TN501_WBAL_Builder_11012016

NUMERICAL EXAMPLE FOR LOAD BALANCING RESULT IN ADAPT-FLOOR PRO 2016

INTRODUCTION

This Technical Note illustrates a numerical example for validation of the load balancing result in ADAPT-Floor Pro 2016. This result is indicated in the form of a percentage (%) at each design strip span. The balanced loading check is hard-coded and is not dependent on the selection of a load combination selection in the "Result Display Settings" dialogue window. The result is dependent on:

1. Post-tensioning tendons modeled within a slab and/or beam

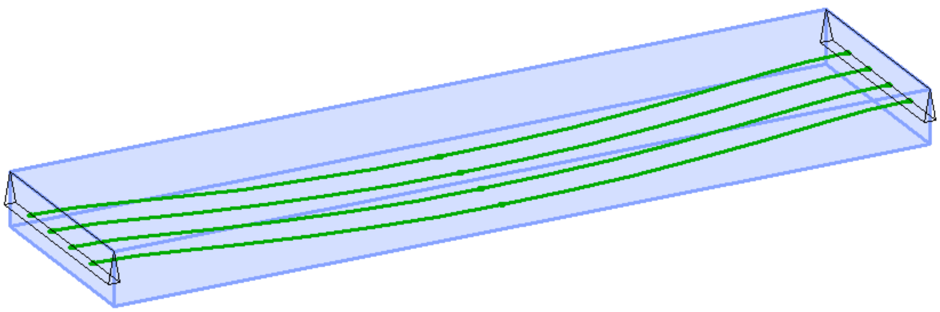


FIGURE 1 - Slab with tendons

2. Selfweight of the slab and/or beams and superimposed dead load assigned to the reserved load case "Dead Load" defaulted to in the program.

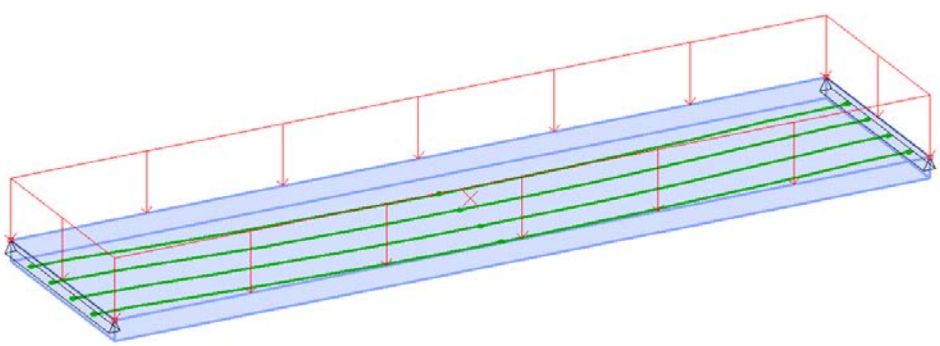


FIGURE 2 - Slab loading

3. Tributary region for each design strip span as a result of support line and splitter input.

FIGURE 3 - Tributary Region

After a model has been meshed, analyzed and the design of sections has been completed, the user can generate the balanced loading results using the option shown below.

