

Interactive Design and Analysis of Slender Reinforced Concrete Columns without Sidesway

Ko-Young Shao¹ Jhin-Young Huang^{2*} Chung-Hsien Tsai³ Terry Chang⁴

¹Associate Professor Department of Civil Engineering, I-Shou University, Kaohsiung, Taiwan

²Graduate Student, Department of Civil Engineering, I-Shou University, Kaohsiung, Taiwan

³Undergraduate Student, Department of Civil Engineering, I-Shou University, Kaohsiung, Taiwan

⁴Master of Science, Department of Civil Engineering, I-Shou University, Kaohsiung, Taiwan

*Corresponding author Email: andy26412035@hotmail.com

(Received Apr. 12, 2010; Accepted Dec. 24, 2010)

ABSTRACT

Interactive web pages for design and analyses of non-sidesway slender reinforced concrete columns were investigated. The object-oriented programming techniques were employed to perform interactive web pages for analysis and design of non-sidesway slender reinforced concrete columns. The major factors for the analysis and design of slender columns are slender ratio, and the column ends conditions. The second order moments ($P-\Delta$ affects) will be generated according to the large deformations. Several examples will be provided for validation purpose. Excellent agreement has been obtained when comparing the design results with the reference results.

KEYWORDS: Interactive Web Page, Reinforced Concrete, Non-sidesWay Slender Columns Design

1 Introduction

The purpose of this paper is to investigate the interactive web pages for design and analyses of non-sidesway slender Reinforced Concrete (RC) columns using Active Server Pages (ASP) technology. The last several years have witnessed a profound transition in business and technical computing. The internet is growing explosively as users demand new services and as businesses rush in to provide them. In practical RC column design, many design tables and charts, such as the American Concrete Institute (ACI) design tables and charts (ACI 318-05), the Concrete Reinforcing Steel Institute (CRSI) design tables and charts (CRSI Design Handbook, 1996), the Chinese Institute of Civil and Hydraulic Engineering (CICHE) design tables and charts (CICHE Design Handbook, 2006), are used. However, it is still relatively slow by using these tables and charts (Shao, 2000; 2006).

The ASP technologies are server-based scripting language, which includes HTML, script code and PWS (Personal Web Services). Design tables or charts are convenient in the design of reinforced concrete columns. ASP is a highly flexible, extensible, and easy to master scripting environment that combines HTML and scripting code into the same page. Conventional HTML can present texts, pictures, and links, but cannot control the interactive information translated between client-side and server-side. By using a component in ASP (Bit Culture, 2000; Shao, 2002), an HTML page can submit the values required for the calculation to the web server (Homer, 1998; Shao, 2002; 2006). To execute this on the client-side page put the HTML controls on `<FORM>`; whose ACTION is the name of the ASP page that will calculate the results on the server-side. Then place the ASP file that processes the request in the same directory on the server as the HTML page that references it. Users can create components using ASP. These kinds of components are called script lets or just scripts (Mier, 2001). ASP scripts can be embedded into an HTML page to make the page more powerful (Shao, 2005). Code between the `<%` and `%>` delimiters is ASP, and is executed on the server. These codes cannot be reached on the client-side (Shao, 2006). Only the calculated results will be sent to the user.

Design tables or charts are convenient in the design of reinforced concrete columns. Therefore, by using HTML, ASP, and MS-ACCESS (from Microsoft) database, a Web-page non-sidesway Slender Reinforced Concrete Column Design (WSRCD) interactive web page database system was developed. The RC column design results, i.e. steel area A_s , are used to create the MS-ACCESS database. Users can use a browser to reach the WSRCD system home page (Connor, 2001), input the necessary RC column design information, go through the SQL query statements, acquire the design results from the database, and have the design results displayed on the monitor. This interactive RC column design process can be completed in real-time. The response time is very fast, and WSRCD interactive web pages are user friendly.

An example of reinforced concrete non-sidesway slender column design was tested. A rectangular shaped column section was investigated; excellent agreement was obtained when compared to the design results (Shao, 2000). This test was used to verify the interactive web pages, the data transfer interfaces, and the database query statements. The result correlated well, and the response time was very fast. In addition, more tests will be possible as the database continues to expand.

