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Safety Risk Management in the Reformation of Bracket Girder and Cut Column for an Existing Industrial Single-storey Building

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Abstract The adaptability is important in the technological reformation of industrial building. Bracket girder and cut column (BGCC), are widely used to expand the space and to increase the inner working room of the buildings. Reformation of the exiting industrial building is limited to the continuous and non-stop working and (must be) in service and the reformation is required to be non-stop. Industrial buildings, especially the industrial single-storey workshops mostly belong to static determinate and low-order static indeterminate structures and many risks may be faced during the BGCC reformation under the complicated working conditions, such as variable structure risk, structural failure caused by overload, injuries of workers resulted from the unsafe construction, injuries of the production workers due to construction operation, etc. Research on the safety risk management of the industrial building BGCC reformation is of great significance for ensuring the technological transformation of industrial enterprises and controlling the risks from the reformation of adaptability of industrial buildings in China. Consequently, based on the approaches of risk identifying on work decomposition structure(WBS) and the questionnaire, the whole process design and construction management methods are proposed to control the risks in the reformation of the exiting industrial buildings, and the total management of construction process can be used to reduce injury risks of engineering staffs. In this paper, the technological key points of the whole process design control and construction management are discussed in details based on examples of BGCC reformation of exiting industrial single-storey buildings and the corresponding injury risk management methods are suggested.

Key words: Existing industrial single-storey building, reformation. bracket girder and cut column (BGCC), risk management, whole process design

Introduction

Following the massive newly built industrial buildings, reconstruction of existing industrial buildings has been increased rapidly by more than 50 percent in China. With the rapid development of industrial modernization, the exiting industrial buildings have not suited to the development of modern production, and are unable to meet the demand of new production process (Zhang 2007). The exiting industrial buildings are urgently needed to be reformed accompanying with the enterprise technological renovation in China. Meanwhile, the reformation of the existing industrial buildings has been warmly welcomed by industrial members due to its superiority, for example, little effect on production, shorter time and quicker schedule, less investment and shorter fund recoupment period than that of newly-built (GB/T 50344, Fu et al. 2006), etc.

For the existing industrial buildings, the reformation technology of bracket girder and cut column (BGCC) is an excision that a newly made beam or bracket girder has been used to replace the column to be cut and supports the loads that are supported by the column to be cut. BGCC can effectively expand the spacing between the existing columns, and increase the area of working space. The excision in the reformation of existing industrial building may be traced to the 1960s,

but the practice of BGCC had been put into effect in 1985 (Cai and Huang1988). Nevertheless the systematic design theory and construction technology have not been formed until today. So based on the practicing of industrial building reformation in Daye special steel factory, this paper explores the BGCC method.

Methodology

The activities of BGCC are recognized by systemic engineering. The construction process of BGCC is analyzed usually by structural decomposition method. The safety risks in construction process of BGCC are recognized, and evaluated by the expert's interview and questionnaire. Then the key points of structured design and construction technology in BGCC is proposed in order to provide reference for the technology reforming of industrial enterprises and the risk management of the adaptation reformation of industrial buildings.

Project Background

Daye special steel factory was built at the beginning of 20 century. It is a double-bay and one story structure with the spans being 9 meter and 32 meter respectively. Steel truss roof and reinforcement concrete roof slab are also used. The up column is an I-shape steel and the under column is of lattice-type steel. The column spacing is 5 meter. Because the steel-making process has been changed, one bay building with a span of 32.5 meter, and steel columns and beams has been built near the old building. As column M20 is on the path of the new production line cross axis M, it needs to be extracted, which then the authors have done experiment.

Common Method of BGCC

The BGCC is good to expand the column spacing for industrial building. Usually including bracket roof and cut column, bracket girder and cut wall, bracket girder and cut column, which are two cases, as non-removing and removing little part of the upper structures. The key construction technology is the reinforcement techniques of the related structures, the lifting technology of the upper structure and the technology of cutting column. The BGCC in this paper especially refers to manufacturing steel girder in site and then cutting column. According to the construction process, it can be classified as BGCC with lifting or not. Three methods of BGCC are shown in Table 1.

In these methods, the non-integral bracket with lifting contains two bracket making and two lifting activities processes, the firstly bracket making is non completed bracket and only fixed temporary; the second bracket making is completed bracket after second lifting. The former occurred before the cutting column and the latter occurred after the cutting column. And the integral bracket with lifting needs to be one time lifting after the bracket completed. Nevertheless processes of the integral bracket without lifting are the simplest, which cutting column is doing after the bracket completed, and the jack set before the cutting column acts as an additional protection device.

Risk Analysis of BGCC Project

To evaluate the reformation risk of industrial building, five indicators are chosen to establish the semi-quantitative parameters for both risk consequence and risk likelihood, as shown in Tables 2 and 3.

