Development of a Program for Design and Drafting of Reinforced Concrete Staircases

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Abstract

A general approach to produce structural drawings includes designing by an engineer and drafting by a draftsman. This approach takes time and requires coordination to complete the drawings for construction. This research aims to develop a program that can help the engineer to work alone on the designing from a beginning to an end, which will reduce work time and coordination errors. Drafting of the reinforced concrete staircase has many details to do, so a program for designing and drafting reinforced concrete staircases was developed. For the design part, worksheets in Microsoft Excel that are normally used by engineers were employed. A program using Visual Basic for Application (VBA) in Microsoft Excel was also employed to read data from the worksheet and convert it into a Script file (.scr), a format that is readable by drafting programs such as AutoCAD. The program can be used to design and draft three types of staircases, which are, simple, continuous, and free-standing staircases, allowing an efficient design of the staircases. The approach used in this research also shows that the development of a program for designing and drafting is not difficult and can be used to further develop similar programs for other parts of structures.

Keywords: *Reinforced Concrete Staircases, Design and Drafting, Program Development.*

1. Introduction

Typical structural design calculations use hand calculations, which are time-consuming and subject to errors. Later, the technology was advanced such that computers were implemented to help in calculating, designing, and drafting, making these works more convenient and faster. A 2-dimensional structural analysis program, SUTStructor (Alongkorn, 2000), is good for analyzing structures but not applicable for designing and drafting. An application using Microsoft Excel was later developed to improve the design of reinforced concrete structures by helping to design floor slabs, stairs, retaining walls, and reinforced concrete walls (Natthawut and Chawanwit, 2012). The application can be efficiently used in designing those structures but cannot be used for drafting drawings of the structures.

Adisorn had written a structural designing and drafting program that can be done in just one step by a civil engineer without a need to coordinate with a draftsman. It reduces working hours and possible errors caused by coordination. This program was developed for analyzing, designing, and drafting reinforced concrete slab and beam structures by using the Visual Basic for Application (VBA) feature in Microsoft Excel and AutoCAD (Adisorn, 2016). In developing this type of program, the developer must know both VBA in Microsoft Excel and VBA in AutoCAD, which are not common for any civil engineer. Afterward, there was a further development by writing design calculations in Microsoft Excel worksheet and using VBA to convert those data from the worksheet into a Script file, which is a format that can be read and translated into a drawing by AutoCAD or other drafting programs. Software that was developed based on this approach was, for instance, a program for designing and drafting reinforced concrete beams using strength design method (Pisanunan, Waris, and Jeeranan, 2013) and a program for designing and drafting short reinforced concrete columns (Pheera and Ongart, 2017). The development of a program using this approach is suitable for civil engineers with some programming knowledge since it is based on Microsoft Excel worksheets, which is familiar for civil engineers. VBA in Microsoft Excel is used to increase the capabilities of the program. Additional knowledge only on the VBA can be studied without difficulty.

The approach was used in this research to create a program for designing three types of the reinforced concrete stairs; simple span, continuous span, and free-standing stairs, to reduce time consumed in designing and errors from coordination.

[649]

2. Objectives

This research has two main objectives as follows;

1) To develop a program for designing and drafting the reinforced concrete staircases.

2) To determine an appropriate approach for civil engineers to develop a program for designing and drafting other parts of the structures.

3. Program Development

The program uses a Microsoft Excel worksheet in creating calculation sheets for designing a reinforced staircase and uses VBA in Microsoft Excel in reading the data in the worksheet and converting them into a Script file. The file can be read and automatically translated into a drawing by any drafting programs such as AutoCAD or IntelliCAD. The details of the developments are as described in the following section.

3.1 Development of Calculation Sheets for Design of Staircases

Strength Design was used based on the Building Code Requirements for Structural Concrete of The American Concrete Institute (ACI Committee 318, 1999). Worksheets for designing three types of staircases were developed as follows.

3.1.1 Simple Span Staircase

This type of stair has two beams at the ends to support the stair as shown in Figure 1, with a lower landing of length L1, a flight of length L2, an upper landing of length L3. Dimensions of riser and tread are R and T, respectively. Nosing length and width of stair are defined as N and b, respectively.

The staircase has 3 intervals of loads. Intervals corresponding to L1, L2, and L3 have uniformly distributed loads of w1, w2, and w3, respectively. These loads are factored loads calculated from the weight of the floor (DL1), the weight of step (DL2), superimposed dead load (SDL), and live load (LL). The details of the calculations are explained in Equations 1-3.

$$w1 = 1.4(DL1 + SDL) + 1.7LL \qquad (1)$$
$$w2 = 1.4(DL1 + DL2 + SDL) + 1.7LL \qquad (2)$$
$$w3 = 1.4(DL1 + SDL) + 1.7LL \qquad (3)$$

The staircase is considered a simple beam. Shear force and bending moment are then calculated. Program users can choose the size and spacing of main reinforcements and temperature reinforcements. The worksheet will show the shear strength and bending strength, accordingly. The selected size and spacing of the reinforcements must be appropriate so that the staircase has higher shear strength and bending strength than the resulting forces. The screen showing the design worksheet was given in Figure 3.

