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Computer-Aided Design AND APPLICATIONS

Application of AutoCAD in Auxiliary Design of Highway Bridge Pile Foundation

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Abstract. With the rapid development of computer hardware and software technology, CAD technology is widely used in the field of engineering technology, and various design software in different fields are constantly being introduced. Based on the analysis of the pile foundation design steps and key calculations in the design, this paper adopts the method of parametric design and drawing. The calculation results show that the foundation pile will not buckle under the vertical design load of the pile top, and the stability of the bridge foundation pile meets the design requirements. Subsequent inspection results showed that all indicators of the bridge pile foundation and superstructure met the requirements, and the bridge was operating well and no safety hazards were seen. The analysis of the influencing factors of the engineering example shows that there is a critical pier height for the pile-column bridge foundation pile in the steep slope section, which is related to the depth of the foundation pile; The depth ratio should not exceed 0.5. With the increase of the elastic modulus E of the pile, the critical buckling load of the foundation pile gradually increases, while the length of the calculated stability pile gradually decreases. With the increase of the pile diameter, the critical pier height value of the pile gradually decreases, and the ratio of the height of the pier to the depth of the foundation pile decreases with the increase of the pile diameter. When designing the foundation pile of a type bridge, a reasonable and effective selection of the diameter of the foundation pile plays an important role in improving its buckling stability.

Keywords: Highway bridge pile foundation; AutoCAD; two-dimensional automatic drawing; pile foundation calculation
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1 INTRODUCTION

With the rapid development of highway bridges, pile foundations are widely used because of their high bearing capacity, good stability, small and uniform settlement [1]. Due to the large diameter of the pile foundation of highway bridges, a large number of highway bridges have adopted single piles under the conditions that topographical conditions, geological conditions, freezing depth, hydrological conditions and other factors are satisfied. Therefore, the research on the bearing characteristics and engineering technology of pile foundations mainly focuses on the single pile [2]. In actual engineering, due to factors such as the type of bridge superstructure, topographical conditions, geological conditions, freezing depth, hydrological conditions, etc., the application of pile foundations in large-scale bridges, super-large bridges, and special areas in China is also very common. However, the current research on the bearing characteristics of pile group foundations is still insufficient. With the popularization of computer technology and the rapid development of computer software and hardware technology, CAD has gradually been used in computing and design fields. With the development of computer technology and computer graphics technology, CAD technology has become a practical technology and has been widely used in engineering design fields such as machinery, electronics, construction, chemical engineering, energy, and transportation [3]. It liberates people from a lot of repeated heavy physical and mental work. The application of CAD technology in highway survey and design has caused major changes in traditional highway design methods and design methods. It has greatly promoted the technological progress of the highway transportation industry and has become one of the main signs of the modernization of highway surveying and design. Small and medium-sized bridges are important structures in highway engineering. The design of small and medium-sized bridges occupies a large proportion in the entire highway project, and their cost accounts for about 20% of the cost of highway engineering. The number of pile foundation designs for small and medium-sized bridges is large, and the amount is larger. Although there are some auxiliary design software in China, a common problem is that it is mainly developed for the design of the upper structure of the bridge, rather than specifically designed for the lower structure of the bridge. The lower structure is only a sub-function of it, and it is not very specific. The use of computer-aided design for the calculation and drawing design of bridge pile foundations can make full use of the large amount of computer information storage, fast calculation speed, fast drawing and intuitive characteristics, and at the same time, it can also give play to the practical ability and analytical judgment ability of the designer. So the use of computer-aided design instead of manual design and drawing is an inevitable trend of development. The goal of computer design and drawing has greatly increased the demand for design software in the design department [4]. At the same time, it has also prompted engineers and technicians to work hard to develop convenient and applicable engineering design software to improve design efficiency and drawing quality.

