Developing Excel-VBA Spreadsheet for Truss Element Analysis and Design

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ABSTRACT In this paper EXCEL Visual Basic application spreadsheet has used in analyzing and designing truss elements. EXCEL spreadsheet was developed to draw and analyzes different type of truss elements for tension and compression forces. The truss members were tested under dead, imposed, and wind load. Members capacity was provided according to BS 5950. Different type of joints connection was designed and recommended for support and internal joints.

Keywords: Analysis, Design, MS Excel, Truss

1. INTRODUCTION

An Excel-VBA computer program is developed to analyze truss element structures using stiffness method. Trusses are fabricated from various steel sections available which jointed together by welding or bolting. Loading on trusses consist of dead load, live load and wind loads, dead and live loads act directly in gravity direction As in Fig. 1, and wind loads are act normal to truss inclination As in Fig. 2. Combination of load according to type of code applied gives a maximum effect of forces in individual members.

Fig. 1. Nodal forces for Dead load and Live load in gravity direction.

Fig. 2. Nodal forces for Wind load normal to truss inclination.

A. Tension and compression members

Most truss structures resist direct axial force that result in tension or compression effect on truss members. According to BS 5950 Part 1 [1]

tension capacity is evaluated as follows

$$P_t = A_e \cdot p_y \quad (1)$$

Where

A_e is the effective area for tension

p_y is the design strength

Compression capacity evaluated as follows

$$P_c = A_g \cdot p_c \quad (2)$$

Where

A_g is the gross area for compression

p_c is the design compression strength

The primary reason for using Excel is that it is generally available software, and it comes with every computer system (both PC and Mac) with Microsoft office installed. VBA is a programming environment that comes with Excel and greatly enhance the capabilities of excel spreadsheets [2].

Spreadsheets are characterized by arrays of cells in which data are input either as numbers or text or as formulae. Comments on data in the cells can also be input and hidden if desirable [3]. Because of the mathematical nature of engineering studies, the use in which spreadsheet allows for numerical computations and for creation of good charts makes it the favorite tool for engineers [4].

2. MATERIAL AND METHODS

One of the strong points of Excel is its macro

capability of using macro programming language to shorten and simplify the repetitive works. VBA can also serve as a programming language to solve many problems, iteration and the analysis of civil structures that are not easily or cannot be done rely on the built-in functions and spreadsheet standard commands.

A. Theory/calculation

A truss 16-meter span and 3.2 meter in height is analyzed using vba program shown in figure 6. The input data required for analyze the truss structure is listed below:

Number of joints are 15, Number of members are 27, number of supports are 2, and number of jointed loads are 9 as shown in fig 3.

Fig. 3. Plane truss structure analyzed using vba program.

The sheet named geometry calculate member length, member angle and coordinates to plot truss shape fig 4. The truss member designation properties are selected from sheet named section properties according to BS 4848 part 4[5] fig 5. All members are analyzed for same material having E equal to 210 GPa and constant cross-sectional area. After inserting truss coordinates the program calculate length of each member according to its coordinates, three sheets are prepared and linked with vba program by the following command ActiveSheet.Select fig 9,fig 10 and fig 11 this command order the program to run selected sheet in the workbook.

Member Data	Length	Slope V/H	Angle(Deg)
1	1.13	1	45.00
2	0.89	-2	-63.43
3	1.79	-0.5	-26.57
4	2.91	-0.2857143	-15.95
5	5.66	0.14285714	8.13
6	8.44	0.0952381	5.44
7	11.23	0.07142857	4.09
8	14.02	0.05714286	3.27
9	0	Vertical	90.00
10	2.32	0	0.00
11	4.64	0	0.00
12	11.36	0	0.00

Fig. 4. Part of truss geometry calculated in geometry sheet.

Designation D x B x t mm x mm x mm	Mass Per M kg/m	Radius of Gyration				Elastic		Area of A cm ²
		Axis x-x cm	Axis y-y cm	Axis u-u cm	Axis v-v cm	Axis x-x cm ⁴	Axis y-y cm ⁴	
200x150x18	47.2	6.3	4.38	6.97	3.22	175	104	60.1
200x150x15	39.7	6.34	4.42	7.02	3.24	148	87.8	50.6
200x150x12	32.1	6.38	4.45	7.07	3.26	120	71.4	40.9
200x100x15	33.9	6.41	2.65	6.6	2.13	138	39	43.1
200x100x12	27.4	6.45	2.68	6.65	2.15	112	31.9	34.9
200x100x10	23.1	6.48	2.7	6.68	2.17	94.5	26.9	29.4
150x90x15	26.7	4.74	2.47	4.99	1.93	78	30.6	34
150x90x12	21.6	4.78	2.5	5.03	1.95	63.6	25	27.6
150x90x10	18.2	4.81	2.52	5.06	1.96	53.6	21.2	23.2
150x75x15	24.9	4.75	1.95	4.89	1.58	75.5	21.1	31.7
150x75x12	20.2	4.79	1.98	4.93	1.59	61.6	17.3	25.7
150x75x10	17	4.82	2	4.96	1.6	52	14.7	21.7