In the risk factors, two categories can be grouped as technical risk and personal safety risk. The former is caused by the quality of design or construction, the appraisal of existing structures, the construction-drawing design of BGCC, install and fix bracket; the latter is caused by errors of the using of temporary facilities and construction machinery, and the construction personals or management staff.

Table 1: Construction processes of three method of BGCC

Number	*non- integral bracket with lifting*	*integral bracket with lifting*	*integral bracket without lifting*
1	Appraisal of the existing structure	Appraisal of the existing structure	Appraisal of the existing structure
2	The construction-drawing design	The construction-drawing design	The construction-drawing design
3	Site preparation	Site preparation	Site preparation
4	Foundation treatment and reinforcement	foundation treatment and reinforcement	foundation treatment and reinforcement
5	the column reinforcement of supporting bracket	the column reinforcement of supporting bracket	the column reinforcement of supporting bracket
6	the brace reinforcement of columns and the roof trusses	the brace reinforcement of columns and the roof trusses	the brace reinforcement of columns and the roof trusses
7	Install and fix bracket temporarily with bolts	Install and fix bracket permanently	Install and fix bracket permanently
8	Making reaction frame	Making reaction frame	Making reaction frame
9	equipment(jack) installing	equipment(jack) installing	equipment(jack) installing
10	Lifting the column to be cut until load transfer	Lifting the column to be cut until load transfer	—
11	Cutting out the up column to be cut	Cutting out the up column to be cut	Cutting out the up column to be cut
12	Lifting the bracket to the designated height	—	—
13	fix bracket permanently	—	—
14	Jack relieved load by steps	Jack relieved load by steps	Jack relieved load by steps
15	Perfect the bracket	Perfect the bracket	Perfect the bracket
16	Removing the existing crane beam and the bottom column to be cut	Removing the existing crane beam and the bottom column to be cut	Removing the existing crane beam and the bottom column to be cut
17	Installing the new crane beam, braking structure and track System	Installing the new crane beam, braking structure and track System	Installing the new crane beam, braking structure and track System
18	Inspection acceptance	Inspection acceptance	Inspection acceptance

Table 2: The definition of risk likelihood parameters

descriptor	*rare*	*unlikely*	*possible*	*likely*	*Almost certain*
description	This event may occur in exceptional circumstances	This event could occur at some time	This event should occur at some time	This event will probably occur in most circumstances	This event is excepted to occur in most circumstances
L value	1	2	3	4	5

Table 3: The definition of risk consequence parameters

descriptor	*insignificant*	*minor*	*moderate*	*major*	*extreme*
description	Insignificant impact on objectives	Minor impact on objectives	moderate impact on objectives	Moderate impact on objectives	extreme impact on objectives
C value	1	2	3	4	5

The risk value of factors, namely D, equals that L times C, as LC method. Risk rankings are shown in Table 4.

Some risk factors are identified and assessed for the reformation with integral bracket without lifting of industrial building, through interviewing related experts who are engaged in the design of reformation and strengthening industry, construction and safety management for a long term. The results of BGCC during construction are shown in Table 5.

Table 4: The definition of risk degree

descriptor	*small risk*	*moderate risk*	*dangerous*	*more dangerous*	*serious dangerous*
D value	1-5	5-10	10-15	15-20	20-25

Table 5: Safety risk analysis of the integral bracket without lifting during construction

Activities	*Risk factors*	*Risk assessment*			*measures of risk management*
		Risk likelihood (L)	*Risk consequence (C)*	*Risk degree (D)*	
preparation	Shock	unlikely /2	minor /2	Small risk /4	1 wearing safety helmets and belts;; 2 checking on the power line、power socket
	Collapse	rare /1	extreme /5	Medium serious /5	
	object hitting	unlikely /2	minor /2	Small risk /4	
Install and fix bracket permanently	Welding failure	unlikely /2	moderate /3	Medium serious /6	1 training for the welding sequence of bracket's rods; 2 wearing safety helmets and belts; 3 checkingthe power line and power socket's protection;
	Fall	possible /3	extreme /5	More dangerous **/15**	
	object hitting	unlikely /2	minor /2	Small risk /4	
	Shock	rare /1	minor /2	Small risk /2	
	Crane injury	unlikely /2	moderate /3	Medium serious /6	
Produce reaction frame	Fall	unlikely /2	minor /2	Small risk /4	checking the power line、power socket
	Shock	rare /1	minor /2	Small risk /2	
	object hitting	rare /1	minor /2	Small risk /2	
Install equipment(jack)	Fall	unlikely /2	minor /2	Small risk /4	wearing safety helmets and belts
	object hitting	rare /1	minor /2	Small risk /2	
Cut and demolish the up column which is to be drawn by stages	Fall	possible /3	extreme /5	More dangerous **/15**	1 checking the deformation and welded joint; 2 checking jack's pressure and welding tools; 3 strictly conducting the construction program; 4 checking the power line and socket; workers wear safety helmets and belts
	object hitting	unlikely /2	minor /2	Small risk /4	
	Shock	rare /1	minor /2	Small risk /2	
Jack relieved load by stages	Fall	possible /3	extreme /5	More dangerous **/15**	wearing safety helmets and belts
Perfect the bracket	Fall	possible /3	moderate /3	Medium serious /9	wearing safety helmets and belts
Remove the existing crane beam and the bottom column	Fall	possible /3	extreme /5	More dangerous **/15**	wearing safety helmets and belts
	object hitting	unlikely /2	minor /2	Small risk /4	
	Crane injury	unlikely /2	extreme /5	dangerous **/10**	
Install the new crane beam and brake structure	Fall	possible /3	extreme /5	More dangerous **/15**	wearing safety helmets and belts
	object hitting	unlikely /2	minor /2	Small risk /4	
	Injury by Crane	unlikely /2	extreme /5	dangerous **/10**	
Inspection acceptance	Fall	possible /3	moderate /3	Medium serious /9	wearing safety helmets and belts

