Statistics and Analysis of Steel-Concrete Composite Simply Supported Box Girder Bridges in china

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Abstract. This paper collects the basic information of steel-concrete simply supported box girder bridges in China, analyzes And Summarizes its design parameters such as span, height-to-span ratio, bridge width, steel bottom plate thickness, steel web thickness, concrete roof thickness, and material grade. The results show that compared with the ordinary concrete beam bridge, the steel-concrete composite simply supported box girder bridge has a 70% reduction in web weight, and has a stronger spanning ability,and has a Lower beam height under the same span. The correlation equation between height-span ratio and span is fitted, which can be used as a reference for future design research of steel-concrete composite simply supported box girder bridges.

Keywords: steel-concrete composite structure, simply supported box girder bridge, statistical analysis, design parameters.

1. Introduction

The steel-concrete composite simply supported box girder can maximize the tensile and compressive properties of steel and concrete, and it has been increasingly used in bridge construction in recent years. This paper collects the basic data of 28 steel-concrete composite simply supported box girder bridges, analyses and summarizes the design parameters such as span, height-to-span ratio, bridge width, steel bottom plate thickness, steel web thickness, concrete top plate thickness, and material grade , It can provide reference for the design and research of steel-concrete composite simply supported box girder bridge.

2. Investigation status

As early as the beginning of the 20th century, the research and application of the composite beam structure system began abroad. [1]。In contrast, domestic steel-concrete composite bridges were almost zero before the 1990s, and their overall development was lagging behind the international level.

Since 1993, experts and scholars represented by Nie Jianguo have conducted a large number of experiments and theoretical studies on the bending performance, shear resistance and stability characteristics of steel-concrete composite bridges.Then, based on the experimental and theoretical research results, national and industry standards such as "Code for Design of Steel-Concrete Composite Bridges" [2] and "Code for Design of Highway Steel Structure Bridges" [3] were formulated and gradually improved.improved the basic theory of steel-concrete composite structure to a new level. The 2005 National Bridge Academic Conference [4] discussed the development status of composite structure bridges and a large number of studies on the load-bearing system of composite steel plate girder bridges in various countries over the years. Since 2010, Nie Jianguo and other scholars analyze and research the most advanced development profile in terms of corrugated steel web composite girder bridges, channel steel-concrete composite girder bridges, steel-concrete composite rigid frame bridges, double composite continuous composite girder bridges, and cable-stayed bridge composite deck systems,They found that the advantages of steel-concrete composite structures will become more and more significant with the continuous improvement and development of conventional structural forms.， so it has broad application prospects [5-6] .

At present, on the basis of the same construction conditions, design theory and construction technology in China, steel-concrete composite structures are quite competitive on medium and long span bridges of 40m to 100m or even larger span bridges. There are a total of 28 steel-concrete composite simply supported box girder bridges collected in this paper. The main statistical design parameters include bridge name, span, bridge width, beam height, section form, concrete roof thickness, Steel floor thickness, etc., in order to understand the parameter value range of the steel-concrete composite simply supported box girder in more detail. The main design parameters of the investigated bridge can be seen in Table 1.