2 Web Page Architecture

Client/server, in its basic form, is an approach that lets the processing tasks of an application be divided up so as to provide optimum efficiency. In reality, the processing itself can be divided up into different sub-tasks, such as the interface code, the rules code, the database access code, and in between them, the network operating system. In the client/server relationship as shown in Figure 1, a WSRCD system was established for interactive reinforced concrete column design.

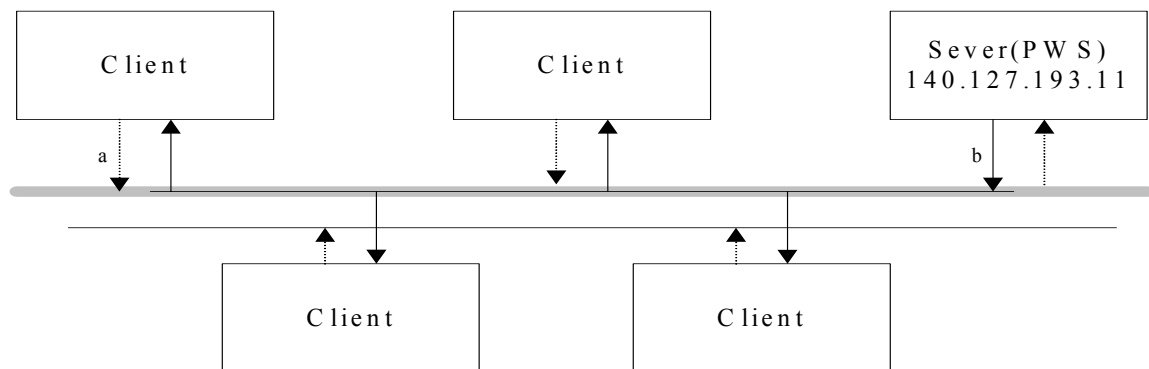


Figure 1 Client/server relationship

The objective oriented interface ASP was implemented on the server-side to communicate between client and server. Users provide information on the client-side, this information is sent to the server through path 'a' to query. After the process is completed, queried information will be sent to the client-side through path 'b'.

The architecture of the WSRCD system is shown in Figure 2. In Figure 2, the detailed data access application of the WSRCD system was described using arrow lines. The client and the web server communicate over a standard network with TCP/IP and the HTTP web protocol as the common format. At the same time, the web server can talk to a back-end data store using TCP/IP as well. Therefore, changing the data source is simply a matter of changing the IP address and making sure that the correct Object Linking and Embedding Database (OLE-DB) or Open Database Connectivity (ODBC) drivers are set up. Also, expanded data storage could be easily added in the web server.

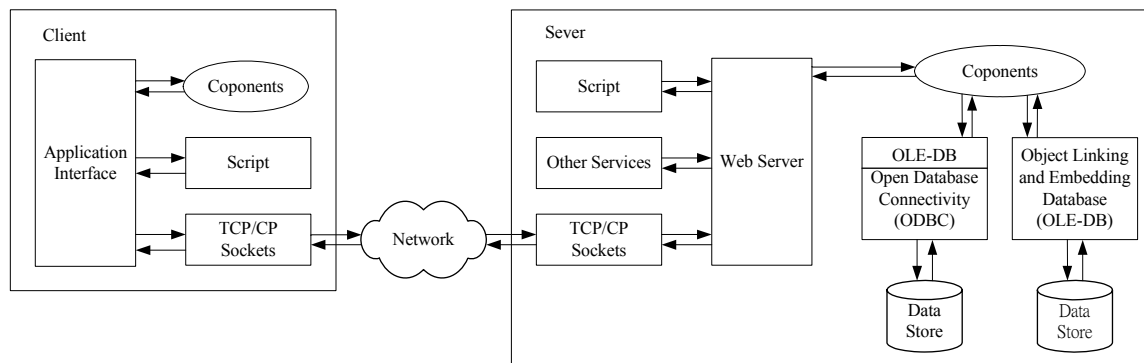


Figure 2 WSRCD system architecture, data access with the services relevant

3 Components

In Figure 2, different levels were classified, such as client, server, data storage, and other data storage. The first level is the client or browser that serves as the user interface, which is a custom application created with a language like C++, Java, Visual Basic (VB), Delphi, HTML, Jscript, VBScript, or ASP. WSRCD system is a thin client network system. Only minimum applications on the client-side were executed.