It can be found that: (1) the method of BGCC without lifting is more frequently used in the removed column project because the bracket newly made is completed in place before cut-off column. It is already a load-bearing member and the construction of reformation of industrial building can be safer; (2) accidents of high falling and object hitting are the main injuring types; (3)

command and operation against rules, no training or insufficient training, lack of on-site inspection and acceptance, and without proper safety checks are the deep reasons resulting accidents.

Risk Control

Design Control For the engineering structures, the high risk factor is the structural failure, and the reformation of existing building is also the same. Moreover, structural failure risk factors, particularly the new structure themselves made in place and their cooperation, need to be paid more attention. Therefore, the design process should be adopted to eliminate risk of degeneration of existing building reliability and sub-structural failure of construction process; in design philosophy, limits state should be based on stiffness not limited to bearing capacity to ensure the spatial stability of the reformed structure.

Construction Control To realize the personnel safety during construction and the structural safety, some principle should be followed in the BGCC project management.

Firstly, making project plan to prevent unsystematic construction;

Secondly, following the program and forbidding starting next process before the last process not be inspection and acceptance;

Thirdly, on the structural welding construction method, first down chord, next the upper chord, and last the web member; for the member welding construction, first ends then the middle for the compress member, and contrary for the tension member welding.

Staff Management No command and operation against rules is fundamental. Therefore, it must be emphasized that only qualified personnel of safety training can be engaged in the reformation engineering of existing building. And the training should be doing to all of the workers and managers. Its content should be included, but not limited, the construction procedures, construction organization design and technical check, etc. Simultaneously, only safety equipments in site are set according to the management regulations, and workers are wearing individual protective devices (safety helmets, safety belts, etc.), then under the supervision of the supervisor, construction of existing building reformation can be executing.

Example

The industrial building reformation with BGCC in Daye special steel factory has been completed on 21 Dec. 2009. In the reformation design, structural stiffness is controlled under [*l*/2000], here *l* means the span of the bracket.

In the construction, the extracted column has been cut off piece by piece, from web to flange plate, the extraction column to be cut off was divided into eight.

Stress histories of the member in bracket of BGCC are tested, measurements and theoretical results are good consistent, shown in Fig. 1.

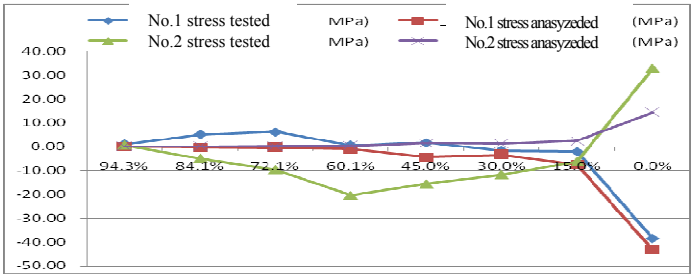

Figure 1*: The comparison between test and theoretical stress value of bracket chord*（*Unit*：*MPa*）

Free vibration frequencies during the pre and post-reformation of the industrial building are also tested. The results indicate that there is no obvious change in structural free vibration frequency. The first key free vibration frequency at bracket is far away that of structural roof truss about 3.9 times. Maximum displacement of the mid of the bracket is about 5 millimeters, which conforms to the design requirement as *l*/2000.

Conclusion

The BGCC, as an industrial building's transformation technology of expanding the space and increasing the inner working room of the building，is of small impact on site and short duration. To its high safety risk on structure failure and injuring, the paper studies its risk management by expert interviews, questionnaire and on-site testing. Some results are acquired, as follows.

1 Identified the different processes of three BGCC methods, namely non-integral bracket with lifting, integral bracket with lifting and integral bracket without lifting.

2 Analyzed the risk factors of the integral bracket without lifting, as the resistance deterioration of existing structure, incorrect design model, the construction facility failure, etc.

3 Given the strategy of risk control, including engineering design, construction process and personnel safety management.

4 measurements in site shown the suggestions are feasibility.

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