2 RELATED WORK

With the continuous improvement of computer drawing functions and the emergence of office automation, the drawing of a large number of design drawings and the preparation of design documents in engineering design are gradually completed by computers, and the digital ground model system has gradually moved from theory to practical stage. Rasouli and Fatahi [5] pointed out that with the advent of GPS technology, highway CAD systems have gradually entered systematization, integration, and commercialization. Many countries have established integrated systems formed by aerial survey equipment, computers and special highway design software packages. Highway CAD software is gradually developing towards the integration of survey and design. German CARD/1, British MXRoad (formerly MOSS), American InRoads, and American GEOPAK Road are all excellent software born during this period. Azizkandi et al. [6] pointed out that with the introduction of high-interaction true three-dimensional graphics support systems and object-oriented language compilation systems, highway CAD systems are gradually transitioning to integration and automation. The functional coverage of the CAD system is becoming wider and wider, involving the establishment and application of digital ground models, the collection and processing of terrain data, the horizontal and vertical design of road routes and interchanges, the design of pavement structures, the design of subgrade drainage systems, and the design of structures. Due to national conditions and low prices, most of the software used in road engineering design in my country is domestic software, among which the representative ones are Xi'an Hyde (HEAD), HintCAD and Southeast University's AHCAD and DICAD. The Bridge XB system developed by Salamakhin and Chasovnikov [7] solves the function of drawing construction drawings of pile foundations, but it does not have functions such as instant modification and instant generation. The Bridge Doctor system adopts object-oriented development ideas, and has won a place in the domestic bridge engineering community with its simple, easy-to-use, intuitive, flexible and rich features. The user interface of the basic calculation module it contains is relatively simple and has visualization functions, but it lacks Visualization of construction drawings and other functions. The bridge pile foundation calculation program developed by Su et al. [8] using FORTRAN language is widely used because of its simplicity and practicality. However, the software can only perform general design calculation analysis, without visualization and automatic graphing functions, and cannot perform engineering quantity statistics. At present, certain research results have been made in the development and application of CAD software for bridge pile foundations, such as bridge pile foundation calculation program, Pile2000 (bridge pile foundation design program), Bridge XB, a comprehensive analysis system for the lower part of the bridge in the bridge software and reinforcement program, etc. These softwares have realized the design and calculation functions of pile foundations, and have achieved expected results in practical applications, which have improved calculation accuracy and design efficiency for the majority of design departments, and reduced design costs. Asumadu et al. [9] pointed out that the existing software (such as the bridge 3D modeling module Bridge3D system, etc.) has relatively complete functions in bridge modeling. However, there is no three-dimensional visual design software for highway bridges and culverts, let alone three-dimensional visual design of bored pile foundations. Through the design of three-dimensional visualization graphics, it is possible to observe the configuration of steel bars inside the entity from different angles, making it clear at a glance, and technicians can make correct judgments based on this, without ambiguity, and have certain implications for the construction of pile foundations. Valeryevna and Vitalievna [10] believe that the research on the three-dimensional visual design of bored pile foundations can also be used as a reference for the research on the three-dimensional visual design of prestressed beams, slabs, cap beams, and other structures with more complex reinforcement configurations.

3 HIGHWAY BRIDGE PILE FOUNDATION CALCULATION AND AUTOCAD TWO-DIMENSIONAL AUTOMATIC DRAWING

3.1 Dimension-driven Parametric Drawing

The dimension-driven parametric drawing is essentially an extension of the program-driven parametric drawing. The user constructs a sketch with the application of the dimension-driven method, and then modifies an entity in the sketch, assigns a new dimension value to the entity, and the entire graphic will be automatically updated according to the new dimension. This method is suitable for graphic designs whose structure is not very complicated. For a specific structural form, you compile a parameterized drawing program of the dimension-driven method. Once this kind of program is debugged, it can only be used to design a specific entity, which can be called a special dimension-driven drawing. It does not aim at a specific structural form, but compiles a dimension-driven parametric drawing program for ordinary "arbitrary" shapes composed of straight lines, arcs, text, etc., which is called universal dimension-driven drawing.