3.1.2 Continuous Span Staircase

This type of stair has four beams to support the stair as shown in Figure 2, with the same notations for stair dimensions and loadings as described in section 3.1.1. The staircase is considered a continuous beam, and the resulting shear force and bending moment are calculated by an approximation method, with coefficients C_m and C_v for moment and shear, respectively (Figure 2). The equations for shear and moment when the applied uniformly distributed load is W and span length is L can be described in Equations 4 and 5.

$$\text{Bending Moment} \qquad M = C_m W L_n^2 \qquad (4)$$
$$\text{Shear Force} \qquad V = C_v W L_n / 2 \qquad (5)$$

Program users can choose the size and spacing of the main reinforcements and temperature reinforcements. The worksheet will show the shear strength and bending strength, accordingly. The selected size and spacing of the reinforcements must be appropriate so that the staircase has higher shear strength and bending strength than the resulting forces. The screen showing the design worksheet was given in Figure 4.
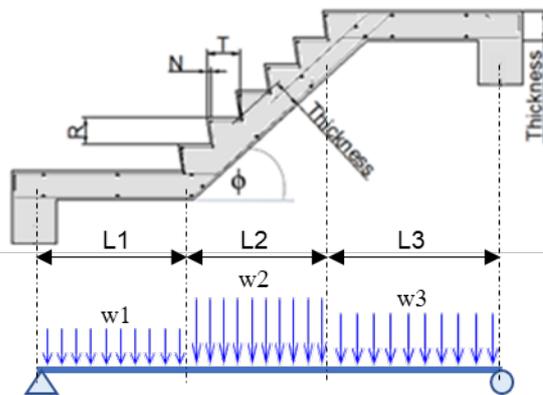
[650]

Figure 1 Simple Span Staircase
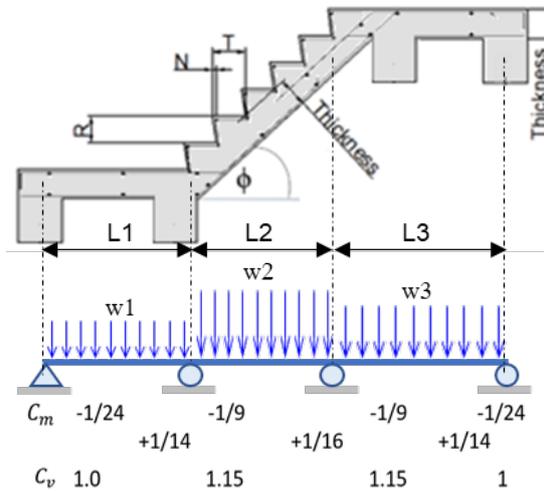
Figure 2 Continuous Span Staircase

SIMPLE SPAN										
f'c	210	ksc				save file		D:\CEN499\Test01		
Rebar	DB	12								
fy	4000	ksc			Width of support		0.3	m		
Stirrup	RB	9			Height of support		0.5	m		
fy	2400	ksc			scale	1:	20		**GEN FILE**	
covering	2	cm								
β1	0.85									
DL Factor	1.4									
LL Factor	1.7									
LL	500	ksm								
SDL	200	ksm								
H	3.5	m								
L1	1	m								
L2	1.73	m								
L3	1.2	m								
b	170	cm								
b1	190	cm								
R	18.1	cm	ϕ	42.87						
T	22	cm	w1	1634	ksm		shear	3622.35	3582.49	kg
N	2.5	cm	w2	2087	ksm		moment max	3752.66	kg-m	
thickness	15	cm	w3	1634	ksm		at	1.95	m	
No. of riser	20									

Main Steel				Temperature Steel			Shear Capacity		
ρ max	0.01720			ρtemp	0.0018		Vu [kg]	3622.35	
ρ min	0.00350			As,min	2.7	cm^2	ϕVc [kg]	8095.173	ok
ρ req	0.00739	ok		DB	12 @	0.400 m			
As	9.166	cm^2	ok						
	DB	12 @	0.123 m						
use	DB	12 @	0.120 m	O.K.					