Table 1. Investigation of steel-concrete composite simply supported box girder

Serial number	Bridge name	Span (m)	Bridge width (m)	Beam height (m)	Concrete roof thickness (m)		Steel floor thickness (mm)		Steel web thickness (mm)	
					Fulcrum	midspan	Fulcrum	midspan	Fulcrum	midspan
1	Bridge1	20	19.5	1.84	0.24	0.24	12	12	14	10
2	Bridge2	60	12.75	2.6	0.45	0.3	35	35	22	22
3	Bridge3	55	12.75	2.6	0.45	0.3	30	30	22	22
4	Bridge4	50	26	2.8	0.22	0.22	30	40	16	12
5	Bridge5	50	27	2.795	0.22	0.22	20	40	16	12
6	Bridge6	55	13.25	2.8	0.22	0.22	30	45	16	12
7	Bridge7	45	17.25	2.29	0.22	0.22	25	35	16	12
8	Bridge8	45	18.627	2.29	0.22	0.22	25	35	16	12
9	Bridge9	45	21.369	2.29	0.2	0.22	25	35	16	12
10	Bridge10	58	19.5	2.9	0.35	0.35	18	25	18	14
11	Bridge11	55	10	2.7	0.35	0.35	18	32	18	14
12	Bridge12	60	24.25	2.7	0.2	0.2	20	28	18	14
13	Bridge13	50	12.75	2.5	0.25	0.25	18	38	16	16
14	Bridge14	50	16.25	2.312	0.3	0.3	16	28	14	14
15	Bridge15	51	12.25	2.934	0.36	0.26	26	30	20	16
16	Bridge16	62	20.2	2.9	0.24	0.24	30	60	20	16
17	Bridge17	42	31.5	2.2	0.45	0.35	25	25	16	16
18	Bridge18	22.16	12	1.3	0.2	0.2	16	16	14	14
19	Bridge19	40	5.5	2	0.25	0.25	18	30	16	14
20	Bridge20	50	5.5	2.5	0.25	0.25	18	38	16	16
21	Bridge21	50	13.75	2.692	0.36	0.26	16	32	16	12
22	Bridge22	13	13.5	0.75	0.2	0.2	12	12	12	12
23	Bridge23	16	13.5	0.85	0.2	0.2	12	12	12	12
24	Bridge24	20	13.5	1	0.2	0.2	14	14	14	14
25	Bridge25	25	13.5	1.3	0.2	0.2	14	14	14	14
26	Bridge26	30	13.5	1.6	0.2	0.2	14	14	14	14
27	Bridge27	35	13.5	1.8	0.2	0.2	14	14	14	14
28	Bridge28	40	13.5	1.8	0.2	0.2	14	14	14	14

Note:Due to the space limitation in this paper, only the main design parameters of the investigated bridge are listed

This article introduces the existing diseases of the Songkou Bridge, and through the analysis of the causes of the diseases, three types of reinforcement and reconstruction schemes are formed. Then take economic efficiency, construction period, traffic pressure during construction and long-term economic benefits as the main evaluation indicators, compare and select the best plan to reform the bridge to meet the requirements of structural safety and traffic.

3. Analysis of calculation parameters for bridge design

The design and calculation parameters of the steel-concrete composite simply supported beam bridge: span, height-to-span ratio, bridge width, steel bottom plate thickness, steel web thickness, concrete top plate thickness, material grade, etc. are analyzed.

3.1. Span statistics

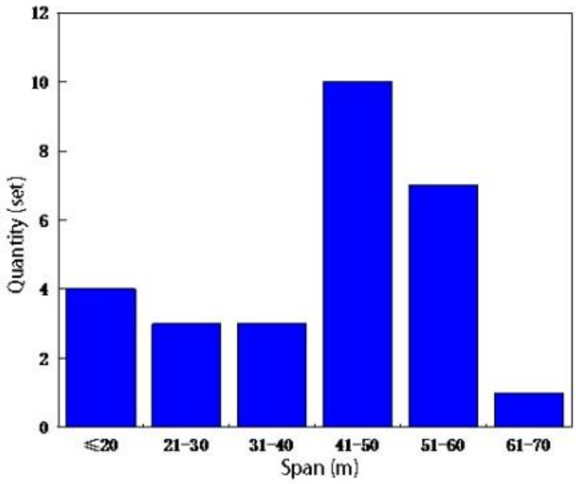

Figure 1. Span distribution of steel-concrete composite simply supported box girder bridge

Figure 1 shows the distribution of the span of the steel-concrete composite simply supported box girder bridge.It can be seen from the figure that the span of the steel-concrete composite simply supported box girder is mainly distributed between 41 and 60m, the largest number is distributed between 41～50m (10 seats) accounting for 35.7% of the total number of surveyed bridges (28)the maximum span of the steel-concrete composite simply supported box girder bridge is 62m,At present, the span of reinforced concrete box girder bridges is generally not more than 20m.，The span of prestressed concrete simply supported beam bridges is generally not more than 40m.，It shows that the steel-concrete composite simply supported box girder has a greater spanning capacity than the steel/prestressed concrete box girder bridge.