The second level is the server. WSRCD system software on the server can be called as a component server to distinguish from the MS-WIN2000 server, which is the operation system used. The component server can do holding component instances, holding database connections, and database connection pooling. In an object oriented programming system, system components are installed to function the basic services: creating screen windows, writing to the disk, processing mouse, and keyboard events. These are generally Dynamic Link Library (DLL) files, system-only executables, ActiveX Controls or provided with windows programming languages OLE Control Extension (OCXs) files. Examples are windows file comdlg32.dll, in system or system32 directory, user.exe, kernal386.exe, gdi.exe, or mscal.ocx files.

The component server holding component instances can serve multiple users. When the page finishes executing, the results are sent to the client, and the ASP code is removed from memory. However, if it is decided that the component is needed again later in the page, then it has to create a new instance. The new instance will contain the default values.

The component server is capable of holding database connections. However, that is not necessarily the best scenario. WSRCD system requires access to a data store. Usually a database such as Oracle, SQL server, Sybase, MS-ACCESS, etc. is used. WSRCD system uses the MS-ACCESS database. To provide database access in a component, a connection to the appropriate database through an OLE-DB or ODBC driver should be created. Holding onto one in the ASP page, the database driver will begin to refuse

connections, or the server will run out of resources. If not holding the database, creating the connection over and over again slows the application down. The ASP page will perform far more slowly.

To minimize the delays, many database drivers implement connection pooling. When another application requests a connection, the driver software searches the pool for available unused connections and supplies this connection instead of creating a new one. This provides a much faster response.

The component instances, in the WSRCD system, include reinforced concrete column design components, and system components. The RC column design components are developed to function the major services: acquiring column sizes (width b , depth h), concrete strength f'_c , steel bar strength f_y , design axial load P_u , design bending moment M_u , querying the database, and translating the design steel area A_s , between the client and the server.

The third level is the data stores and includes the other data stores if needed. If more than one data store is used, it requires each data store to implement its own proprietary Resource Manager (RM). The RM is generally part of the driver software – perhaps OLE-DB but more often ODBC at the moment. The OLE-DBs or ODBC are data store drivers. The component can work with the data on the data stores through the driver software; adding, updating and deleting records as required. If some other data stores on different IP addresses are used, then network connections through the TCP/IP are needed.

4 Active Server Page

In ASP, the combination of scripts, HTML, and reusable server components were used to create the reinforced concrete column design applications. In Figure 3, the arrangements of the WSRCD system home page was presented. The WSRCD system flowchart was shown in Figure 4. To provide the ASP working environment, Microsoft Co. provided PWS and Internal Information Server (IIS). On WIN98 operation system, PWS is standard for installing web server. IIS is the web server software included with Microsoft Windows NT and WIN2000. In this investigation, PWS was implemented as the web server software.

The ASP of WSRCD system can be shown in Figure 5. The user can use a browser through a monitor to visit ASP pages. The browser will connect to the server IP address, i.e. 140.127.193.114. After the server has been connected, the server will send the HTML instructions to the user. ASP script languages are embedded in the HTML instructions. When the HTML instructions were executed, the ASP script will require executing the “.asp” files. The “.asp” files on the server will begin to execute and then send the results to the user’s monitor. It starts to execute the “.asp” files: cc4.asp to generate the home page, cd1.asp to create RC column sizes interface page, c13-1.asp to create force, moments on RC

column interface page, c13-2.asp to receive column sizes information, c12-1.asp to create design interface page, c12-2.asp to receive design information.