The general dimension-driven method drawing actually realizes the function of the CAD software with parametric features. Of course, the function of the universal size-driven drawing program developed by myself is limited after all. The so-called "arbitrary" shape component can be designed is also relative. In the process of parameterized drawing in the dimension-driven method, the first half is the same as the program-driven method, and the second half is added with processing sentences for selection sets and primitives. When designing a product in principle or conceptual design, it is often not concerned about the actual size of the design model (in fact, it is impossible to know the specific size), and the energy is mainly concentrated on the principle of the conceptual model. Reflected on the drawing, it is to outline the sketch of the model. After the principle design is completed, it can enter the detailed design stage. The drawn model sketch already contains various design constraint relationships between elements. In the subsequent design, using size-driven and modifying the size of the elements in the sketch, the required graphics can be generated. The key to the parameterized drawing of the dimension-driven method is to establish the dimension constraint model. The dimensional constraint model is composed of dimensional chains in various directions, including horizontal, vertical, radial, and angular dimensional chains. Before establishing the size constraint model, first determine the reference point of the graph. This reference point is the reference positioning point of the graph. Therefore, the dimensional chain is established with this point as the starting point, and its position will affect the refinement of the entire size constraint model. The position of the reference point should be determined according to the geometric characteristics of the whole drawing. Constraint-driven is the ultimate goal of parametric drawing, and size-driven occupies an important position. The size constraint driving first establishes the constraint size set, determines the size constraint domain and the size driving amount, and then traverses the linked list and constraint relationship table of the size matrix, and drives each geometric element one by one through feature points, thereby realizing the driving of the entire or partial graphics.

3.2 AutoCAD Design of Pile Foundation Program

The steps of pile foundation design can be complicated or simple, and are related to the nature of the project and its importance, calculation criteria, pile type, geological conditions, environment and other factors, and are often variable. The designer' s experience and hobbies will ultimately determine design steps of pile foundation. Generally speaking, the steps followed in the design of pile foundations are shown in Figure 1.

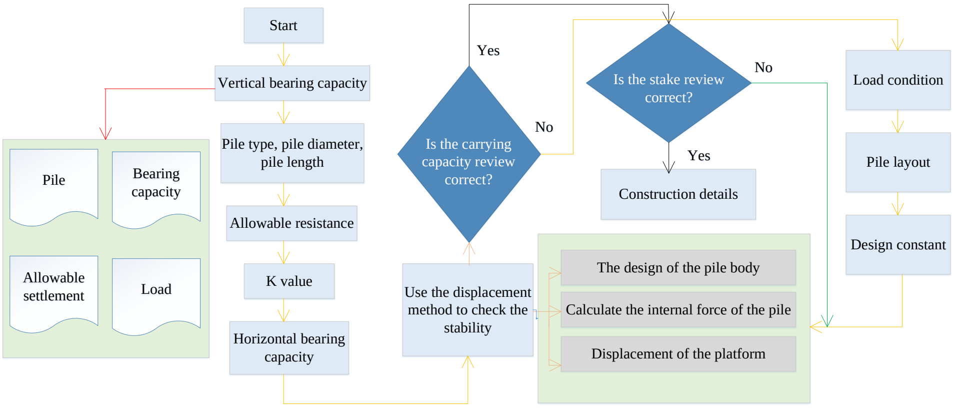


Figure 1: Flow chart of pile foundation design.

3.3 Calculation of Pile Foundation

In the actual design process, when the application environment or design conditions change, the size of the graphics will change accordingly. Program-driven parametric drawing design can easily solve this change process. The method used in the program-driven method is the variable geometry method, which converts geometric constraints into nonlinear equations for overall solution, and determines a set of characteristic points. Geometry can be represented by a point set, and the change of the point set will inevitably change the figure. Therefore, the transformation of graphics is essentially the transformation of point sets.

Since the point set of a two-dimensional graph is a matrix with n rows and 2 columns, in order to perform matrix operations on it, the change matrix must be a matrix with 2 rows and 2 columns. Suppose the transformation matrix is δ, then δ can be written as:

$$\delta = \begin{bmatrix} a & d \\ b & c \end{bmatrix} \tag{1}$$

$$y' = ax' - bx + cdy \tag{2}$$

Among them, a, b, c, d are called the operators (or elements) of the transformation matrix. Suppose the old point is [x,y] and the new point is [x’ ,y’], then:

$$[x', y'] = [x, y] \bullet \delta \tag{3}$$

The coordinates of the transformed point are:

