Modeling Method and Engineering Application of Climbing Formwork Equipment for Super High-Rise Construction Based on Midas/Gen: Postprint

Authors: Xia Juwei, Fang Tingchen, Yang Jialin, Chen Yuanhong

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Abstract

Climbing formwork equipment, typified by hydraulic climbing formwork and integral steel platform formwork, has played a crucial role in super high-rise building construction. To address the current issue of low modeling efficiency in computational analysis of climbing formwork equipment, this paper introduces an interactive modeling method based on Midas/Gen mgt files. First, two conventional modeling methods for computational analysis of climbing formwork equipment are introduced. Next, the interactive modeling method using mgt commands and mgt files is presented, with a focus on analyzing the framework and format of mgt command-based modeling. Finally, the effectiveness of the proposed method is verified through a practical super high-rise project. Engineering applications demonstrate that this method can significantly improve modeling efficiency and be applied to refined computational analysis.

Full Text

Preamble

The Modeling Method of Climbing Formwork Equipment for Super-High Structure Construction and Engineering Application

Xia Juwei, Fang Tingchen, Yang Jialin, Chen Yuanhong
Shanghai Construction Group Co., Ltd., Shanghai 200080, China

Abstract

Climbing formwork equipment, typified by hydraulic climbing formwork and integral steel platform systems, plays a critical role in the construction of super-high-rise buildings. Addressing the current inefficiency in computational modeling and analysis of climbing formwork equipment, this paper introduces an interactive modeling method based on Midas/Gen mgt files. First, two conventional modeling approaches for climbing formwork equipment analysis are reviewed. Next, the interactive modeling method using mgt commands and files is presented, with particular emphasis on analyzing the framework and format of mgt command-based modeling. Finally, the effectiveness of the proposed method is validated through a practical super-high-rise engineering application, demonstrating that the method significantly improves modeling efficiency while enabling refined computational analysis.

Keywords: Super-high structure construction; Climbing formwork equipment; mgt modeling

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Climbing formwork equipment, represented by hydraulic climbing formwork and integral steel platform systems, is essential for the green, efficient, and safe construction of super-high-rise buildings. For instance, the Guangzhou Pearl River Tower (309.6m) [1] and Shenyang Maoye Center (311m) [2] utilized hydraulic climbing formwork for core wall construction, while China' s tallest building, the Shanghai Tower (632m) [3] [Figure 1: see original paper], employed a tube-frame alternating support formwork system for its nine-grid core tube construction. Similarly, the Magnolia Plaza super-high-rise (320m) in Shanghai [4] [Figure 2: see original paper] adopted a steel column-tube alternating support formwork system.

Analyzing the mechanical performance of climbing formwork equipment under construction conditions constitutes a crucial aspect of super-high-rise construction. Due to its user-friendly interface, comprehensive pre- and post-processing capabilities, and powerful computational analysis and simulation functions, Midas/Gen is widely applied in the design, construction process simulation, and performance modeling of climbing formwork equipment under complex working conditions. For example, references [5] and [6] respectively employed Midas/Gen to simulate and analyze the mechanical states of hydraulic climbing formwork exterior frames and integral steel platforms during construction processes. However, a prominent issue when using general finite element software for computational analysis is the substantial time consumption during pre-processing and modeling. Reference [7] notes that modeling time accounts for 70% of the total computational analysis time. Consequently, existing literature has begun to focus on modeling techniques for computational analysis objects, such as parametric modeling methods for high-rise reinforced concrete structures based on ABAQUS [8], continuous bridge modeling techniques based on Midas/Civil [9], and parametric finite element modeling methods for hexagonal honeycomb sandwich panels [10]. Nevertheless, few studies have addressed finite element modeling methods specifically for super-high-rise climbing formwork equipment.

Unlike bridges and conventional high-rise building structures, climbing formwork construction equipment attaches to the core tube structure of super-high-rise buildings. Therefore, when architectural schemes undergo modifications, the layout and configuration of climbing formwork equipment must be adjusted accordingly. Safety verification of climbing formwork equipment during construction often requires repeated model construction, consuming substantial computational time. This paper first introduces the conventional modeling methods currently used in climbing formwork equipment computational analysis. Subsequently, it presents an interactive modeling method based on mgt commands and files, focusing on analyzing the framework and format of mgt command-based modeling. Finally, through practical super-high-rise engineering applications, the modeling method based on Midas/Gen mgt files is demonstrated. Engineering applications show that this method significantly improves modeling efficiency and can be applied to refined computational analysis, with the presented concepts and modeling methods serving as references for practical engineering projects.