Figure 3 Design Worksheet for Simple Span Staircase

3.1.3 Free-Standing Staircase

       This type of stair has a landing that extends freely without any support. The stair slabs for upper and lower flights are used as main structures to support the free-standing landing of the stair, as shown in Figure 5. Various forms of internal forces are induced in the staircase structure, e.g., torsional moment and horizontal shear force in the landing. The design of this type of staircase has much more details than the simple span and continuous span staircases. This research employed the equations developed in the Reinforced Concrete

[651]

Designer's Handbook (Reynolds, Steedman, and Threlfall, 2008). The free-standing stair has 2 variations, i.e., free-standing stair with fixed supports and free-standing stair with hinge supports.
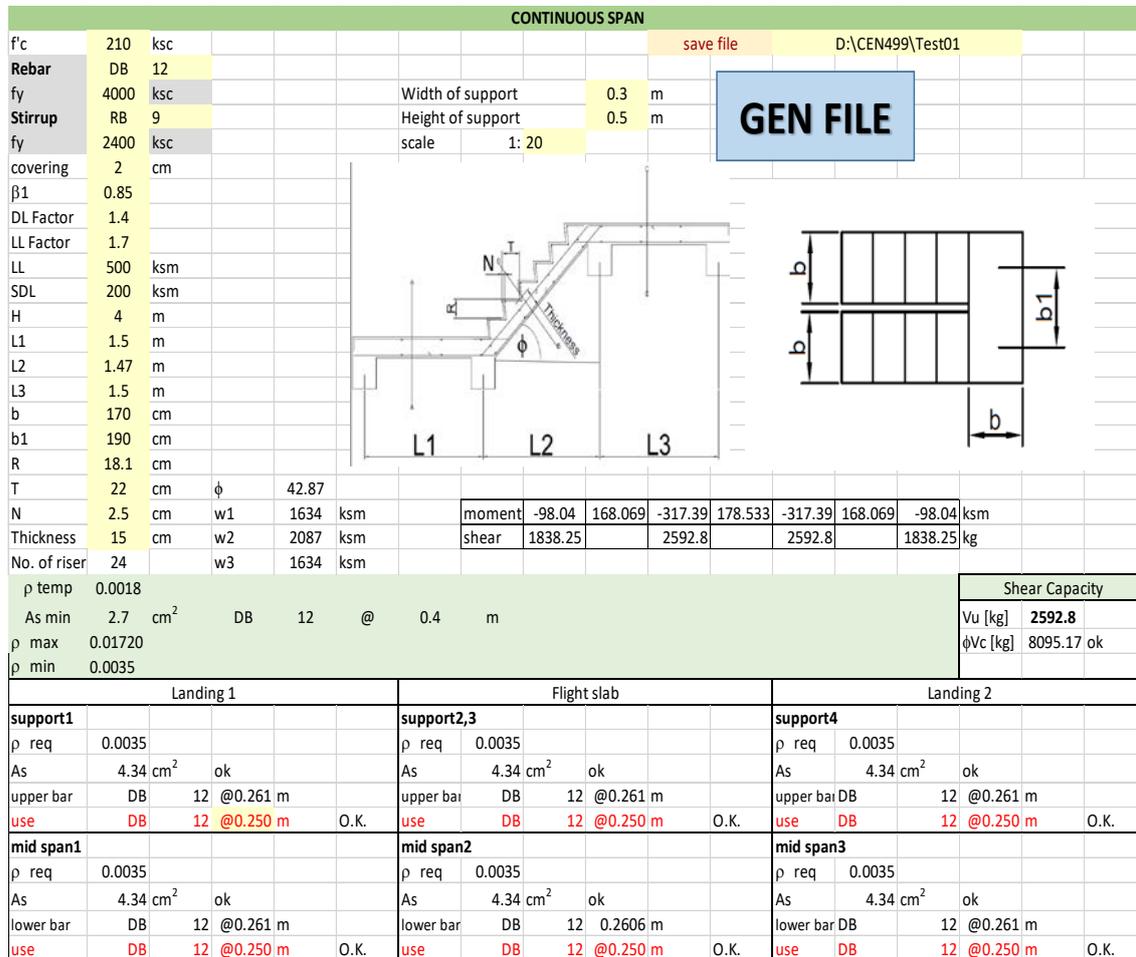
CONTINUOUS SPAN													
f'c	210	ksc					save file		D:\CEN499\Test01				
Rebar	DB	12											
fy	4000	ksc		Width of support		0.3	m		**GEN FILE**				
Stirrup	RB	9		Height of support		0.5	m						
fy	2400	ksc		scale	1: 20								
covering	2	cm											
β1	0.85												
DL Factor	1.4												
LL Factor	1.7												
LL	500	ksm											
SDL	200	ksm											
H	4	m											
L1	1.5	m											
L2	1.47	m											
L3	1.5	m											
b	170	cm											
b1	190	cm											
R	18.1	cm											
T	22	cm	φ	42.87									
N	2.5	cm	w1	1634	ksm		moment	-98.04	168.069	-317.39	178.533	-317.39	168.069	-98.04 ksm
Thickness	15	cm	w2	2087	ksm		shear	1838.25		2592.8		2592.8		1838.25 kg
No. of riser	24		w3	1634	ksm								
ρ temp	0.0018										Shear Capacity		
As min	2.7	cm²	DB	12	@	0.4	m				Vu [kg]	**2592.8**	
ρ max	0.01720										φVc [kg]	8095.17	ok
ρ min	0.0035												