$$x' = ax - dy \tag{4}$$

$$y' = bx - cy \tag{5}$$

The coordinates of the transformed point are determined by the values of the operators of the transformation matrix. At this time, the operation of the original transformation matrix is actually a process of parameterization. It is reflected in the CAD software that basic geometric elements (points, lines, circles, etc.) undergo geometric constraints (including topological relations, shape positions, and sizes), and are calculated by computers to obtain new geometric figures. For example, if the size parameter is used as a variable, the data that controls the size of the geometric figure is embodied in the form of a parameter variable. Assign different values to the parameter variables, imply the topological relationship of the geometric figure, and define the coordinates of the key points. Then the change of the size parameter will make the geometric figure change accordingly. The calculation formula for the allowable bearing capacity of bored piles is:

$$\Gamma = K_2 \gamma_2 (h-2) - \frac{1}{3} U l_i - m_0 A \lambda \sigma_0 \tag{6}$$

h is the embedded depth of the pile bottom (m). For piles with scouring, it refers to the depth below the general scouring line; for piles without scouring, the buried depth is calculated from the natural ground line or the actual ground line after excavation; the calculated value of h0 is not more than 40m; Γ is the allowable bearing capacity of a single pile in axial compression (KN); U is the perimeter of the pile (m); l_i is the pile on the bottom of the cap or below the maximum scour line; λ is the correction coefficient related to the pile length, pile diameter and the water permeability of the pile bottom soil; m_0 is the bottom clearing coefficient, which is related to the thickness of the pile bottom sedimentation soil and the pile diameter related. A is the cross-sectional area of the bottom of the pile (m2), calculated with the design diameter (drill diameter). When the mortar change method is used for construction, it is calculated according to the hole diameter; σ_0 is the allowable bearing capacity of the soil at the pile tip (kPa); K_2 is the correction coefficient of the allowable bearing capacity of the ground soil with depth; γ_2 is the bulk density of the soil above the pile tip (KN/m3).

3.4 AutoCAD Two-dimensional Automatic Drawing Design Method of Pile Foundation

In engineering practice, two-dimensional engineering drawings are essential. The two-dimensional graphics generated by the design software developed in this paper are mainly the elevation view and section view of the pile foundation reinforcement, as well as the calculation, size and text annotation of the reinforcement engineering quantity. Two-dimensional drawing is the most important application of the parametric drawing method. When the program generates the reinforcement drawing, it mainly decomposes the various parts of the reinforcement drawing, and generates them through the program. The position of the drawing is controlled by setting the insertion point. In the program design of the two-dimensional visualization drawing, the schematic diagram of the pile reinforcement parameters shown in Figure 2 is set.

The user enters the relevant parameters according to its prompts and realizes the visualization function of data input. The focus and difficulty of the program design lies in the program design of the section and elevation graphics of the main reinforcement. In the pile foundation design, there may be only one type of main reinforcement, or two types, which requires the program itself to have the function of judging according to the input parameters. In the program design, the main difficulty is the use of the filling function in the profile view, the algorithm for the location of the two main ribs, and the algorithm for the location of the two main ribs in the elevation view.