Fig. 5. Unequal angle section properties.

Fig. 6. Part of Excel VBA program.

Total dead load including cladding and insulation is 0.12KN/m² and self-weight assumed to be 8 KN, the total live load is 0.75 KN/m², for calculating wind load a sheet named wind pressure is used, according to BS 6399 [6]. Angle data are stored in a list for user selection using data validation property as shown in fig 7 the external wind coefficients are selected from table for zero and 90 degree direction the vertical lookup function is used to find coefficient values by the lookup command VLOOKUP(lookup value, table array, column index num, lookup range). The maximum wind pressure coefficients are shown in figure 8 which give a value of 20.97 KN outward wind forces on truss members are shown in fig 10. Forces are combined together to give worst case according to BS 5950, since member forces due to wind result in opposite action, all truss members are tested to satisfy tension and compression code requirements.

Fig. 7. Data validation for storing range of cells in one cell.

		0	90		
	angle	EF	GH	EG	FH
$h/w \leq 0.5$	22	-0.32	-0.4	-0.7	-0.6
$0.5 < h/w \leq 1.5$	22	-0.6	-0.5	-0.8	-0.64
$1.5 < h/w \leq 6$	22	-0.84	-0.58	-0.8	-0.78
	23				
	24				
	25				
	26				
	27				
	28				
	29				
		Cpe			
		-0.32	-0.4	-0.7	-0.6
wind load		-0.351	-0.405	-0.608	-0.541
		-8.784	-20.27	-15.2	-27.03
			q=	0.6757	
			-0.9		
			p=	-0.608	
			ww=	-20.97	

Fig. 8. Wind pressure coefficients calculation.

Elements	Length	Element Force	Force Type
1	2.200	-22.335	Compression
2	2.200	-21.455	Compression
3	2.200	-20.575	Compression
4	2.200	-19.694	Compression
5	2.200	-19.694	Compression
6	2.200	-20.575	Compression
7	2.200	-21.455	Compression
8	2.200	-22.335	Compression
9	2.300	20.738	Tension
10	2.300	17.775	Tension
11	6.700	11.850	Tension
12	2.300	17.775	Tension
13	2.300	20.737	Tension
14	0.900	-2.200	Compression
15	2.300	2.963	Tension
16	1.700	-4.401	Compression
17	2.300	2.963	Tension

Fig. 9. Dead load force result.

Elements	Length	Element Force	Force Type
1	2.200	-56.544	Compression
2	2.200	-54.316	Compression
3	2.200	-52.088	Compression
4	2.200	-49.859	Compression
5	2.200	-49.859	Compression
6	2.200	-52.088	Compression
7	2.200	-54.316	Compression
8	2.200	-56.544	Compression
9	2.300	52.500	Tension
10	2.300	45.000	Tension
11	6.700	30.000	Tension
12	2.300	45.000	Tension
13	2.300	52.500	Tension
14	0.900	-5.571	Compression
15	2.300	7.500	Tension
16	1.700	-11.142	Compression
17	2.300	7.500	Tension

Fig. 10. Live load force result.

Elements	Length	Element Force	Force Type
1	2.200	45.895	Tension
2	2.200	45.897	Tension
3	2.200	45.899	Tension
4	2.200	45.901	Tension
5	2.200	45.901	Tension
6	2.200	45.899	Tension
7	2.200	45.897	Tension
8	2.200	45.895	Tension
9	2.300	-41.638	Compression
10	2.300	-34.575	Compression
11	6.700	-20.450	Compression
12	2.300	-34.575	Compression
13	2.300	-41.637	Compression
14	0.900	5.246	Tension
15	2.300	-7.062	Compression
16	1.700	10.492	Tension
17	2.300	-7.063	Compression

Fig. 11. Wind load force result.