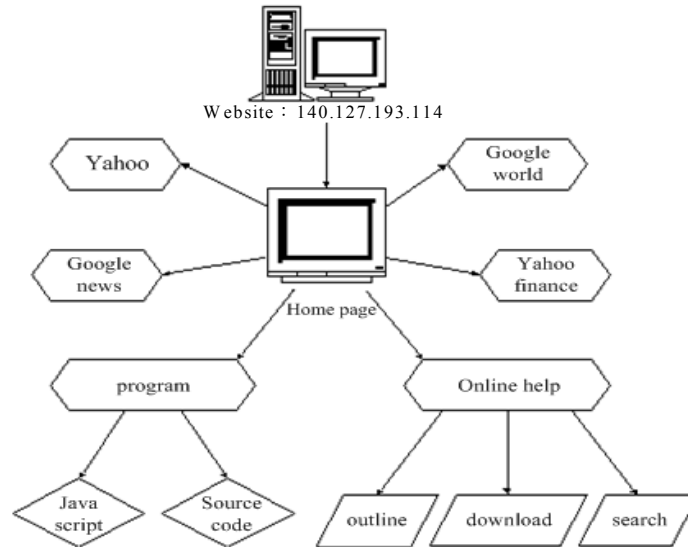


Figure 3 The arrangements of the WSRCD system home page.

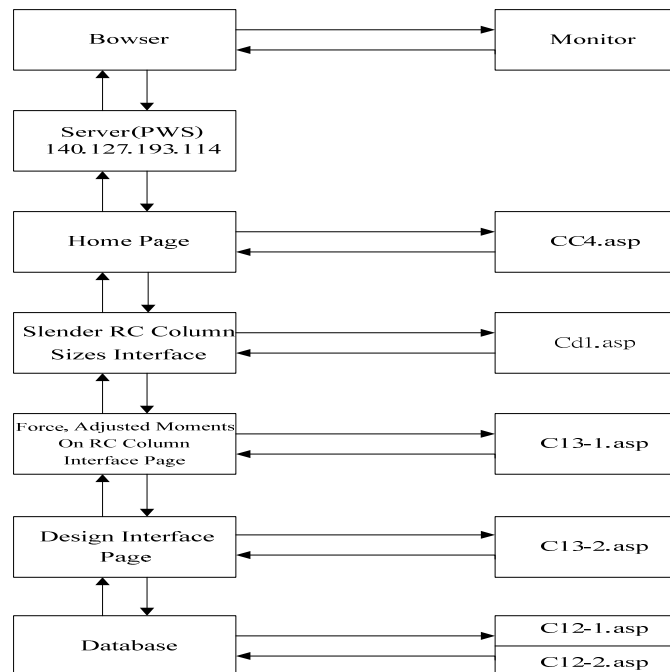


Figure 4 WSRCD system flowcharts

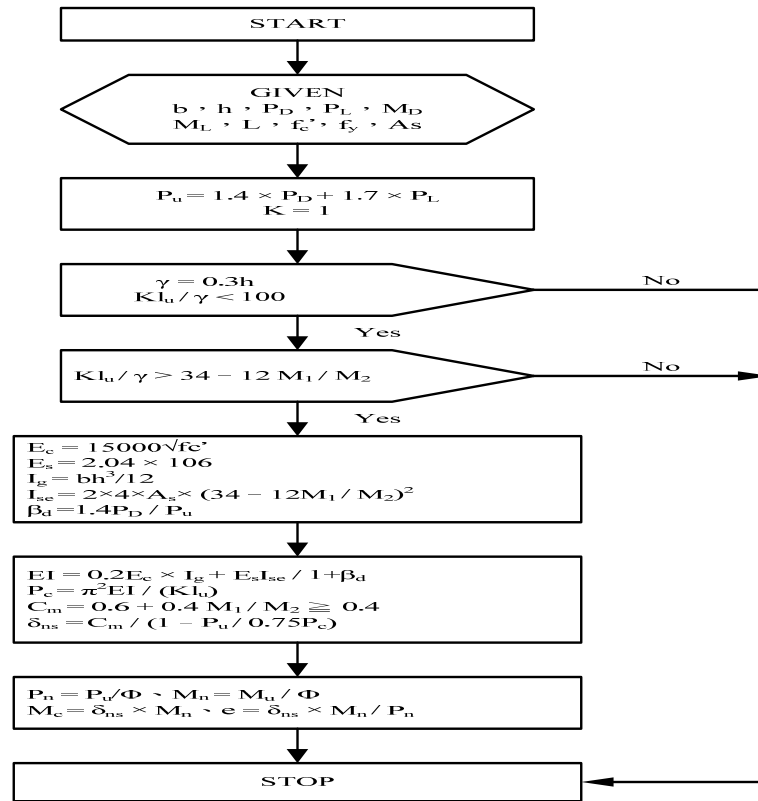


Figure 5 The ASP and “.asp” files of WSRCD system

5 Database

The purpose of the database of WSRCD system is to provide the steel area for reinforced concrete column design. Several tables were designed to make the query search faster. Two table files c4221.mdb and c4228.mdb were built for testing purposes. The fields of the c4221 table include: stress of concrete (f'_c), stress of steel (f_y), eccentricity (e), and design steel area (A_s). The relationships between the tables can be determined by using the sizes and the shapes of the columns.