Landing 1					Flight slab					Landing 2				
support1					**support2,3**					**support4**				
ρ req	0.0035				ρ req	0.0035				ρ req	0.0035			
As	4.34 cm²	ok			As	4.34 cm²	ok			As	4.34 cm²	ok		
upper bar	DB	12	@0.261 m		upper bar	DB	12	@0.261 m		upper bar	DB	12	@0.261 m	
use	DB	12	@0.250 m	O.K.	use	DB	12	@0.250 m	O.K.	use	DB	12	@0.250 m	O.K.
mid span1					**mid span2**					**mid span3**				
ρ req	0.0035				ρ req	0.0035				ρ req	0.0035			
As	4.34 cm²	ok			As	4.34 cm²	ok			As	4.34 cm²	ok		
lower bar	DB	12	@0.261 m		lower bar	DB	12	0.2606 m		lower bar	DB	12	@0.261 m	
use	DB	12	@0.250 m	O.K.	use	DB	12	@0.250 m	O.K.	use	DB	12	@0.250 m	O.K.

Figure 4 Design Worksheet for Continuous Span Staircase
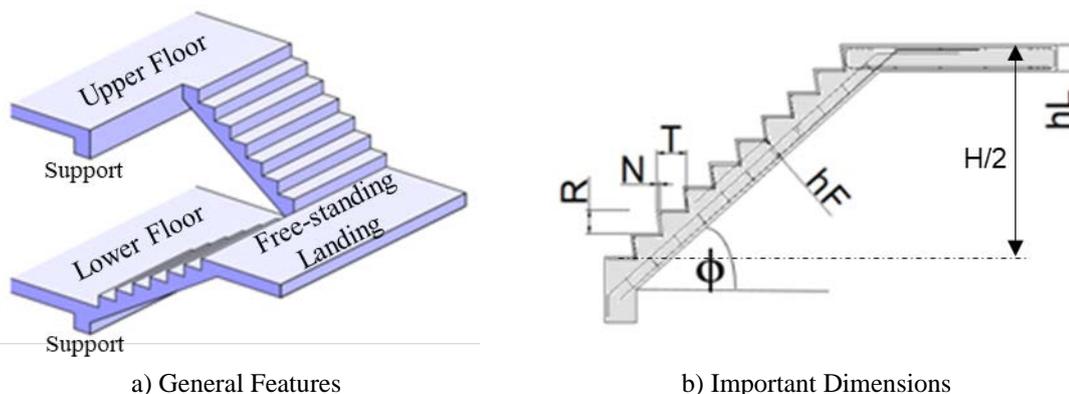
a) General Features

b) Important Dimensions

Figure 5 Free-Standing Staircase

[652]

The same notations for stair dimensions and loadings as described in section 3.1.1 were used. Total stair height is H with equal length of the upper and lower flights. The analysis is divided into three cases: 1) Live loads are on both flight and the landing, 2) Live loads are on flight only, and 3) Live loads are on landing only. The largest forces from the three cases are used for later design work. The screen showing the design worksheet for free-standing stair with fixed supports was given in Figure 6. A similar worksheet for free-standing stair with hinge was also developed in this research.

3.2 Application of VBA to Generate Script Commands

VBA in Microsoft Excel is a computer language developed by Microsoft (Walkenbach, 2013), which allows users to write instructions to control operations or manage data in Microsoft Excel worksheets conveniently and efficiently. In this research, VBA instructions are used to read data from the design worksheets, convert them into Script commands that are readable by other drafting programs (Luintel, 2005), open a Text file to write the generated Script commands, and save it in the ".scr" format. A stair drawing can be obtained by executing the saved file (.scr) in any drafting programs such as AutoCAD or IntelliCAD. These programs will automatically generate the drawing. The flowchart of the developed program is shown in Figure 7. The program consists of different parts as described below.

3.2.1 VBA Instructions for Reading and Writing Data

a) Command to open a text file for writing data is "Open". Figure 8a shows an example of opening a file named "Stair1.scr" for receiving data ("for Output") and the file is assigned as Number 1 ("#1"). Script for drafting generated by VBA will be later stored in this opened file.

b) Command to read data from the worksheet is "Cells". For example, $Cells(13, 2)$ will read data from Row 13 and Column 2 of the worksheet. Figure 8b shows data reading of total height of stair, riser height, tread length, and nosing size and storing them in Variables H, R, T, and N, respectively.