Combination of load cases are tabulated in fig 12. Section properties for unequal angles are stored in the first column of fig 13 so by clicking on any cell in the column a list of all angle sizes appear and other properties of dimension, thickness, radius of gyration and area are change automatically. Compression capacity for each member were calculated from table 27 (c) of BS 5950 which stored in sheet named section properties in the workbook, the slenderness ratio (λ) was exerted from table by lookup command as in fig 14 column one, compression strength p_c and compression capacity P_c calculated in column two and three of fig 14. The affective area of tension members and tension capacities are stored in column six and seven of fig 14.

element	length	1.4DL+1.6LL	1.0DL+1.4WL
1	2.200	-121.74	41.92
2	2.200	-116.94	42.8
3	2.200	-112.14	43.68
4	2.200	-107.35	44.57
5	2.200	-107.35	44.57
6	2.200	-112.14	43.68
7	2.200	-116.94	42.8
8	2.200	-121.74	41.92
9	2.300	113.03	-37.56
10	2.300	96.89	-30.63
11	6.700	64.59	-16.78
12	2.300	96.88	-30.63
13	2.300	113.03	-37.55
14	0.900	-11.99	5.14
15	2.300	16.15	-6.92
16	1.700	-23.99	10.29
17	2.300	16.15	-6.93

Fig. 12. Load combination effect.

section properties					
size	L1	L2	t	ry	Area
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x65x8	100	65	8	1.83	12.7
100x75x8	100	75	8	2.18	13.5
100x65x8	100	65	8	1.83	12.7
65x50x6	65	50	6	1.46	6.59
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22
75x50x6	75	50	6	1.42	7.22

Fig. 13. Section properties.

lamda	pc	Pc	a1	a2	Ae	PT
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
120	97	123.19	608	488	1028.5	282.84
124	92	116.84	608	488	1028.5	282.84
124	92	116.84	608	488	1028.5	282.84
306	19.4	26.19	608	568	1086.58	298.81
126	90	114.3	608	488	1028.5	282.84
158	62.6	41.2534	252	282	482.43	132.67
63	195	140.79	312	282	550.83	151.48
162	59.8	43.1756	312	282	550.83	151.48
120	97	70.034	312	282	550.83	151.48
162	59.8	43.1756	312	282	550.83	151.48

Fig. 14. Tension and compression capacities.

3. RESULTS AND DISCUSSION

Bolt and weld capacities are stored in sheet named section properties and called to design sheet by selection size of weld or bolt in design sheet. Tension and compression capacities are stored in cells with a conditional formatting test that if member capacity less than force calculated light red color shade the cell to notice user that the section that selected is not satisfactory. Weld length due to tension and compression members are calculated and the maximum of two cases is selected, fig 15. According to bolt size selected number of bolts end each member joint is provided limiting a minimum of two in each member as shown in fig 17. The total weight of truss is calculated by multiplying each member length by section weight kg per meter called from section properties sheet.

weld dia	capacity	bolt	tension	shear
6	0.92	20	130	25.9
5				
8				
10				
12				

Fig. 15. Bolt and weld sizes and capacities.

section properties	Pc	a1	a2	Ae	PT
100x65x8	123.19	608	488	1028.5	282.84
100x65x8	123.19	608	488	1028.5	282.84
100x65x8	123.19	608	488	1028.5	282.84
100x65x8	114.3	608	488	1028.5	282.84
40x25x4	4.018	72	92	145.27	39.95
75x50x6	140.79	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	70.034	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	140.79	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	140.79	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	43.1756	312	282	550.83	151.48
75x50x6	140.79	312	282	550.83	151.48

Fig. 16. Shaded cells for failed angle selected.

length of weld		Provided	NO of bolt	wt kg/m	wt
compression	tension				
132	46	132	5	10	22
127	47	127	5	10	22
122	47	122	5	10	22
117	48	117	5	10	22
117	48	117	5	10	22
122	47	122	5	10	22
127	47	127	5	10	22
132	46	132	5	10	22
41	123	123	2	10	23
33	105	105	2	10	23
18	70	70	2	10.6	71.02
33	105	105	2	10	23
41	123	123	2	5.2	11.96
13	6	13	2	5.7	5.13
8	18	18	2	5.7	13.11
26	11	26	2	5.7	9.69
total wt		0.47276		ton	

Fig. 17. Connection type and member weight of truss.

4. CONCLUSIONS

An Excel-VBA spreadsheet was developed to analyzed truss structures the developed program was tested for 16 m span truss, the member size and connection type were adopted according to BS 5950.

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