The MS-ACCESS database was selected to be the database of WSRCD system. The size of the database can be as large as 1GB. There are no limitations on the tables, or the records. Relationships can be defined between the tables. After the relationships have been set up, it is easy to create queries, forms and reports to display information from several tables at once. On the internet, 255 users can use the same access database at the same time.

SQL query is used in the WSRCD system for the access database query. An SQL query is user created using an SQL statement. Examples of SQL-specific queries are the union query, pass-through query, data-definition query and sub query. MS-ACCESS can create a query instead of designing a query from scratch. The sub query of SQL-specific queries is selected to create the SQL statements in the

WSRCD system. The sub query consists of an SQL SELECT statement inside another select query or action query. Users can enter these statements in the field row of the query design grid to define a new field, or in the criteria row to define criteria for a field.

Maintenance of the database should be done by the WSRCD system-designer. Any transactional processes, such as edit, add and update data, of the database is not allowed. Because, the contents in the database are the results of a lot of calculations for reinforced concrete column design, data should be verified before put into the database.

6 Reinforced concrete column design

Reinforced concrete non-sidesway slender columns may have different types: tied, spiral, composite and concrete-filled pipe columns. The shapes of columns can be square, rectangular, circle or irregular. For a non-sidesway slender rectangular column, the theoretic results can be derived with amplify the bending moments. The moment amplified factor can be derived as shown:

$$\delta_{ns} = \frac{C_m}{1 - \frac{P_u}{\phi_k P_c}} \geq 1.0(\phi_k \times 0.7) \quad (1)$$

Where the equivalent moment factor $C_m = 0.6 + 0.4M_1/M_2 \geq 0.4$

The Euler buckled load $P_c = \pi^2 EI / L_u^2$

The design load $P_u = 1.4P_D + 1.7P_L$

The reduction factor $\phi_k = 0.75$

The amplified bending moments:

$$M_{c1} = \delta_{ns1} M_2, \text{ double curvature columns}$$

$$M_{c2} = \delta_{ns2} M_2, \text{ single curvature columns}$$

For given design information such as: column width (b), column depth (d), reinforced steel protection concrete thickness (d'), ultimate stress of concrete (f_c'), yielding stress of steel (f_y), axial load on column (P_n), bending moment on column (M_n), the design results (reinforced steel area A_s and A_s') can be calculated. The calculation equation of according (Shao, 1999) can be expressed as:

$$A_s = A_s' = \frac{P_n e' - 0.85 f_c' ab(d - \frac{a}{2})}{f_s'(d - d')} \quad (2)$$

A_s is reinforced steel area on tension side. The eccentricity distance e' is defined as $e' = P_n / M_n$. The stress of compression steel is f_s' . If the compression steel is yield, f_s' is equal to f_y . The compression zone depth of concrete is defined as “a”, which can be expressed as:

$$a = \frac{P_n - A_s(f_s' - f_s)}{0.85 f_c' b} \quad (3)$$

The stress of tension steel is f_s . If the column is tension failure control, then f_s is equal to f_y . If the column is compression failure control, the concrete in the compression zone were collapse before the tension steel yield. The calculation of A_s is complicated by using equation (2) and (3). In equation (2), compression zone depth of concrete “a” is unknown. In equation (3), reinforced steel area A_s is unknown. Therefore, it is convenient to use tables and charts to design.

7 Example

An example was chosen (Shao, 2000) to present a reinforced column design: The reinforced concrete non-sidesway slender column has an unsupported length $l_u = 5.5\text{m}$ design axial load $P_D = 49\text{t}$, $P_L = 40\text{t}$, and design bending moment $M_D = 12.5\text{t}\cdot\text{m}$. The ultimate concrete stress is $f_c' = 280\text{ kg/cm}^2$ and ultimate steel stress is $f_y = 4200\text{ kg/cm}^2$. The rectangular column cross section has width $b = 40\text{cm}$, and depth $h = 50\text{cm}$. Design the reinforced steel, needed for this rectangular column.