3.2. Parameter analysis of height span ratio

For a simply supported girder bridge, its height-to-span ratio (the ratio of the height of the box girder to its calculated span) is an important parameter in the design of the bridge structure, which has a greater impact on the stability of the bridge, and should be controlled at a certain level during design.If the height-span ratio of the simply supported beam is too large, the weight of the beam will increase, thereby increasing the cost; on the contrary, if the height-span ratio of the simply supported beam is too small, it will not be able to meet the bending, shear resistance and structure stiffness of the bridge's normal section.

Figure 2 shows the relationship between the height-span ratio and the span of the steel-concrete composite simply supported box girder.It can be seen from the figure that when the span of the steel-concrete composite simply supported box girder is greater than 50m, the height-span ratio is mainly concentrated between 0.04 and 0.05. When the span is less than 50m, the height-span ratio is mainly concentrated between 0.05 and 0.06.From the statistics of the height-span ratio of ordinary concrete simply supported beams, the height-span ratios of simply supported T beams with spans less than 20m are mainly concentrated in the range of 0.056 to 0.091; when the span is greater than 20m, the height-span ratios are mainly concentrated in the range of 0.05 to 0.059.It can be seen from the comparison of the two that when the span is the same, the height of the steel-concrete composite simply supported box girder is usually slightly lower than that of the ordinary concrete simply supported girder.

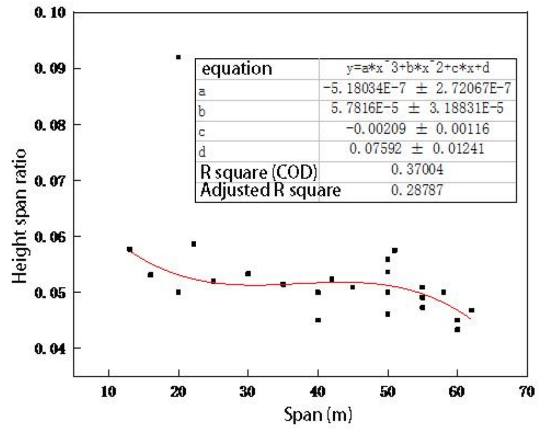

Figure 2. Relationship between height span ratio and span of steel-concrete composite simply supported box girder

Fitting the data in Figure 2, the correlation equation between the height-span ratio and the span of the steel-concrete composite simply supported box girder can be obtained, As shown in formula (1), The average ratio of the survey data to the fitting formula is 1.027, and the mean square error is 0.151. It can be used as a reference for the design of the beam height of the steel-concrete composite simply supported box girder in the future.

$$H/L = -5.180L^3 + 5.782L^2 - 0.002L + 0.076 \quad (1)$$

3.3. Bridge width parameter analysis

The width-to-span ratio of a simply supported girder bridge is the ratio of the bridge deck width of the simply supported girder bridge to its calculated span, which is controlled by the amount of traffic.When the width-to-span ratio of the simply supported beam bridge does not exceed 0.5, it can be considered that the bridge is a narrow bridge, and the force of the beam is close to that of a one-way slab;When the width-to-span ratio of a simply supported beam bridge is greater than 0.5, it can be considered that the bridge is a wide bridge, and the force of the beam is close to that of a two-way slab.

It can be seen from Figure 3 that the width-to-span ratio of the steel-concrete composite simply supported box girder bridge is mainly distributed between 0.2 and 0.6, with the 0.2-0.4 section being the most concentrated, and as the span increases, the width-to-span ratio Shows a decreasing trend.The width-to-span ratio of simply supported beam bridges is mainly between 0.3 and 0.5, and the deck width of the steel-concrete composite simply supported box girder bridge is almost the same as that of the simply supported T-beam bridge.