2 Conventional Methods

Structurally, climbing formwork equipment represents typical three-dimensional spatial steel frame structures. Currently, two conventional modeling approaches exist. The first involves directly establishing structural models in Midas/Gen by sequentially creating nodes, elements, materials, and sections, utilizing Midas' copy, mirror, and modify functions—essentially forming elements by connecting nodes and assigning material and section properties to complete member construction. The second method is the import approach, commonly implemented by establishing three-dimensional wireframe models of climbing formwork equipment in CAD, saving them as dxf files, and importing these into Midas/Gen to assign material and section properties to each line element. While simple and straightforward, these two methods exhibit certain limitations: (1) Manual modeling (or model conversion) involves substantial workload, requiring GUI-based operations in Midas/Gen or CAD software, with modeling precision and efficiency dependent on software proficiency. (2) The modeling process is non-reversible; when super-high-rise building or structural schemes change, requiring corresponding modifications to climbing formwork equipment design schemes, model reconstruction must be repeated.

[Figure 3: see original paper] Climbing formwork dxf model
[Figure 4: see original paper] Integral steel platform formwork dxf model

3 Midas Interactive Modeling

(1) mgt Interactive Modeling

Similar to general finite element analysis software such as ANSYS and ABAQUS, Midas/Gen provides interactive modeling methods through gmt (abbreviation for Midas Gen Text) command windows or mgt files (see Figures 5 and 6), enabling the establishment of structural geometry, materials, sections, boundary conditions, loads, and numerous other information through mgt commands or command text files. This modeling approach offers two advantages: (1) All structural information is stored via mgt commands or text files, making the modeling process traceable, reviewable, and modifiable through command windows or text files. (2) The modeling process exhibits excellent interactivity; once familiar with mgt modeling rules, users can conveniently and efficiently construct finite element models, reducing repetitive modeling work and improving efficiency.

[Figure 5: see original paper] mgt command window
[Figure 6: see original paper] mgt text editor

(2) mgt Commands and Format

Utilizing Midas/Gen' s mgt command window or text files for modeling requires mastery of the software' s default commands and data formats. In Midas/Gen' s mgt files, commands are preceded by "" *, such as* VERSION, *UNIT, and* MATERIAL for version, unit, and material commands, respectively. The" ;" symbol serves as a comment marker, typically following commands to provide annotations or data format requirements for command streams. Figure 7 shows the mgt command stream for a single-beam finite element model with 1m length, H-section HN400x200x8x13, and Q345 steel. For clarity, Chinese annotations are provided for each command and command stream in Figure 7. Figure 8 displays the import result in Midas/Gen. If errors occur during mgt file import, the information window indicates the error location and cause, allowing users to modify and debug accordingly. Table 1 lists several commonly used mgt commands in Midas, their data formats, and annotations for key parameters. Overall, mgt commands demonstrate strong readability and regularity. Users can consult the mgt command descriptions in Midas/Gen user manual appendices or convert existing Midas/Gen models into mgt files to gain deeper understanding of mgt command data formats and usage patterns. Proficiency in mgt commands significantly enhances finite element modeling efficiency and accuracy.

VERSION ; Version command
8.6.0 ; Version number 8.6.0
UNIT ; Unit command
KN, m, KJ, C ; Force unit KN, length unit m, energy unit KJ, temperature unit °C
MATERIAL ; Material command
1, STEEL, Q345, 0, 0, , C, NO, 0.02, 1, GB12(S), , Q345, NO, 21.0062 ; Material setting command stream, material 1 is Q345 steel
SECTION ; Section command
1, DBUSER, HN400x200x8/13, CC, 0, 0, 0, 0, 0, 0, YES, NO, H, 1, GB-YB05, HN400x200x8/13 ; Section setting command stream, beam section is HN400x200x8x13
NODE ; Node command

; Node number, X coordinate, Y coordinate, Z coordinate
1, 0, 0, 0
2, 1, 0, 0
ELEMENT ; Element command
1, BEAM, 1, 1, 1, 2, 0, 0 ; Element 1, beam element, material 1, section 1, start node, end node
*ENDDATA ; File ending

[Figure 7: see original paper] Single beam mgt modeling command stream
(a) Import mgt file (b) Successfully import mgt file
[Figure 8: see original paper] Single beam mgt modeling command stream

Table 1 Common mgt commands, formats, and annotations

Command	Format & Annotation
*VERSION	Version number
*UNIT	Force, LENGTH, HEAT, TEMPER
*MATERIAL	iMAT, TYPE, MNAME; STEEL, CONC, USER
*SECTION	iSEC, TYPE, SNAME, [OFFSET], SHAPE, [DATA1]
*NODE	iNO, X, Y, Z
*ELEMENT	iEL, TYPE, iMAT, iPRO, iN1, iN2, ANGLE, iSUB
*GROUP	NAME, NODE_LIST, ELEM_LIST, PLANE_TYPE
*ENDDATA	File ending

4 Engineering Application

(1) Project Overview

The Nanjing Golden Eagle Plaza super-high-rise project comprises three towers (T1, T2, T3). T1 has 79 above-ground floors with a building height of 365.5m; T2 has 69 floors at 322.3m; and T3 has 62 floors at 292.1m. All three towers adopt a "core tube + exterior frame" structural system with reinforced concrete core tubes. The exterior shear walls contain H-shaped steel columns and steel plates, while the perimeter consists of steel-reinforced columns and beams forming a frame with composite floor systems using steel bar truss decking. T1' s core tube exterior dimensions are 29.6m × 25.4m, forming a "nine-grid" pattern. T2 and T3 core tubes measure 25.4m × 20.2m and 26.2m × 17.5m respectively, forming "four-grid" patterns. T1 utilized a new tube-frame alternating support hydraulic climbing formwork system independently developed by Shanghai Construction Group, while T2 and T3 employed steel column-tube alternating support hydraulic climbing formwork systems.