The design procedures:

- (1) From the client-side, execute the WSRCD page.
- (2) Input the material properties and the column size; $f_y = 4200\text{ kg/cm}^2$, $f_c' = 280\text{ kg/cm}^2$, $b = 40\text{cm}$, $h = 50\text{cm}$, input page of the slender column analyses as shown in Figure 6. Moment magnify factors page of the slender column analyses as shown in Figure 7. Magnified moments page of the slender column analyses as shown in Figure 8.
- (3) The analyses results; $P_u = 195.1\text{t}$, $M_u = 49.3\text{t}\cdot\text{m}$, input page for the slender column analyses and designs as shown in Figure 10. Home page for the slender column analyses and designs as shown in Figure 9. Interactive drawing page for the slender column analyses and designs as shown in Figure 11. Analyses output page for the slender column analyses and designs as shown in Figure 12. Designs output page for the slender column analyses and designs as shown in Figure 13.
- (4) The design results; $P_u = 140\text{t}$, $M_u = 15\text{t}\cdot\text{m}$ for double curvature column, $P_u = 140\text{t}$ $P_u = 140\text{t}$ $P_u = 140\text{t}$, $M_u = 19.58\text{t}\cdot\text{m}$ for single curvature column, as shown in Figure 14.

The design results from the WSRCD system are the same (single curvature: $P_u = 140\text{t}$, $M_u = 19.58\text{t}\cdot\text{m}$; double curvature: $P_u = 140\text{t}$, $M_u = 15\text{t}\cdot\text{m}$) with the example (Shao, 2000). This demonstrates that using Active Server Page and the database Access query is accurate.

Figure 6 shows the input page of the slender column analyses. It includes a diagram of a column cross-section with dimensions and input fields for material properties and dimensions.

Figure 6 Input page of the slender column analyses.

Figure 7 shows the moment magnify factors page of the slender column analyses. It includes a diagram of a column cross-section with dimensions and input fields for moment magnification factors.

Figure7 Moment magnify factors page of the slender column analyses.

Figure 8 shows the magnified momeents page of the slender column analyses. It includes a diagram of a column cross-section with dimensions and input fields for magnified moments.

Figure 8 Magnified momeents page of the slender column analyses.



Figure 9 Home page for the slender column analyses and designs.

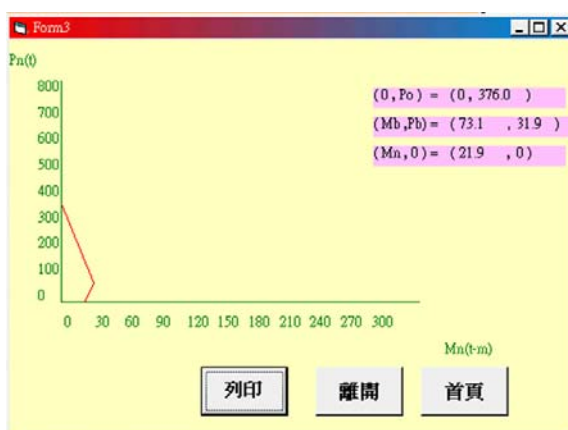


Figure 10 Input page for the slender column analyses and designs.

Figure 11 shows the interactive drawing page for the slender column analyses and designs. It includes a diagram of a column cross-section with dimensions and input fields for various parameters.

Figure 11 Interactive drawing page for the slender column analyses and designs.

Figure 12 displays the analyses output page for the slender column analyses and designs. The interface shows a cross-section diagram of a rectangular column with dimensions $b = 35$ cm and $h = 56$ cm. The results table includes the following data:

Parameter	Value	Unit
偏心距 (e)	30.1	cm
放大彎矩 (Mc)	70.8	t-m
平衡破壞點 (Pb)	209.9	t
平衡破壞點 (Mb)	113.7	t-m
純軸力破壞點 (Po)	671.6	t
純彎矩破壞點 (Mo)	49.3	t-m
標準載重 (Pn)	235.4	t
標準彎矩 (Mn)	60.6	t-m

Additional parameters shown include $Pd = 57$ t, $Pl = 50$ t, $Md = 14.5$ t-m, $Ml = 13$ t-m, $lu = 5.8$ m, $f'c = 280$ kg/cm², $fy = 4200$ kg/cm², and $Ast = 51.76$ cm². Buttons for calculation, clearing, printing, and home are available.