c) Command to write data into the opened text file is "Print" or "Write." Figure 8c shows an example of a script for drafting a Polyline in file Number 1.
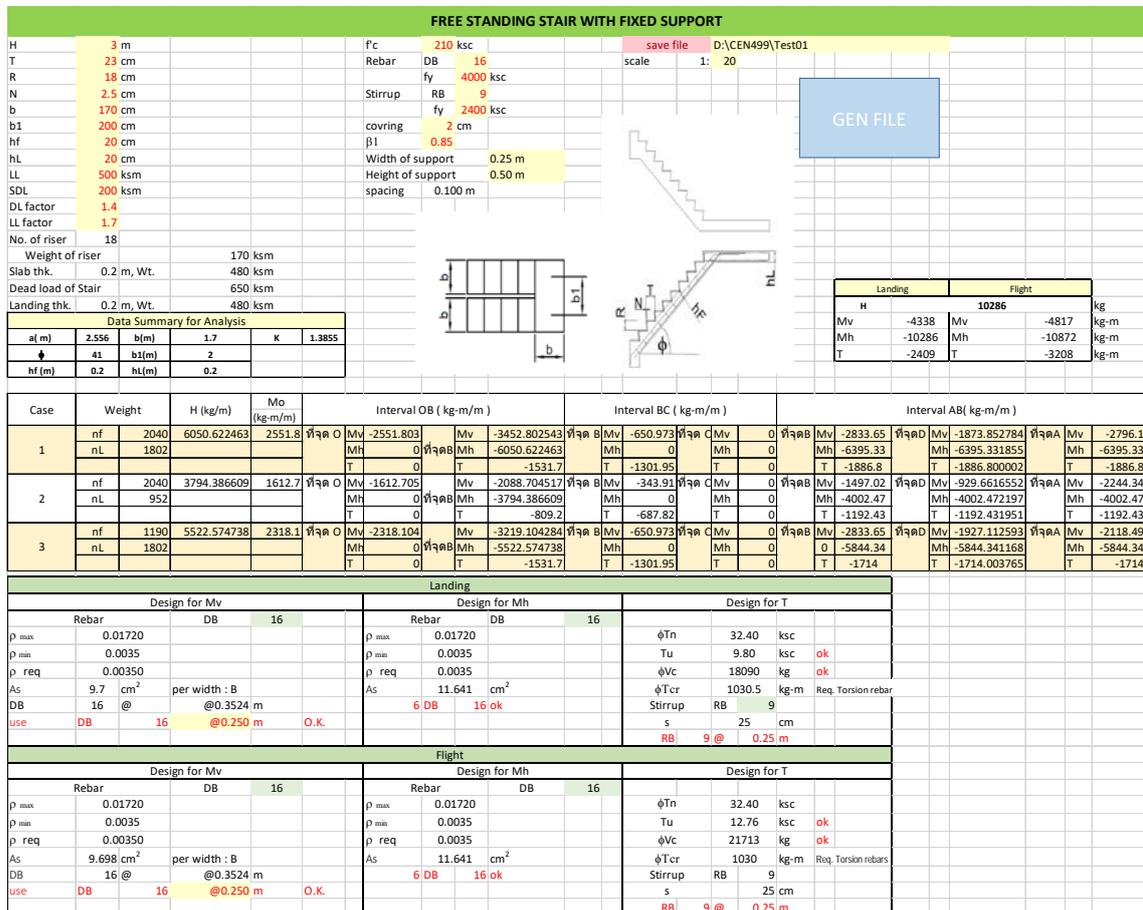
FREE STANDING STAIR WITH FIXED SUPPORT

H	3 m	f'c	210 ksc	save file	D:\CEN499\Test01
T	23 cm	Rebar DB	16	scale	1: 20
R	18 cm	fy	4000 ksc		
N	2.5 cm	Stirrup RB	9		
b	170 cm	fy	2400 ksc	GEN FILE	
b1	200 cm	covring	2 cm		
hf	20 cm	β1	0.85		
hL	20 cm	Width of support	0.25 m		
LL	500 ksm	Height of support	0.50 m		
SDL	200 ksm	spacing	0.100 m		
DL factor	1.4				
LL factor	1.7				
No. of riser	18				
Weight of riser	170 ksm				
Slab thk. 0.2 m, Wt.	480 ksm				
Dead load of Stair	650 ksm				
Landing thk. 0.2 m, Wt.	480 ksm				

Data Summary for Analysis

a(m)	2.556	b(m)	1.7	K	1.3855
Φ	41	b1(m)	2		
hf (m)	0.2	hL(m)	0.2		

Landing	
H	10286	kg
Mv	-4338	Mv	-4817	kg-m
Mh	-10286	Mh	-10872	kg-m
T	-2409	T	-3208	kg-m