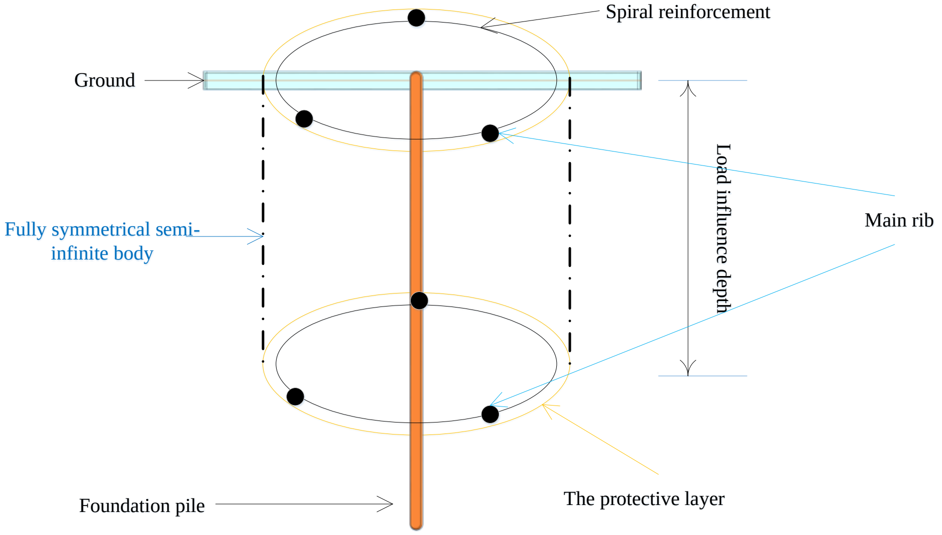


Figure 2: Schematic diagram of pile foundation reinforcement in AutoCAD aided design.

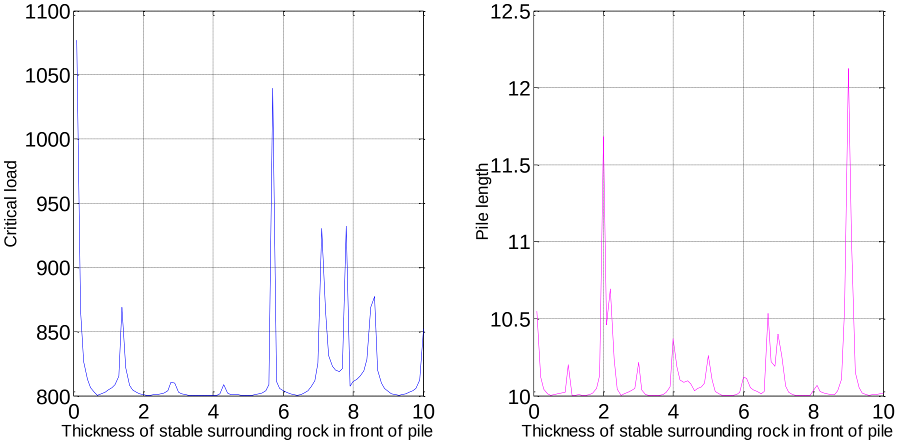
4 ANALYSIS OF ENGINEERING APPLICATION EXAMPLES OF AUTOCAD AIDED DESIGN

4.1 Project Overview

The ground elevation of the top of the hillside on the side of the bridge pile number is 364.5m, and the elevation of the foot of the slope is about 200m. The slope of the slope changes more evenly; the design elevation of the corresponding section is 250m~255m. The sideline ground height difference is between 30m and 50m, and the local slope of the mountain is between 45° and 60° . The plane of the Sixi River No. 1 bridge is located on the easement curve, the circular curve and the easement curve respectively, and the radius of the circular curve is R=1000m. The left bridge layout is set to (1.8×40+50+7×40) m. The prestressed concrete is first simply supported. The starting and ending pile numbers are K101+091.92~K101+508.08, and the total length is 416.16m; the right bridge layout is set to (2.4×40+50+4×40) m prestressed concrete simply supported T-beams, starting and ending pile numbers K101+091.92~K101+388.08, total length 296.16m, corresponding to the half-span subgrade design scheme used for the 8th to 10th spans of the left span of the bridge. The lower structure is a double-piled double-column foundation, and the abutment is a pile-column abutment. According to the geological survey data, the main strata at the bridge site are planting soil, gravel soil, strongly weathered dolomitic limestone and moderately weathered dolomitic limestone.

4.2 The Calculation Results and Analysis of AutoCAD Pile Foundation Auxiliary Design

The calculation parameters of the No. 6 pier on the left panel are: pier column height l3=8.1m; foundation pile length l=25.2m. The diameter of the pier column is d2=1.7m, and the diameter of the foundation pile is d1=2.0m. The piers are made of C30 concrete with an elastic modulus of 30 GPa; the foundation piles are made of C25 concrete with an elastic modulus of 28 GPa. The proportional coefficient of foundation resistance is: m0=60000kN/m4, m1=80000kN/m4. Taking n=10, the critical buckling load of the foundation pile and the stability calculation pile length are obtained by the energy method, as shown in Figure 3.



(a) Critical load (b) Pile length

Figure 3: Analysis of calculation results.