Figure 12 Analyses output page for the slender column analyses and designs.

Figure 13 displays the designs output page for the slender column analyses and designs. The interface shows a cross-section diagram of a rectangular column with dimensions $b = 35$ cm and $h = 40$ cm. The results table includes the following data:

Parameter	Value	Unit
Mut	14	t-m
Mub	11	t-m
b	35	cm
h	40	cm
f'c	280	kg/cm ²
fy	4200	kg/cm ²
lu	4.5	m
Pd	49	t
Pl	42	t

Buttons for calculation, clearing, printing, and viewing design steps are available.

Figure 13 Designs output page for the slender column analyses and designs.

Figure 14 displays the received design results. The interface shows a cross-section diagram of a rectangular column with dimensions $b = 40$ cm and $h = 50$ cm. The results table includes the following data:

Parameter	Value	Unit
Mut	15	t-m
Mub	-15	t-m
b	40	cm
h	50	cm
f'c	280	kg/cm ²
fy	4200	kg/cm ²
l	5.5	m
Pd	52	t
Pl	55	t

Buttons for OK and clear are available.

Figure 14 Received design results

8 Discussion

The WSRCD system is a new developed system for RC column design on network computer systems. Network computer systems, such as windows98/2000 and NT systems, have a whole range of integrated networking software. The traditional networked PC systems required add-on software to allow them to talk to each other. With current integrated networking software capabilities, the developer can migrate the processing to the client-side or to the server-side. The fundamental judgment should be dependent on cost efficiency. The WSRCD system integrated with ASP and MS-ACCESS becomes a powerful RC column design system on network computer. Advantages include:

(1) Fast response and simple usage

Instead of executing the calculation on the client-side, the querying network database on the server-side can fetch the results and send it back to the user. Querying from the database is faster than the complicated calculations of the RC column design. So, this process has fast response. The user on the

client-side need only key-in the necessary information through a web page interfaces. It is simple for user to use.

(2) Stable processing and resource savings

Client-side resources are limited. Through the ASP and the connection with ACCESS database however, most processes and resources are executed on the server-side. Processes executed on the server-side rather than the client-side tends to be more stable. Therefore, the client can experience stable processing and resource savings.

(3) Complete database connection

Through the ASP connection to the database, a complete set of tools, i.e. OLE-DB, ODBC, can be used. Also, using MS-ACCESS can create the database. Using MS-SQL to query can require design results from the database. For the transaction of the records, such as edit, add and update data, MS-ACCESS can be used to implement the necessary functions.

9 Conclusions

From the discussion and development of the WSRCD system, several conclusions can be stated as follows:

- (1) The object oriented ASP page was used in this study to investigate the web pages, data transfer interfaces, database queries. Therefore, using the same pattern, it is more convenient to develop an interactive web page than using Common Gateway Interface (CGI) or using Internet Server Application Programming Interface (ISAPI).
- (2) The WSRCD system is resident on the internet server-side. Any remote user can reach the WSRCD system easily as long as the user can reach the internet.
- (3) The WSRCD system is easy to expand to different types of columns. The tables of the database can be used to create a new table, which can be added to the database. Then, it creates the capability of new type column designs.

Acknowledgements

The authors would like to acknowledge the I-Shou University research project (ISU99-02-03) for their support.

REFERENCES

ACI Committee 318(2005)*Building Code Requirements for Structural Concrete (ACI318-05) and Commentary (ACI318R-05)*, American Concrete Institute, Detroit.