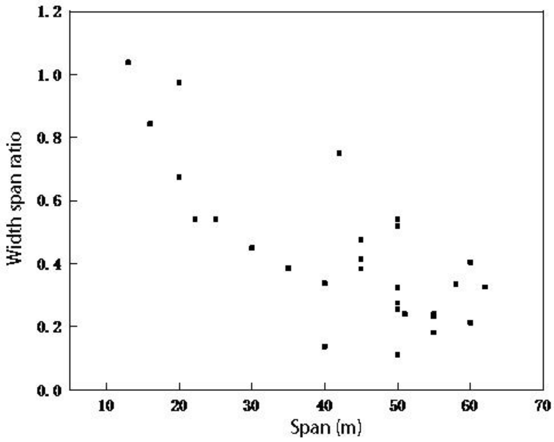

Figure 3. Relationship between width span ratio and span of steel-concrete composite simply supported box girder bridge

3.4. steel bottom plate thickness parameters Analysis

The thickness of the steel base plate of the steel-concrete composite simply supported box girder is related to the bending moment borne by the section. The bending moment of the section from the mid-span to the fulcrum varies from maximum to zero.In the design, the thickness of the steel bottom plate at the middle of the span is the largest, and the thickness at the fulcrum is the smallest.

It can be seen from Figures 4 and 5 that the ratio of the maximum floor thickness to the span is mainly distributed between 0.0004 and 0.0008, and the section of 0.0004 to 0.0006 is more concentrated; the ratio of the minimum floor thickness to the span is mainly distributed between 0.0002 and Between 0.0006, among which the 0.0004 to 0.0006 section is the most concentrated.

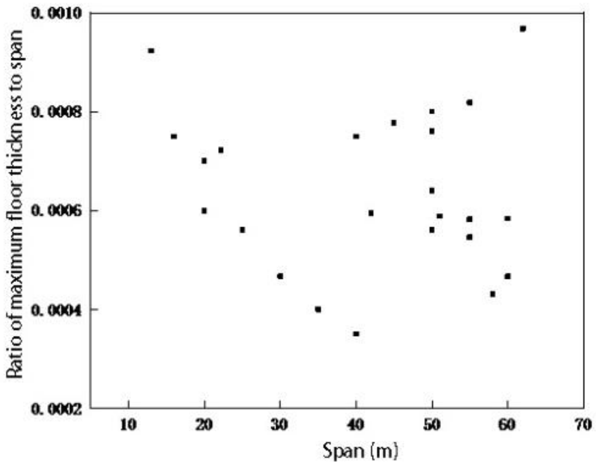

Figure 4. Relationship between the ratio of the maximum floor thickness to the span and the span

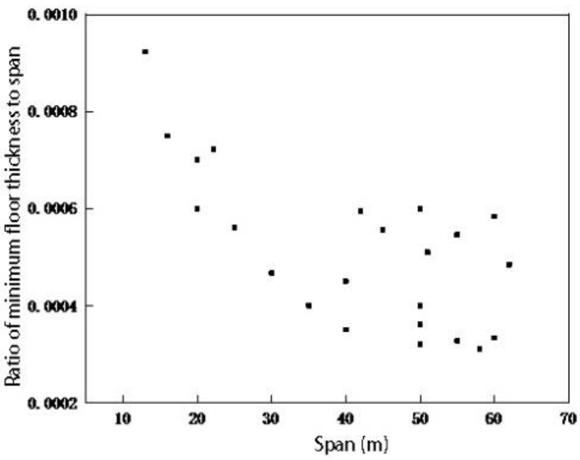

Figure 5. Relationship between the ratio of minimum floor thickness to span and span

3.5. Analysis of Steel Web Thickness Parameters

The main function of the web of the box girder structure is to resist shear and connect the top and bottom plates to form an overall cross-section, but the web has a small contribution to the bending moment of inertia of the box girder structure, and the use efficiency of the web is not high. For prestressed reinforced concrete box girder, because the web needs to be arranged with bent steel bars and stirrups, considering the thickness of the protective layer, the weight of the concrete web will account for about 30% of the weight of the entire box girder structure, which will severely restrict This improves the ability of the concrete box girder structure to span larger spans.Therefore, lightweight and high-strength steel webs can be used to replace concrete webs. In the design of a real bridge, the thickness of the steel webs at the fulcrum is the largest, and the thickness at the middle of the span is the smallest.

Figures 6 and 7 show the relationship between the ratio of the maximum/minimum thickness of the steel box web to the span and the span. It can be seen from the figure that the ratio of the maximum web thickness to the span is mainly distributed between 0.0002 and 0.0004, of which the 0.0003 to 0.0004 section is the most concentrated; the ratio of the minimum web thickness to the span is mainly distributed between 0.0002 and 0.0004 Among them, the 0.0002～0.0003 section is the most concentrated.

