Parameter analysis of stability bearing capacity of bottom frame beam for container building

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Abstract: In this paper, the bottom frame beam of container building is analyzed by finite element method, and compared with the experimental results, the accuracy of the model is verified to meet the needs of the analysis. On this basis, by changing the stiffening position of the upper flange, the height of the web, the load layout and the thickness of the wall, the variation of the stability bearing capacity of the bottom frame beam was studied, the control factors affecting the stability bearing capacity of the bottom frame beam were obtained, and the selection suggestions were given.

1 Introduction

The container building consists of steel frame and maintenance structure. The wall board is sandwich board, which is fixed by the reserved slot and connecting parts between the column and beam. This kind of building is suitable for earthquake relief, construction site, commercial exhibition hall and other projects. After *technical specification for modular freight co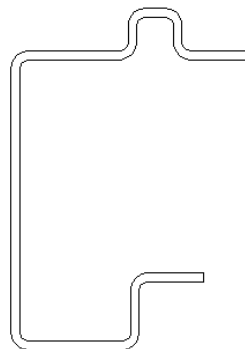ntainer building* [1] has been issued in 2013, more and more scholars have carried out research on container building [2-5]. *Technical standard for modular facilities in construction site* [6] came into being.

Bottom frame beam is the main bending member in the structural system of container building. C-section transformation is adopted to ensure that the connection between the beam and the wallboard and floor meets the structural requirements. Its section form is shown in figure 1, and its connection structure is shown in figure 2.
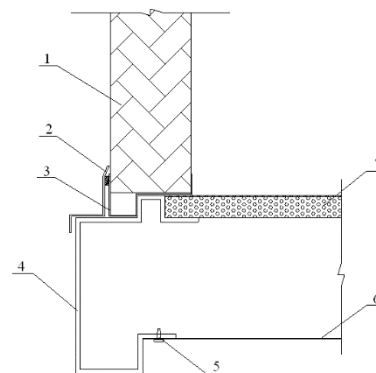

Figure 1. Bottom beam section.

Figure 2. Bottom frame connection diagram.
1.wall; 2. mound bar; 3. warp; 4. beam; 5. rivet; 6. steel board; 7. cement particle board.

Bottom frame beam is required higher stress deformation as chamber room floor beam. On the basis of experimental study, by changing the top flange stiffener location, web height, loading method, wall thickness, the stability bearing capacity of bottom frame beam is studied in this paper. It is concluded that the influence factors on the bearing capacity of bottom frame beam, and the selection suggestions were given.

2 Material and Methods

2.1 Experimental study

The test device of the beam is shown in figure 3. The beam end is hinge joint and the load acts on the upper flange. Hydraulic jacks are used for graded loading and data acquisition instrument is used for real-time data

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acquisition. The final failure of the specimen is shown in figure 4.

Figure 3. Concentrated load at mid-span.

Figure4. Concentrated load at three points.

Under the action of mid-span concentrated load and three-point concentrated load, the final failure mode of bottom frame beam is relatively similar, both of which end in the failure of overall bending and torsion, and there is no local buckling or distorted buckling in the test process.

2.2 Numerical simulation

ANSYS was used for numerical simulation. Ideal elastic-plastic stress-strain relationship, elastic modulus $E=2.11x10^5 Mpa$, yield strength $f_y=337.35Mpa$, poisson's ratio $v=0.3$ were used. In this paper, the stable bearing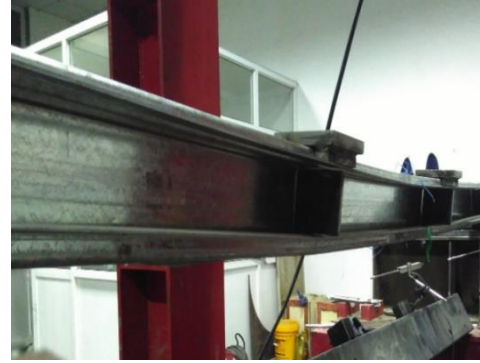 capacity of the bottom frame beam is the key point. The ideal elastic-plastic model is adopted for the stress-strain relationship of steel in nonlinear analysis.

According to the technical specification for cold-formed thin-walled steel structures (GB50018) [7], the initial geometric defect of the specimen is assumed to be sine half wave, and the peak value is 1/750 of the length of the member. In the variable parameter simulation, theoretical values are used for convenience.

2.3 Comparison of results

Table 1 shows the comparison of the maximum bearing capacity obtained by the test and numerical simulation of the bottom frame beam, where p^t is the mean value of the experiments, p^a is the simulated value of ANSYS.

Table 1. Comparison of the maximum bearing capacity.