- Bit Culture(2000)*ASP 3.0 Dynamic Web Pages--- Introduction*, Ven-Qei Press Ltd., Taiwan.
- CRSI(1996)*CRSI Design Handbook*, 8th edition, Concrete Reinforcing Steel Institute.
- CICHE(2006)*CICHE Design Handbook*, Chinese Institute of Civil and Hydraulic Engineering.
- Connor, Deni(2001)IP Storage Taking Center Stage, *Network World*, Volumn 18, Number 22: 25, USA.
- Homer, Alex and Sussman, David(1998)*Professional MTS and MSMQ with VB and ASP*, Wrox Press Ltd., USA.
- Mier, Edwin and Percy, Kenneth(2001)Sizing up Storage Alternatives, *Network Word Global Test Alliance*, Volumn 18, Number 12: 60-66, Network World, USA.
- Shao, Ko-Young and Wang, Yu-Cheng(2000)An Investigation of Reintorced Concrete B eam Design Using ActiveX Technique on Interactive Web Pages, *The 5th National Conference on Structural Engineering*: 1627~1634, Taichung Taiwan.
- Shao, Ko-Young and Chang, Fon-Wei(2000)The Effects of Ultimate Lateral Forces of Earthquake for Reinforced Concrete Multiple Floor Frames With Brick Walls Systems, *Journal for I-Shou University*, Volume 7: 99017-040, Taiwan.
- Shao, Ko-Young, Cho-Yang Chen(2005) An Investigation of Interactive Web Pages for Design and Analysis of Cantilever Retaining Walls, *Proceedings of the 2005 Conference on Computer Applications in Civil & Hydraulic Engineering*: 1271, pdf In a CD-ROM, Tainai, Taiwan.
- Shao, Ko-Young, Terry Chang(2006)An Investigation of Interactive Web Pages for T-Section Reinforced Concrete Beam Design and Analysis, *2006 Culture and Design Conference ISBN 986-81273-5-1*, Volume 2: 2-24(2-19.pdf In a CD-ROM), Taipei, Taiwan.
- Shao, Ko-Young(2000)*Reinforced Concrete Design*: 310-315, Wu-Nan Press Ltd., ISBN 957-11-1944-X, Taiwan.
- Shao, Ko-Young, Terry Chang(2006)Interactive Web Pages for T-Section Reinforced Concrete Beam Design and Analysis, *the 18th Building Association for Building Research Conference*: 10(8c-3 In a CD-ROM), Taipei, Taiwan.
- Shao, Ko-Young, Shin-shih Liu(2002)Investigation of Interactive Web Pages for Torsion Design of Reinforced Concrete Beams, *The 6th National Conference On Structural Engineering*, Kenting, Taiwan. (In a CD-ROM)
- Shao, Ko-Young, Jiin-Po Yeh, Wei-Chin Chen, and Shao-Hsing Yang(2002)An Investigation of Reinforced Concrete Column Design using Active Server Pages Techniques, *the 9th International Conference on Computing in Civil and Building Engineering*: 621~626, Taipei, Taiwan.

鋼筋混凝土無側位移細長柱互動設計與分析

邵可鏞¹ 黃志揚^{2*} 蔡宗憲³ 張志偉⁴

¹ 台灣義守大學土木與生態工程學系副教授

² 台灣義守大學土木與生態工程學系研究生

³ 台灣義守大學土木與生態工程學系大專生

⁴ 台灣義守大學土木與生態工程學系碩士

*通訊作者 Email: andy26412035@hotmail.com

(2010 年 11 月 7 日投稿, 2010 年 12 月 24 日通過)

摘 要

本研究旨在探討互動式鋼筋混凝土無側位移細長柱分析與分析之伺服器網路系統架構。在數位營建之分析及設計中,經常需要透過區域網路(LAN)或資訊網路來分析及設計。網路的核心控制者為伺服器,故伺服器之架設及操控影響網路之運轉及效率至鉅。本文將探討伺服器端(Server-side)及使用者端(Client-side)之架構並將其組合成一互動式之伺服器網路系統。以無側位移細長柱分析為例,測試此互動式系統。系統應用微軟之 IIS(Internet Information Services),HTML(HyperText Markup Language),內建的 script 指令,ActiveX 元件,Java Script 程式等建立所需之 Component 程式。無側位移細長柱之分析法分別有:近似法、二階分析法及彎矩放大法等。本研究以彎矩放大法為例來建立此互動式網頁。為驗證本系統之正確性,文中以一範例驗證,其結果與參考文獻中例題之結果比較,完全相符。

關鍵詞: 互動式網頁, 鋼筋混凝土, 無側位移細長柱設計