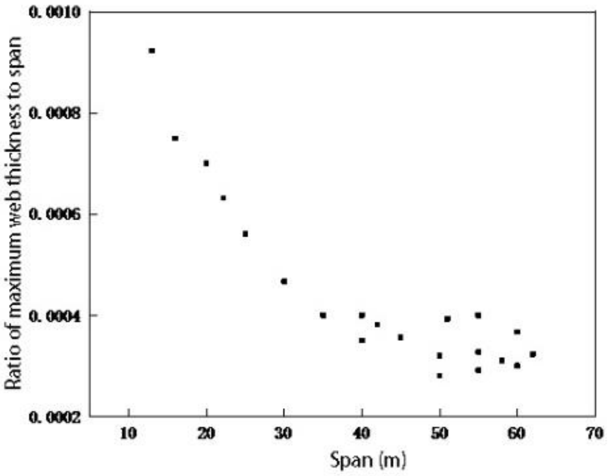

Figure 6. Relationship between maximum web thickness and span ratio and span

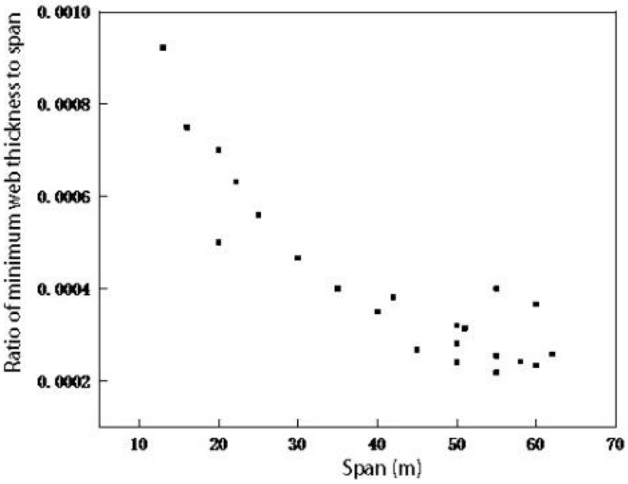

Figure 7. Relationship between minimum web thickness and span ratio and span

The ratio of the minimum web thickness to the span of ordinary concrete simply supported box girder is mainly concentrated between 0.0045 and 0.007, and the ratio of the maximum web thickness to the span is mainly concentrated between 0.009 and 0.028. The comparison of the two shows that when the span is the same, the thickness of the steel web of the steel-concrete composite simply supported box girder is usually less than 1/10 of the thickness of the ordinary concrete simply supported box girder. In the case of the same beam section height, the web structure weight of the steel-concrete composite simply supported box girder will be only 30% of the ordinary concrete simply supported box girder, which will greatly reduce the structural weight and provide a breakthrough for the simply supported beam to achieve larger spans.

3.6. Analysis of Thickness Parameters of Concrete Roof

The concrete top slab in the steel-concrete composite simply supported box girder is in the compression zone, and can give full play to its compressive characteristics under the positive bending moment generated by the load. Its thickness is related to the longitudinal flexural bearing capacity, and the local force is related to The distance between the diaphragms is related to the distance between the steel webs.

Figures 8 and 9 show the relationship between the ratio of the thickness of the concrete top slab to the spacing of the diaphragm and the span.It can be seen from Figure 8 that the ratio of the thickness of the concrete top slab to the distance between the largest diaphragms is mainly distributed between 0.02 and 0.06, of which the 0.04-0.06 section is the most concentrated; the ratio of the thickness of the concrete roof to the smallest distance between the diaphragms is mainly distributed at 0.02 ～ 0.06, of which the 0.04～0.06 section is the most concentrated.