Specimen number	Plate thickness /mm	Comparison of the maximum bearing capacity		
		p^t/KN	P^a/KN	P^a/P^t
BPBS4-2688-1	4	27.03	31.02	1.14
BPBS3.5-2688-1	3.5	22.13	26.0	1.17
BPBS3-2688-1	3	17.85	19.84	1.11
BPBS4-2688-2	4	47.32	50.16	1.06
BPBS3.5-2688-2	3.5	36.90	42.06	1.14
BPBS3-2688-2	3	31.95	33.01	1.03

The analysis shows that the ANSYS simulation results of most specimens are slightly higher than the test results, with a maximum error of 17% and the rest within 15%. It can be considered that the ANSYS simulation is reasonable.

3 Results and Discussion

The specimens were all 2688mm in length. The influence of stiffening position of upper flange, depth-thickness ratio of web, loading mode and wall thickness on bending performance of bottom frame beam was analysed.

3.1 Stiffening position on compression flange

Change the compression flange stiffener location variable parameter analysis, finite element numbering rules as shown in figure 5, BPB on behalf of the bottom frame beam, flange stiffener location can be divided into three, L represents the location far from the web reinforcement, M represents the middle web reinforcement, R represents the location near web reinforcement, corresponding figure 6 (b) (c) (d), thickness consist of 4 mm, 3.5 mm, 3 mm, load consist of mid-span concentrated load and three point load concentrated load.
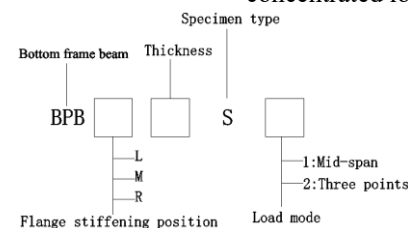

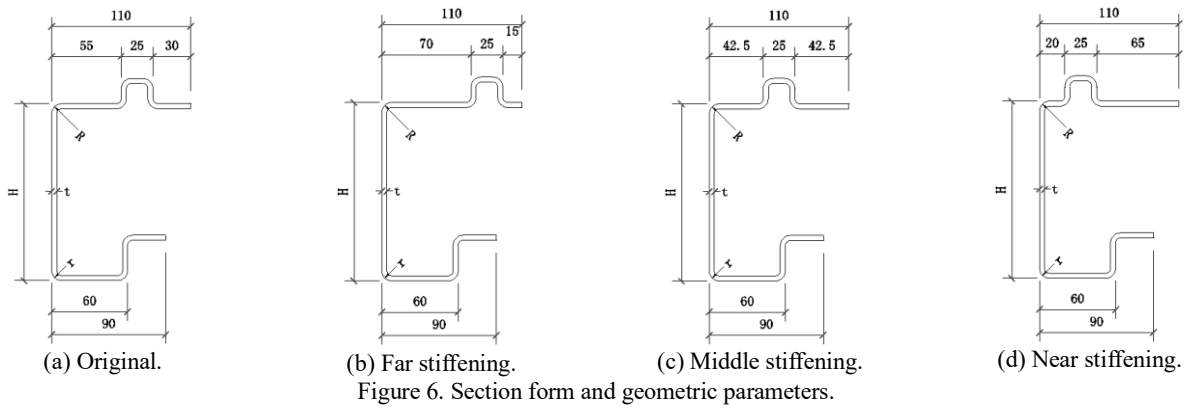Figure 5. the numbering rules of specimen.

(a) Original. (b) Far stiffening. (c) Middle stiffening. (d) Near stiffening.

Figure 6. Section form and geometric parameters.

The stability bearing capacity of each specimen is shown in table 2, In which, p^A represents the result of variable parameter analysis and calculation, p^{AO} represents the original cross section calculation result.

Table2. The results of bottom frame beam changing the stiffening position of compression flange.

	Specimen number	p^A /KN	p^{AO} /KN	$(p^A - p^{Ao})$ / p^{Ao}		Specimen number	p^A /KN	p^{AO} /KN	$(p^A - p^{Ao})$ / p^{Ao}
1	BPBL4S1	31.96	31.02	3.03%	10	BPBL4S2	53.74	50.15	7.16%
2	BPBM4S1	31.11	31.02	0.29%	11	BPBM4S2	50.82	50.15	1.34%
3	BPBR4S1	34.70	31.02	11.86%	12	BPBR4S2	56.32	50.15	12.30%
4	BPBL3.5S1	27.02	26.36	2.50%	13	BPBL3.5S2	44.23	43.29	2.17%
5	BPBM3.5S1	25.75	26.36	-2.31%	14	BPBM3.5S2	41.32	43.29	-4.55%
6	BPBR3.5S1	28.90	26.36	9.64%	15	BPBR3.5S2	47.11	43.29	8.80%
7	BPBL3S1	20.80	19.84	4.84%	16	BPBL3S2	35.11	32.07	9.48%
8	BPBM3S1	19.75	19.84	-0.45%	17	BPBM3S2	32.27	32.07	0.62%
9	BPBR3S1	22.83	19.84	15.07%	18	BPBR3S2	37.94	32.07	18.30%

In which, p^A represents the result of variable parameter analysis and calculation, p^{AO} represents the original cross section calculation result.