(2) Case Study

Using T2 tower' s integral steel platform formwork as an example, the modeling process in Midas/Gen demonstrates a progressive aggregation from "basic components → subsystems → overall system" due to the high degree of standardization and modularization. The process includes: (1) **Basic component modeling**. The integral steel platform formwork primarily consists of bottom steel girder units (GDL), tube-frame column units (TJZ), interior hanging scaffold units (NDJ), and steel platform units (GPT). These components are essentially steel frames composed of beams and columns, whose Midas/Gen finite element models can be conveniently established using mgt commands based on their geometric positions and topological relationships. (2) **Subsystem modeling**. Based on the established basic components, subsystems are generated using copy and translation operations in Midas/Gen. For example, as shown in Figures 9(b) and 10(b), each grid corner of T2' s steel platform requires tube-frame column units, which can be conveniently created by copying and translating a single established column unit. (3) **Basic steel platform formwork modeling**. After completing subsystem modeling, the basic steel platform formwork is formed by superimposing all subsystem models. Figure 10(e) shows the basic steel platform formwork model as a superposition of subsystems from Figures 10(a)-10(d). (4) **Non-standard component modeling**. Based on the basic model established through the interactive method, non-standard components are added to complete the full integral steel platform formwork finite element model. As shown in Figure 10(f), major non-standard components are concentrated in the steel platform subsystem, where additional non-standard connecting steel beams are arranged to strengthen the platform' s capacity for material and equipment storage areas. Since mgt command streams are used, all basic components of the integral steel platform in this project are defined through mgt commands. Subsystems are created by copying and locally modifying basic component command streams, with all subsystem mgt command streams collectively forming the overall steel platform model. To verify the correctness of this modeling approach, finite element analysis was performed on both the proposed method and manual modeling under steel reinforcement stacking loads. Figures 11 and 12 present the vertical deformation and design stress contours obtained using the proposed method. Table 2 compares the maximum deformation, maximum stress, and support reaction results from both methods, showing excellent agreement and validating the effectiveness of the proposed modeling approach. Moreover, when architectural schemes change, this method only requires modifying local mgt files, eliminating repetitive modeling time and substantially improving computational analysis efficiency for formwork equipment.

[Figure 9: see original paper] Basic components of integral steel platform
(a) Steel girder subsystem (b) Tube-frame column subsystem (c) Interior hanging scaffold subsystem (d) Steel platform subsystem
(a) GDL (b) TJZ (c) NDJ (d) GPT

[Figure 10: see original paper] Single beam mgt modeling command stream
(e) Basic steel platform formwork model (f) Steel platform formwork model
[Figure 11: see original paper] Vertical deformation contour of steel platform formwork calculated by proposed method
[Figure 12: see original paper] Stress contour of integral steel platform calculated

by proposed method

Table 2 Comparison of finite element analysis results between conventional and proposed modeling methods

Parameter	Conventional Method	Proposed Method
Maximum vertical deformation (mm)	[value]	[value]
Maximum stress (MPa)	[value]	[value]
Maximum support reaction (kN)	[value]	[value]

5 Conclusions and Recommendations

Given the current situation of heavy workload and low efficiency in manual modeling of super-high-rise construction climbing formwork equipment, this paper proposes an automated modeling method based on Midas/Gen. The Midas mgt command and file-based modeling approaches and learning methods are introduced, and the method's effectiveness is demonstrated through a super-high-rise project application. The main conclusions are:

(1) Engineering practice demonstrates that the interactive modeling method provided by Midas/Gen can significantly improve modeling efficiency, reduce computational analysis workload, and ensure traceability and accuracy of analysis work.

(2) The proposed interactive modeling method based on Midas/Gen is essentially a modeling approach using mgt files (or commands), constructing models according to Midas/Gen's default structural data formats for nodes, elements, materials, loads, etc. Similar modeling methods exist in other Midas modules and general finite element software such as ANSYS and ABAQUS, including Midas/Civil' s mct files, ANSYS' s APDL mac files, and ABAQUS' s inp files. The concepts and procedures presented herein can serve as references for modeling with these software platforms.

(3) Midas/Gen' s mgt structural data file format is simple and easy to read/write. Based on the method introduced in this paper, further exploration of programmatic modeling using Excel, Matlab, VB, and other languages can further enhance modeling efficiency and convenience, representing a worthwhile direction for future research.

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Note: Figure translations are in progress. See original paper for figures.