It can be seen that the designed foundation pile will not be buckled under the vertical design load of the pile top, and the stability of the bridge pile foundation meets the design requirements. At present, the bridge has been opened to traffic, and the follow-up test results show that all indicators meet the requirements, and the bridge is operating well, and no safety hazards are seen.

4.3 Analysis of Influencing Factors of AutoCAD Pile Foundation Auxiliary Design

In order to discuss the buckling mechanism of pile-column bridge foundation piles in steep slopes, and obtain some useful conclusions for the reference of the engineering community, we mainly discuss the pier columns under different pile column elastic modulus E, foundation pile diameter d, and slope slope. The relationship between the height and the critical buckling load Pcr of the pile and the effective calculated pile length Lcr.

1) The influence of pile elastic modulus E

We keep other parameters unchanged, only change the multiples of the elastic modulus E of the pile (0.6E, 0.8E, 1.0E, 1.2E), so that the pier height l_3 and the foundation pile under the elastic modulus of different piles can be calculated. The relationship curve between the critical buckling load Pcr and the effective calculated pile length Lcr is shown in Figure 4 and Figure 5.

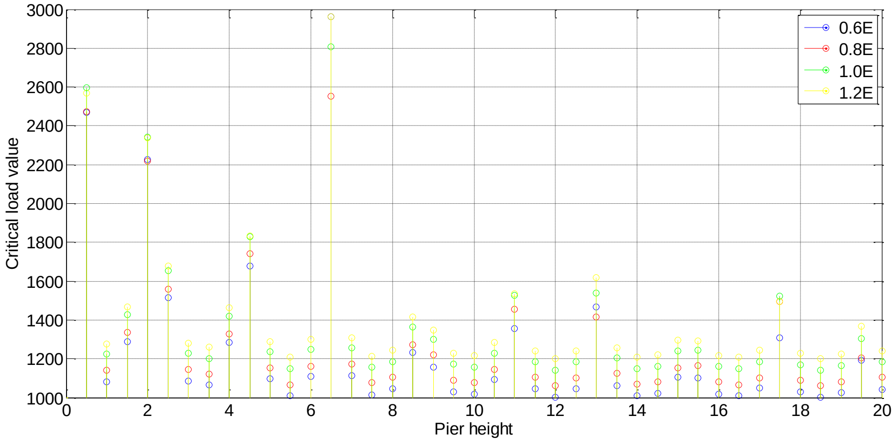


Figure 4: The relationship curve between Pcr and l3 under the influence of pile elastic modulus E.

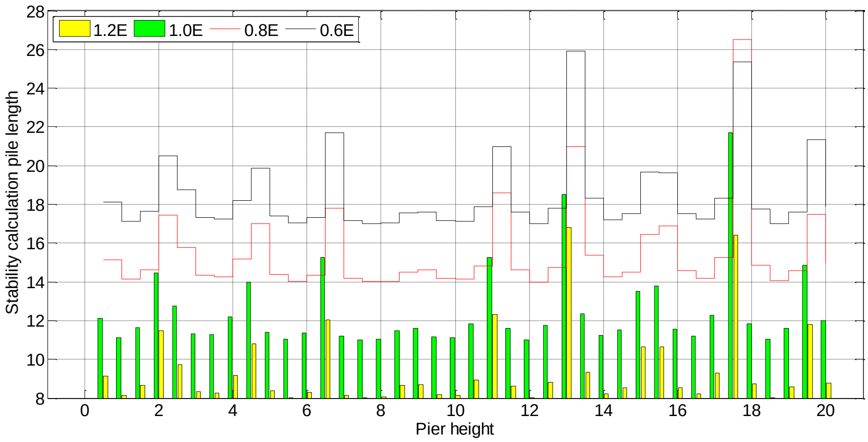


Figure 5: The relationship curve between Lcr and l3 under the influence of pile elastic modulus E.