Case	Weight		H (kg/m)	Mo (kg-m/m)		Interval OB (kg-m/m)			Interval BC (kg-m/m)			Interval AB(kg-m/m)		
1	nf	2040	6050.622463	2551.8	ที่จุด O Mv	-2551.803	Mv	-3452.802543 ที่จุด B Mv	-650.973 ที่จุด C Mv	0	ที่จุด B Mv	-2833.65 ที่จุด D Mv	-1873.852784 ที่จุด A Mv	-2796.1
	nL	1802			Mh	0 ที่จุด B Mh	-6050.622463	Mh	0	Mh	0	Mh	-6395.33	Mh	-6395.331855	Mh	-6395.33
					T	0	T	-1531.7	T	-1301.95	T	0	T	-1886.8	T	-1886.800002	T	-1886.8
2	nf	2040	3794.386609	1612.7	ที่จุด O Mv	-1612.705	Mv	-2088.704517 ที่จุด B Mv	-343.91 ที่จุด C Mv	0	ที่จุด B Mv	-1497.02 ที่จุด D Mv	-929.6616552 ที่จุด A Mv	-2244.34
	nL	952			Mh	0	Mh	-3794.386609	Mh	0	Mh	0	Mh	-4002.47	Mh	-4002.472197	Mh	-4002.47
					T	0	T	-809.2	T	-687.82	T	-1192.43	T	-1192.431951	T	-1192.43
3	nf	1190	5522.574738	2318.1	ที่จุด O Mv	-2318.104	Mv	-3219.104284 ที่จุด B Mv	-650.973 ที่จุด C Mv	0	ที่จุด B Mv	-2833.65 ที่จุด D Mv	-1927.112593 ที่จุด A Mv	-2118.49
	nL	1802			Mh	0 ที่จุด B Mh	-5522.574738	Mh	0	Mh	0	0	Mh	-5844.34	Mh	-5844.341168	Mh	-5844.34
					T	0	T	-1531.7	T	-1301.95	T	0	T	-1714	T	-1714.003765	T	-1714

Landing

Design for Mv			Design for Mh			Design for T		
Rebar	DB	16	Rebar	DB	16			
ρ max	0.01720		ρ max	0.01720		φTn	32.40	ksc
ρ min	0.0035		ρ min	0.0035		Tu	9.80	ksc ok
ρ req	0.00350		ρ req	0.0035		φVc	18090	kg ok
As	9.7 cm²	per width : B	As	11.641 cm²		φTcr	1030.5	kg-m Req. Torsion rebar
DB	16 @	@0.3524 m	6 DB	16 ok		Stirrup RB	9	
use	DB 16	@0.250 m	O.K.			s	25	cm
						RB 9 @	0.25 m	

Flight

Design for Mv			Design for Mh			Design for T		
Rebar	DB	16	Rebar	DB	16			
ρ max	0.01720		ρ max	0.01720		φTn	32.40	ksc
ρ min	0.0035		ρ min	0.0035		Tu	12.76	ksc ok
ρ req	0.00350		ρ req	0.0035		φVc	21713	kg ok
As	9.698 cm²	per width : B	As	11.641 cm²		φTcr	1030	kg-m Req. Torsion rebars
DB	16 @	@0.3524 m	6 DB	16 ok		Stirrup RB	9	
use	DB 16	@0.250 m	O.K.			s	25 cm	
						RB 9 @	0.25 m	

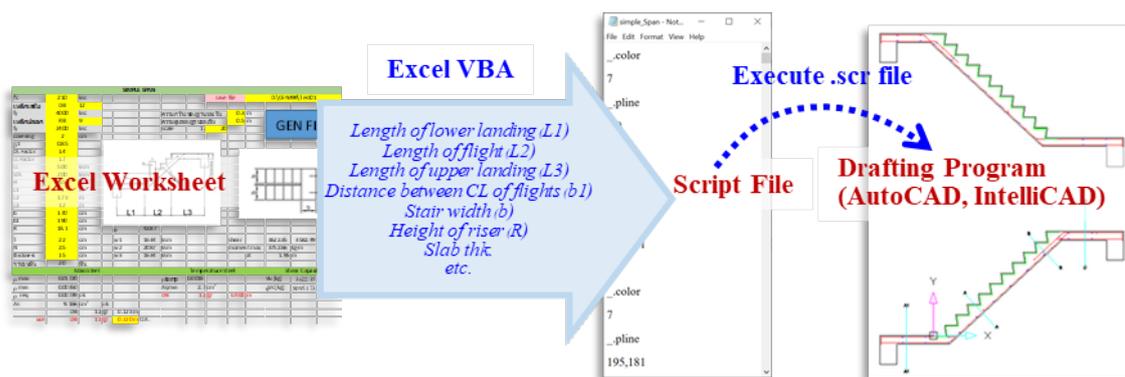**Figure 6** Design Worksheet for Free-Standing Staircase with Fixed Support

Figure 7 Flowchart of The Program

[654]

Open "Stair1.scr" For Output As #1

a) Opening a Text File for Writing Data

H = Cells(13, 2)
R = Cells(19, 2)
T = Cells(20, 2)
N = Cells(21, 2)

b) Reading Data from Worksheet

Print #1, "_.pline"
Print #1, MB11
Print #1, "w"
Write #1, 0.5
Write #1, 0.5

c) Writing Data into a Text File

Figure 8 Examples of VBA Commands for Reading and Writing Data

3.2.2 VBA Instructions for Generating Script commands

Essential data in drafting a structure are the coordinates x and y of various points on the structure. This research used VBA to read data from the design worksheet and translate those data into the coordinates of the points. Then, the Script commands were used to connect those points to create lines of drawing for the desired structure. The example commands are as follows.

a) Command to draw a continuous line "_.Pline." An example of a continuous line in the structural drawing is a line showing steps of a stair. In Figure 9, the coordinates of the first and second points were calculated and stored in Variables MB31 and MB32. The command to draw a continuous line ("_.Pline") connecting MB31 and MB32 was then generated and written in the text file Number 1 ("#1"). The width of the line was specified by Command "w." This set of commands was ended by adding an empty line in the text file.