The load-displacement curve statistics of 4mm specimen is shown in figure 7. Due to limited space, other thickness specimens are not listed here.
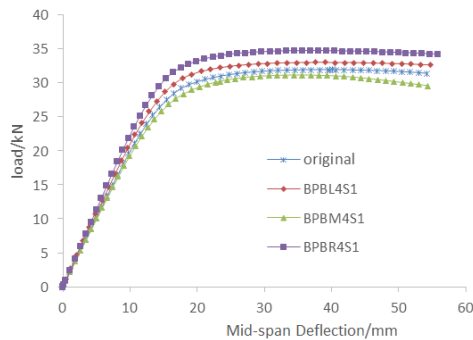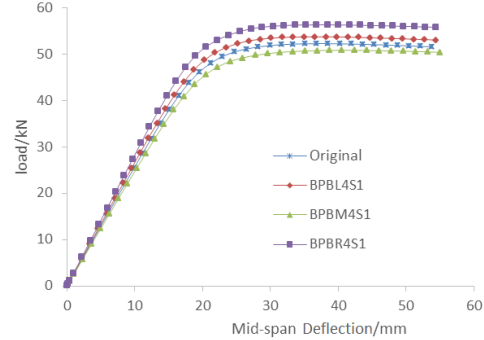
(a) Concentrated load at mid-span. (b) Concentrated load at three points.

Figure 7. The load-displacement curve statistics of 4mm specimen.

AS showed in table 2 and figure 7.

Under concentrated mid-span load, when the stiffening position of the compression flange is in the middle position, its bearing capacity is close to that of the original section; when the stiffening position of the compression flange is away from the web, the bearing capacity increases by more than 2.50%; when the compression flange stiffening position is close to the web, the bearing capacity increases by more than 9.64%.

Under the concentrated load of three points, when the stiffening position of the compression flange is in the middle position, its bearing capacity is relatively close to that of the original section; when the stiffening position of the compression flange is away from the web, the bearing capacity increases by more than 2.17%; when the compression flange stiffening position is close to the web, the bearing capacity increases by more than 8.80%.

3.2. Depth-thickness ratio of web

The finite element specimens were numbered in the analysis, and the numbering rules are shown in figure 4.6. BPB represents the bottom frame beam, the height of the web is 100mm, 120mm, 160mm and 180mm, and the thickness of the plate is 4mm, 3.5mm and 3mm, load consist of mid-span concentrated load and three point load concentrated load.
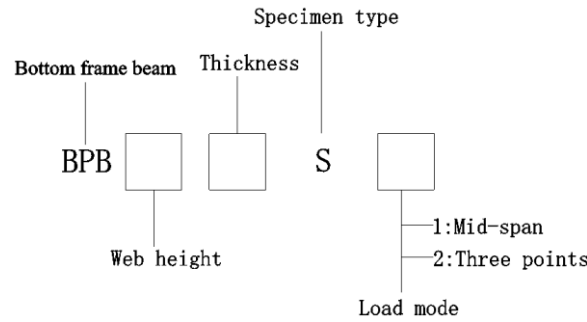
Figure 8. the numbering rules of specimen.

The stability bearing capacity of each specimen is shown in table 3.

Table 3. Influence of different web depth-thickness ratio on stability bearing capacity.

	Specimen number	p^A /KN	p^{AO} /KN	$(p^A - p^{Ao})$ / p^{Ao}		Specimen number	p^A /KN	p^{AO} /KN	$(p^A - p^{Ao})$ / p^{Ao}
1	BPB100-4S1	24.17	31.02	-22.08%	13	BPB100-4S2	36.70	50.15	-26.82%
2	BPB120-4S1	28.36	31.02	-8.58%	14	BPB120-4S2	45.07	50.15	-10.13%
3	BPB160-4S1	34.81	31.02	12.22%	15	BPB160-4S2	57.89	50.15	15.43%
4	BPB180-4S1	37.00	31.02	19.28%	16	BPB180-4S2	62.35	50.15	24.33%
5	BPB100-3.5S1	20.56.	26.36	-22.00%	17	BPB100-3.5S2	31.69	43.29	-26.80%
6	BPB120-3.5S1	23.77	26.36	-9.83%	18	BPB120-3.5S2	38.00	43.29	-12.22%
7	BPB160-3.5S1	29.04	26.36	10.17%	19	BPB160-3.5S2	47.63	43.29	10.03%
8	BPB180-3.5S1	30.70	26.36	16.46%	20	BPB180-3.5S2	51.02	43.29	17.86%
9	BPB100-3S1	16.51	19.84	-16.78%	21	BPB100-3S2	26.49	32.07	-17.40%
10	BPB120-3S1	18.36	19.84	-7.46%	22	BPB120-3S2	31.42	32.07	-2.03%
11	BPB160-3S1	22.05	19.84	11.14%	23	BPB160-3S2	37.50	32.07	16.93%
12	BPB180-3S1	23.04	19.84	16.13%	24	BPB180-3S2	39.63	32.07	23.57%

The load-displacement curve statistics of 4mm specimen is shown in figure 9. Due to limited space, other thickness specimens are not listed here.