It can be seen from Figure 4 and Figure 5 that when the elastic modulus E of the pile column is the same, as the height of the pier column increases, the buckling critical load of the foundation pile gradually decreases, while the stability calculation pile length gradually increases. It can be seen that there is a critical pier height for pile-column bridge foundation piles at steep slopes. From the above analysis, it can be seen that this value is related to the depth of foundation piles. In the design of pile-column bridge foundation piles at steep slopes, the ratio of the depth to the foundation pile into the soil should not exceed 0.5. In addition, it can be seen from the figure that when the height of the pier column is the same, with the increase of the elastic modulus E, the critical buckling load of the foundation pile gradually increases, while the length of the calculated stability pile gradually decreases. Therefore, when calculating the stability of foundation piles, the buckling stability of pile-column bridge foundation piles at steep slopes can be improved by adjusting the strength of the pile concrete.

2) The influence of pile diameter d

We keep other parameters unchanged, only change the size of the pile diameter d (0.5d, 1.0d, 1.5d, 2.0d), and calculate the pile height l3 and the pile buckling critical load Pcr under different pile diameters, and effectively calculate the pile. The relationship curve between long Lcr is shown in Figure 6 and Figure 7.

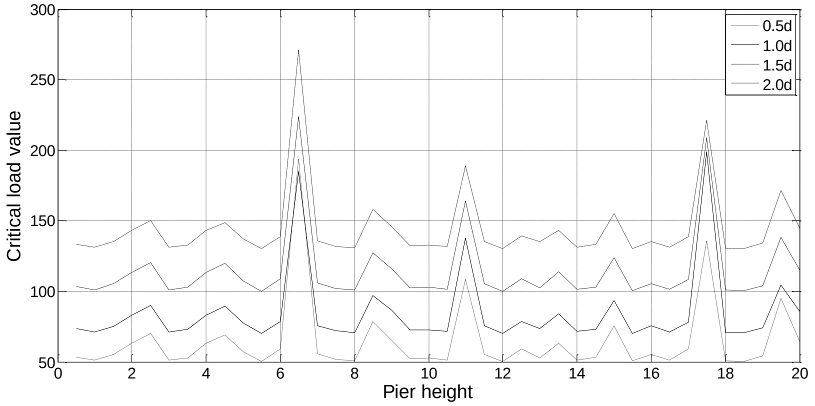


Figure 6: The relationship curve between Pcr and l_3 under the influence of pile diameter d.

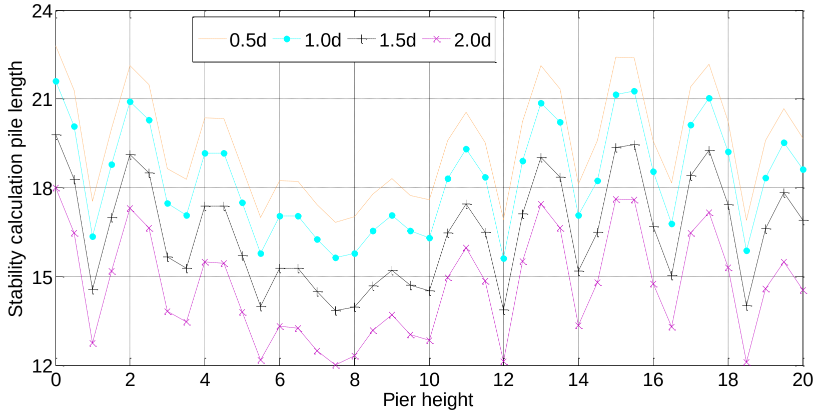


Figure 7: The relationship curve between Lcr and l_3 under the influence of pile diameter d.

Figures 6 and 7 show the critical load value of pile buckling and the value of stability calculation pile length under different pile diameters and pier heights. It can be seen from the figure that when the pile diameter d is the same, the change and development of the Pcr-l3 curve and the Lcr-l3 curve are similar to the relationship curve under the influence of the elastic modulus E of the pile. When the pier column height is the same but the pile diameter d is different, the larger the pile diameter, the larger the critical load value for buckling, and the smaller the pile length for stability calculation; and when the pile diameter increases, the load value changes approximately in the same amount, while the stable calculation pile length shows an obvious non-linear change development trend. With the increase of the pile diameter, the critical pier height value of the foundation pile gradually decreases. The ratio of the critical pier height to the depth of the foundation pile will decrease with the increase of the pile diameter. Therefore, in the design of pile-column bridge foundation piles on steep slopes, a reasonable and effective selection of the pile diameter plays an important role in improving its buckling stability.