MB31x = x6 - (cov * 10) - stir - (1.5 * dia)	← *x-coordinates of Point 1*
MB31y = y6 + (cov * 10) + (1 * dia)	← *y-coordinates of Point 1*
MB31 = MB31x & "," & MB31y	← *x, y coordinates of Point 1*
MB32y = MB31y	← *x-coordinates of Point 2*
MB32x = (MB32y - c3) / slope	← *y-coordinates of Point 2*
MB32 = MB32x & "," & MB32y	← *x, y coordinates of Point 2*
Print #1, "_.Pline"	← *Write command to draw line (_.Pline)*
Print #1, MB31	← *Write coordinates of Point 1*
Print #1, "w"	← *Write command to define line width*
Write #1, 0.5	← *Write line width at starting point*
Write #1, 0.5	← *Write line width at ending point*
Print #1, MB32	← *Write coordinates of Point 2*
Print #1,	← *Write a blank line to end this set of commands*

Figure 9 Example of VBA Command to Draw a Continuous Line

b) Command to draw a circle "_.circle." An example of a circle in the structural drawing is a cross-section of steel reinforcement. In Figure 10, the coordinates of the center were calculated and stored in Variable LLnCo12. The command to draw a circle ("_.circle") was then generated and written in the text file Number 1 ("#1"). The coordinates of the center (LLnCo12) were written to the same file following by the radius of the circle.

[655]

```
LLnCo12x = xx5 - (cov * 10) - stir - (dia / 2) - stir     ← x-coordinates of circle center
LLnCo12y = yy3 - (cov * 10) - (dia / 2)                    ← y-coordinates of circle center
LLnCo12 = LLnCo12x & "," & LLnCo12y                        ← x, y coordinates of circle center
Print #1, "_.circle"                                       ← Write command to draw circle (_.circle)
Print #1, LLnCo12                                          ← Write coordinates of circle center
Write #1, dia / 2                                          ← Write radius of circle
```

Figure 10 Example of VBA Command to Draw a Circle

c) Command to draw a rectangle "_.rectang." An example of a rectangle in the structural drawing is a cross-section of a beam or slab. In Figure 11, the coordinates of the lower-left corner and upper-right corner of the rectangle were calculated and stored in Variables secL_1 and secL_2, respectively. The command to draw a rectangle ("_.rectang") was then generated and written in the text file Number 1 ("#1"). The coordinates of the lower-left corner and upper-right corner (secL_1 and secL_2) were written to the same file.

```
xstart = (2 * R * H * 10) + 4000            ← x-coordinates of reference point
ystart = (2 * R * H * 10) + 3000            ← y-coordinates of reference point
secL_1x = xstart                            ← x-coordinates of lower-left corner
secL_1y = ystart                            ← y-coordinates of lower-left corner
secL_2x = xstart + ((B + B1) * 10)          ← x-coordinates of upper-right corner
secL_2y = ystart - (hL * 10)                ← y-coordinates of upper-right corner
secL_1 = secL_1x & "," & secL_1y            ← x, y coordinates of lower-left corner
secL_2 = secL_2x & "," & secL_2y            ← x, y coordinates of upper-right corner
Print #1, "_.rectang"                       ← Write command to draw rectangle (_.rectang)
Print #1, secL_1                            ← Write coordinates of lower-left corner
Print #1, secL_2                            ← Write coordinates of upper-right corner
```

Figure 11 Example of VBA command to Draw a Rectangle

4. Program Usage

This program consists of Microsoft Excel worksheets and subprograms in VBA. There are a total of five worksheets. The first worksheet is titled "Control" for setting drafting parameters such as colors of the lines and others for the staircase design. The worksheets titled "simple_span," "continuous_span," "Freestanding_with_fixed," and "Freestanding_with_hinge" are for designing simple span staircase, continuous span staircase, free-standing staircase with fixed support, and free-standing staircase with hinge, respectively. Also, four subprograms in VBA titled "SimpleStair1," "SimpleStair2," "FreeStanding1," and "FreeStanding2" are for reading the data from the corresponding design worksheets and generating the Script files for drafting the stairs.