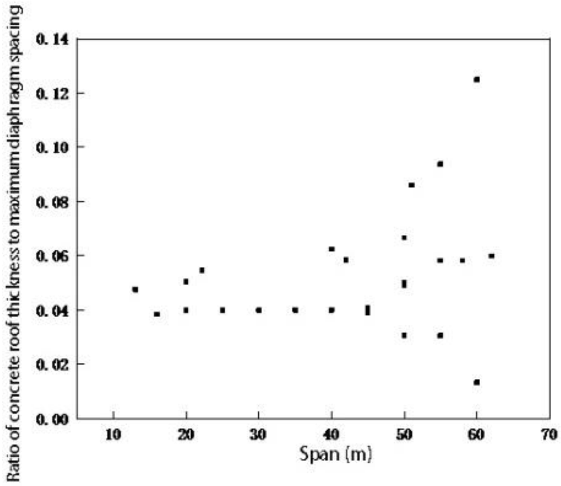

Figure 8. Relationship between the ratio of roof thickness to the maximum diaphragm spacing and span

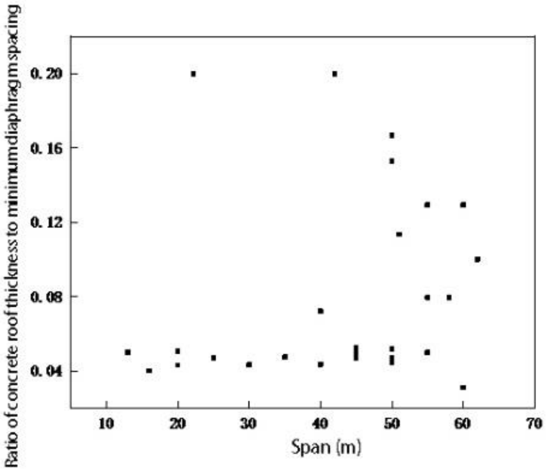

Figure 9. Relationship between the ratio of roof thickness to minimum diaphragm spacing and span

Figure 10 shows the relationship between the ratio of the thickness of the concrete top slab to the lateral spacing of the steel web and the span. It can be seen from the figure that when the span is less than 40m, the ratio of the thickness of the concrete top slab to the transverse spacing of the steel web is mainly concentrated between 0.14 and 0.16; when the span of the steel-concrete composite simply supported box girder is greater than 40m , The ratio of the thickness of the concrete roof to the transverse spacing of the steel web is mainly concentrated between 0.08 and 0.12.The ratio of the top plate thickness to the web spacing of ordinary concrete simply supported box girder is mainly concentrated between 0.089 and 0.100, which means that under the same span, the thickness of the top plate of the steel-concrete composite simply supported box girder is higher than that of ordinary concrete simply supported box girder.

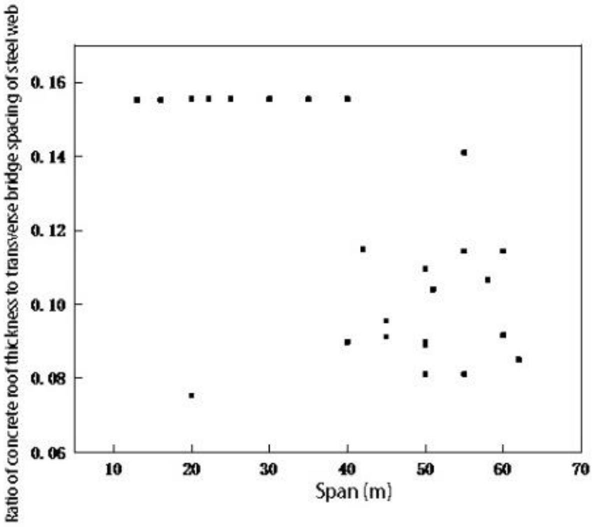

Figure 10. Relationship between the ratio of concrete roof thickness to transverse spacing of steel webs and span