(a) Concentrated load at mid-span.

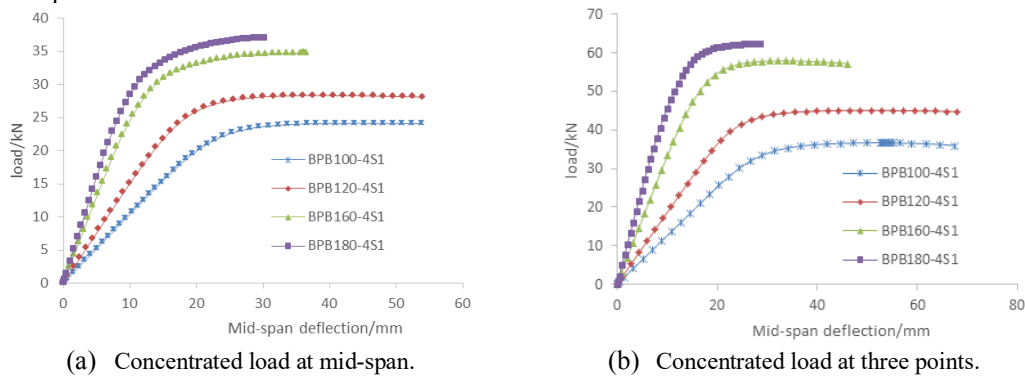(b) Concentrated load at three points.

Figure 9. The load-displacement curve statistics of 4mm specimen.

AS showed in table 3 and figure 9.

Under mid-span concentrated load, when the height of the web is 100mm, the stability bearing capacity of the specimen decreases by at least 16.78%; when the web height is 120mm, the stability bearing capacity of the specimen decreases by at least 7.46%; when the web height is 160mm, the stability bearing capacity of specimens increases by at least 10.17%; when the web height is 180mm, the stability bearing capacity of specimens is increased by at least 16.13%.

Under the concentrated load of three points, when the height of the web was 100mm, the stability bearing capacity of the specimen decreased by at least 17.40%; when the web height is 120mm, the stability bearing capacity of the specimen decreases by at least 2.03%; when the web height is 160mm, the stability bearing capacity of specimens increases by at least 10.03%; when the web height is 180mm, the stability bearing capacity of specimens increases by at least 17.86%.

4 Conclusions

In this paper, the bottom frame beam is simulated and calculated to verify the correctness of the numerical model. By changing the stiffening position, web height, thickness and loading mode for variable parameter analysis, the following conclusions can be drawn:

The bearing capacity of the stiffener near the web is higher than the original section. The bearing capacity of the stiffener in the middle or away from the web is less than the original section. That is to say, under the condition of satisfying the requirements of the structure, the stiffener of the bottom frame beam compression flange is close to the web, which is a good section form, and when the stability bearing capacity of the specimen is higher, it is more scientific and reasonable to change the thickness of the specimen.

The change of web height will cause the change of beam stability bearing capacity. With the increase of web height, the bearing capacity of beam stability increases. The increment of section material caused by increasing web height is less than that caused by increasing wall thickness, namely when the stable bearing capacity of the specimens for higher, under the condition of construction and economy, can give priority to increase web height, and when the stable bearing capacity of the specimens have higher requirements, change the specimen thickness is more scientific and reasonable.

Acknowledgement

References

1. CECS. (2013) Technical specification for modular freight container building. China planning press, Beijing.

2. Yang DY. (2017) Study on the mechanical behavior of disassembled box housing structure. Zhengzhou University, Zhengzhou.

3. Wang W. (2017) Research on mechanical properties and design methods of multi-story box modular building. Xi'an University of Architecture and Technology, Xi'an.

4. Chen SY. (2009) Research on the optimization design of the components and the whole of the box integrated room. Harbin Institute of Technology, Haerbin.

5. Zhang JF, Yang DY, Hu WT. (2016) Study on the overall bending rigidity of disassembled box housing. Steel Structure, 31(12): 28-32.

6. GB. (2018) Technical standard for modular facilities in construction site. China building industry press, Beijing.

7. GB. (2002) Technical specification for cold-formed thin-walled steel structures. China planning publishing house, Beijing.