4.1 Usage Procedure

The program application starts from selecting the worksheet for the desired type of stair (e.g., simple span or free-standing stairs), titling the file, and locating a folder for the later generated Script file. The colors of lines and texts must also be set in the "Control" worksheet. Then, the user must input design parameters such as stair height, riser height, and thread length and click the "GEN FILE" button in the chosen design worksheet. The program will generate a Script file. The file can later be loaded into a drafting program to automatically create a stair drawing. The details on how to use the program are explained in the thesis "A Program for Design and Drafting of Staircase using Strength Design Method" (Nut, Songphon, and Nuttawat, 2018).

4.2 Sample Usage

This article only demonstrates the application of the program to design a free-standing stair with fixed support. The screen showing the design worksheet is shown in Figure 6. The data input section and steel selection section was enlarged for clarity in Figures 12 and 14, respectively. When the button "GEN FILE" was pressed, a Script file named "Test01.scr" was generated almost immediately. The Script file was then loaded into AutoCAD, and a drawing of a reinforced concrete staircase (Figure 13) was created in few seconds. The drawing was also consistent with the design parameters. When the same drawing was created using a conventional procedure, three to four hours were used for designing a stair in the worksheet, sketching a stair drawing, assigning a draftsman to draw, and checking the drawing. The program reduced the working time significantly and minimized the coordination errors.

H	3	m	f'c	210	ksc
T	23	cm	Rebar	DB	16
R	18	cm		fy	4000	ksc
N	2.5	cm	Stirrup	RB	9
b	170	cm		fy	2400	ksc
b1	200	cm	covring	2	cm
hf	20	cm	$\beta1$	0.85
hL	20	cm	Width of support	0.25 m
LL	500	ksm	Height of support	0.50 m
SDL	200	ksm	spacing	0.100 m
DL factor	1.4	
LL factor	1.7	

Figure 12 Data Input Section
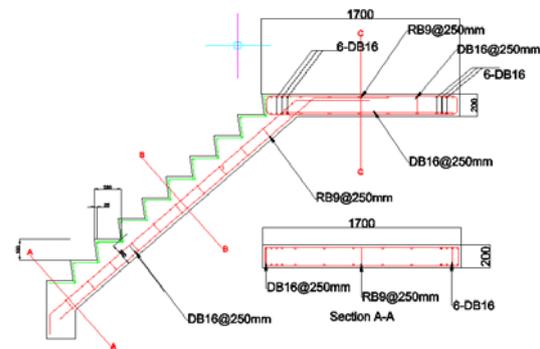
Figure 13 Generated Drawing of the Reinforced Concrete Stair

Landing										
Design for Mv				Design for Mh				Design for T		
Rebar		DB	16	Rebar		DB	16			
ρ_{max}	0.01720			ρ_{max}	0.01720			ϕTn	32.40	ksc
ρ_{min}	0.0035			ρ_{min}	0.0035			Tu	9.80	ksc	ok
ρ_{req}	0.00350			ρ_{req}	0.0035			ϕVc	18090	kg	ok
As	9.7	cm^2	per width : B	As	11.641	cm^2		ϕTcr	1030.5	kg-m	Req. Torsion rebar
DB	16	@	@0.3524 m		6 DB	16	ok	Stirrup	RB	9
use	DB	16	@0.250 m	O.K.				s	25	cm
								RB	9 @	0.25 m
Flight										
Design for Mv				Design for Mh				Design for T		
Rebar		DB	16	Rebar		DB	16			
ρ_{max}	0.01720			ρ_{max}	0.01720			ϕTn	32.40	ksc
ρ_{min}	0.0035			ρ_{min}	0.0035			Tu	12.76	ksc	ok
ρ_{req}	0.00350			ρ_{req}	0.0035			ϕVc	21713	kg	ok
As	9.698	cm^2	per width : B	As	11.641	cm^2		ϕTcr	1030	kg-m	Req. Torsion rebars
DB	16	@	@0.3524 m		6 DB	16	ok	Stirrup	RB	9
use	DB	16	@0.250 m	O.K.				s	25	cm
								RB	9 @	0.25 m

Figure 14 Steel Reinforcement Selection Section

5. Conclusion

A program using worksheets and VBA in Microsoft Excel was developed. Design calculations according to ACI code (ACI Committee 318, 1999) were arranged in the worksheets, and VBA was used to convert their data into a Script file. The file can be read by any drafting programs such as AutoCAD or IntelliCAD to generate a staircase drawing. The program helps engineers in designing staircases more efficiently. It can be employed to design and draw three types of staircases, namely, simple span, continuous span, and free-standing staircases. The design calculations can be easily upgraded to a newer code without difficulty since they were written in Excel worksheets. The research results showed that the design of the

staircases can be done using this program with speed and accuracy. The engineers can design and draft in few minutes. Moreover, the approach used in the program is suitable for civil engineers and can be developed further to create programs for designing and drafting other parts of the structures. The engineers who want to develop a program needs only knowledge of already familiar Microsoft Excel worksheets and command scripts, which are similar to AutoCAD drafting commands. Additional knowledge required that may be unfamiliar is VBA in Microsoft Excel.

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