the reduction in bending resistance of channel steel, especially when concentrated load is applied at the middle of the channel beam. And the significant deformation of the channel beam, which changes the stress mode of the structure, could result in a remarkable displacement which could finally affect the fire resistance of supports and hangers.

4. Conclusion

In this study, taking supports and hangers used for building water supply or drainage pipe, ventilation or smoke extraction duct and cable tray as the typical application in the working condition, an improved testing and evaluating method has been proposed and the burning behavior of supports and hangers has been investigated here. Based on the results from these tests, it can be seen although the excellent fire resistant could be observed from supports and hangers as the seismic bracing during test according to the current standard GB/T 37267 General technical conditions for seismic support and hanger of buildings, many factors affecting the burning behavior of supports and hangers at high temperature range during actual application condition. These factors, including material, quality, the load weight, loading distribution, moment and installation method of the samples have a significant impact on the fire resistance of supports and hangers. Therefore, more factor should be considered in combination with the actual application condition when the evaluation of the fire resistance of supports and hangers, in order to improve the effectiveness and accuracy during supervision in the fire resistance of supports and hangers, which finally increase the fire safety in the building.

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