3) The influence of slope

We keep other parameters unchanged, only change the size of the slope tangent, and calculate the relationship curve between the critical load of the non-dimensional foundation pile buckling and the non-dimensional stability calculation pile length and the slope tangent value under different slopes, as shown in Figure 8.

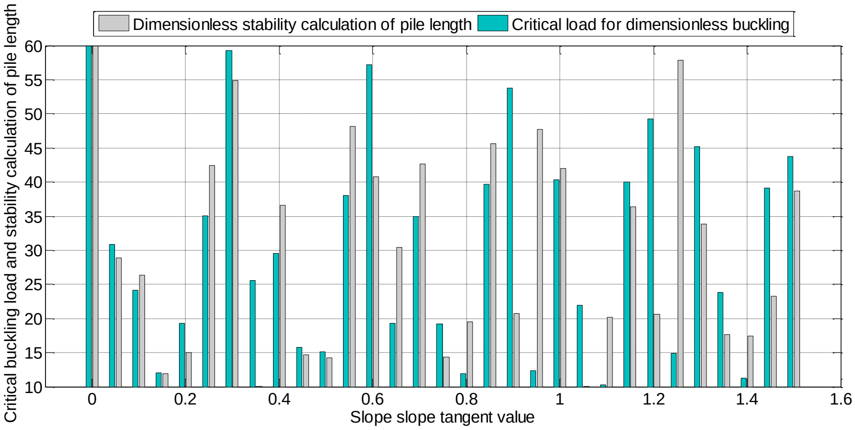


Figure 8: The influence of slope tangent.

It can be found from Figure 8 that the influence of slope tangent on the critical load of pile buckling is very obvious. The buckling stability of pile-column bridge foundation piles at steep slopes is greatly affected by the slope. When the slope tangent value is less than 0.45, the slope has a very significant impact, and when the slope is between 0.45 and 0.75, the impact is relatively small. It can be approximated that the slope gradient of 30° is an inflection point that affects the pile-pillar bridge foundation piles of the slope section. That is, when the slope tangent exceeds 30°, the buckling stability of the foundation piles will change, and attention should be paid to the design calculation.

5 CONCLUSION

This paper adopts the method of drawing the flow chart of pile foundation design, gives the general steps of pile foundation design, and clarifies the relationship between each function module and each parameter in the software design process, which is the calculation and two-dimensional graphics in the pile foundation software. The research of automatic generation mechanism and method has laid the foundation. The ARX application program developed in this article mainly uses the method of adding entity records in the AutoCAD internal database. The user directly calls the graphics database operation function in the ARX program to complete the modification of the entity database, and the graphics display is completed by the AutoCAD system. After analyzing and comparing various AutoCAD secondary development languages, this article decides to use ObjectARX tool as the development method of pile foundation calculation and automatic drawing system. We use MFC class library in ObjectARX, according to the management window provided by MFC, the program interface of the modal dialog box is used to complete the input/output of the basic data, and the program-driven parametric drawing technology is applied to the program. Combined with an engineering example, the influence of pile diameter, pile elastic modulus and slope tangent on the buckling stability of foundation piles is systematically discussed. Comparative analysis shows that there is a critical pier height for pile-column bridge foundation piles at steep slopes, which is related to the depth of the foundation pile; in general, the ratio of the height of the pier to the depth of the foundation pile should not exceed 0.5. With the increase of the elastic modulus E of the pile, the critical buckling load of the foundation pile gradually increases, while the length of the calculated stability pile gradually decreases. With the increase of the pile diameter, the critical pier height value of the foundation pile gradually decreases, and the ratio of the height of the pier column to the depth of the foundation pile decreases with the increase of the pile diameter. The foundation pile should be selected reasonably and effectively. The diameter plays an important role in improving its buckling stability. The buckling stability of pile-column bridge foundation piles at steep slopes is greatly affected by the slope of the slope. When the slope tangent value is less than 0.45, the influence of the slope is very significant; while between 0.45 and 0.75, the influence is relatively small; the slope of 30° is an inflection point that affects the buckling stability of the foundation pile.

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