3.7. Material grade parameter analysis

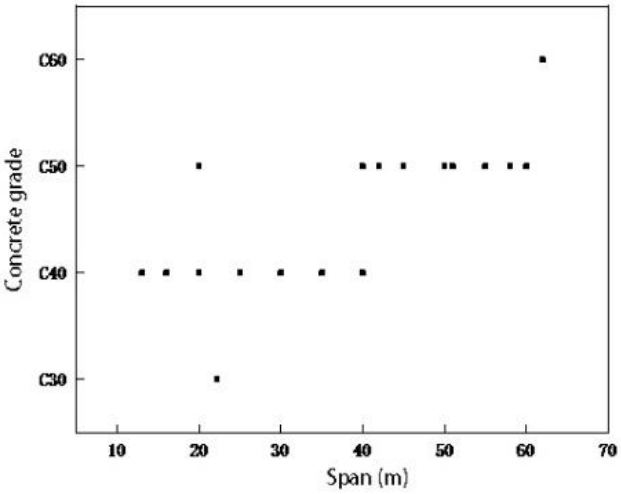

Figure 11. shows the relationship between concrete grade and span of steel-concrete composite simply supported box girder. It can be seen from the figure that when the span is less than 40m, the steel-concrete composite simply supported box girder generally uses C40 concrete; When the span is greater than 40m, most of the C50 concrete is selected, indicating that the concrete grade used in the steel-concrete composite simply supported box girder increases with the increase of the span.

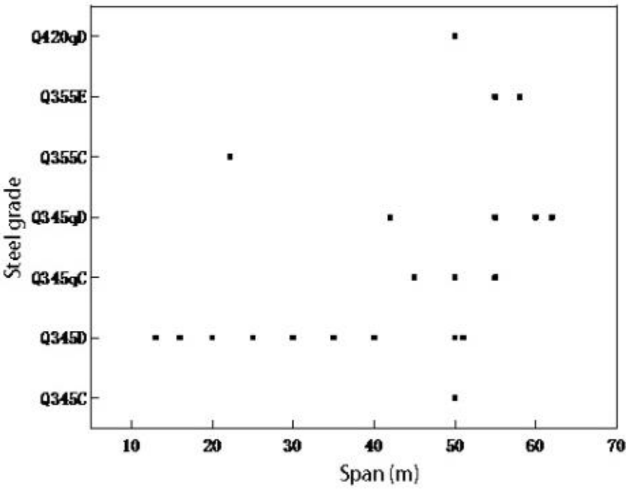

Figure 12. shows the relationship between steel grade and span of steel-concrete composite simply supported box girder. It can be seen from the figure that when the span of the steel-concrete composite simply supported box girder is less than 50m, the steel is mainly Q345D steel, and the grade of steel used increases as the span increases.

4. Conclusion

(1) The spans of steel-concrete composite simply supported box girder are mainly distributed between 41 and 60m. Among them, the number of spans between 41 and 50m is the largest (10), accounting for 35.7% of the total number of surveyed bridges (28). Its maximum span is 62m, which is much larger than the ordinary concrete simply supported box girder bridge, indicating that the steel-concrete composite simply supported box girder has a greater spanning capacity.

(2) When the span of the steel-concrete composite simply supported box girder is greater than 50m, the height-span ratio is mainly concentrated between 0.04 and 0.05; when the span is less than 50m, the height-span ratio is mainly concentrated between 0.05 and 0.06;Under the same span, the beam height of the steel-concrete composite simply-supported box girder is slightly lower than that of the ordinary concrete simply-supported box girder; the correlation between the height-span ratio and the

span of the steel-concrete composite simply-supported box girder is obtained by fitting The equation has an average ratio of 1.027 and a mean square error of 0.151, which can be used as a reference for future design research on the beam height of steel-concrete composite simply supported beam bridges.

(3) The ratio of the web thickness to the span of the steel-concrete composite simply supported box girder is mainly concentrated between 0.0002 and 0.0004. The thickness of the steel web is only 1/10 of the thickness of the concrete web of the ordinary concrete simply supported box girder. Considering the bulk density ratio, the web structure weight of the steel-concrete composite simply supported box girder will only be 30% of the ordinary concrete simply supported box girder, which will greatly reduce the structural weight.

(4) The ratio of the thickness of the concrete roof of the steel-concrete composite simply supported box girder to the spacing of the transverse partitions is mainly distributed between 0.02 and 0.06; the ratio of the thickness of the concrete roof to the transverse spacing of the steel webs is mainly concentrated between 0.08 and 0.16. The thickness of the roof is a bit larger than that of ordinary concrete simply supported box girder.

(5) When the span is less than 40m, the steel-concrete composite simply supported box girder mainly adopts C40 concrete; when the span is greater than 40m, most of the C50 concrete is adopted; when the span is less than 50m, the steel mainly adopts Q345D steel, and the The steel grade increases as the span increases.

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