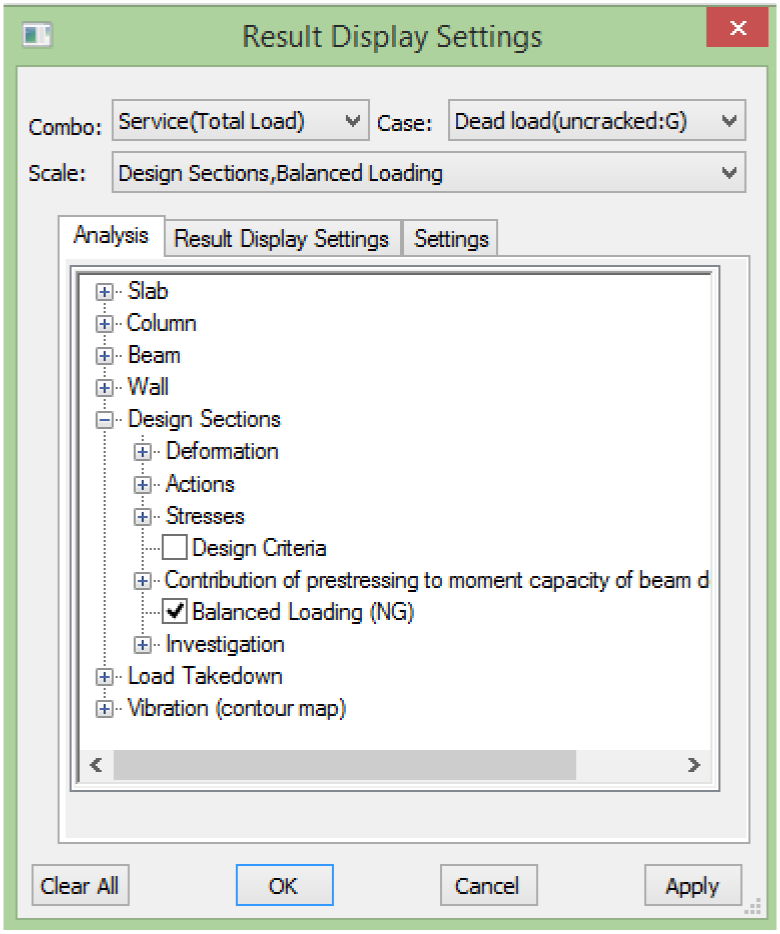


FIGURE 4 - Balanced Loading Check Setting

METHODOLOGY

The balanced loading percentage (%) is presented at each tributary region along design strips. The % is taken as:

$$WBal\% = [\sum Fz_{pt} \; / \; \sum (Fz_{sw} + Fz_{dl})]*100$$

where Fz = Postive vertical force component at shell nodes within the tributary region of the span.

This method is reliant on the FEM solution for forces acting at nodes due to the post-tensioning in the slab and/or beams and nodal forces due to self-weight and superimposed dead load applied using the reserved "Dead Load" loading case in Builder. Some variance in the results may be caused by the mesh size and also numerical tolerance relative to nodes located at or near boundaries of tributary regions along design strips.

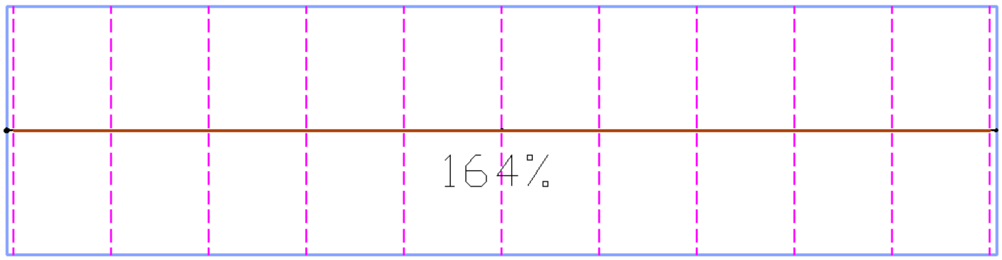


FIGURE 5 - Balanced Loading result on support line

ADAPT-Builder v2016.1 allows the user to change the maximum allowed percentage under the "Result Display Settings" tab from the "Result Display Settings" dialogue. Note that previous versions of the software that include this option have a locked value of 100%. If a span balanced loading % result exceeds the entered value, the design sections along the span will be indicated by a pink, dashed line.

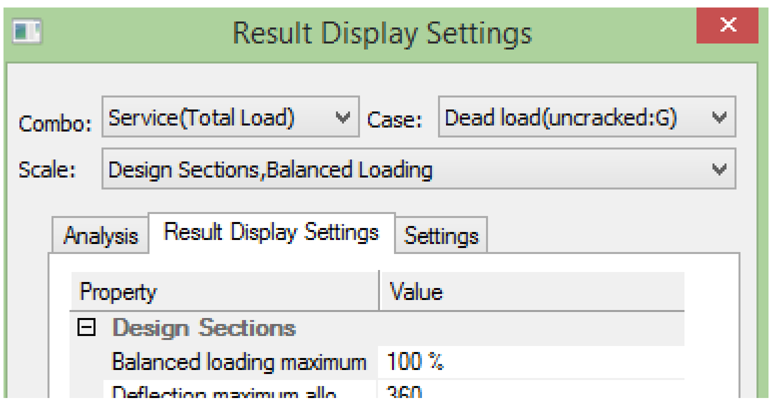


FIGURE 6 - Result Display Settings

VALIDATION

Prior to executing the FEM analysis, the program displays the average uplift for modeled tendons. This can be viewed in the "Shape/System/Friction" tab from the Tendon Properties dialogue. The uplift reported in this window is based on the geometry and force of the modeled tendon. It is for user information only and is not used in the FEM solution for the prestressing load case. It does offer a tool for purposes of validation. In the example shown below we have:

Number of strands = 10- ½" dia.
Effective force/strand = 26.7 k
Total force, P = 10*26.7 = 267 k

Slab depth = 12”
L = 40’
Tendon CGS at support = 6” from top fiber
Tendon CGS at mid-span = 1” from bottom fiber
Drape = 5”

Uplift, w = $8*P*e/L^2$

w = $8*267k*(5/12) / 40^2$ = **0.556 k/ft**

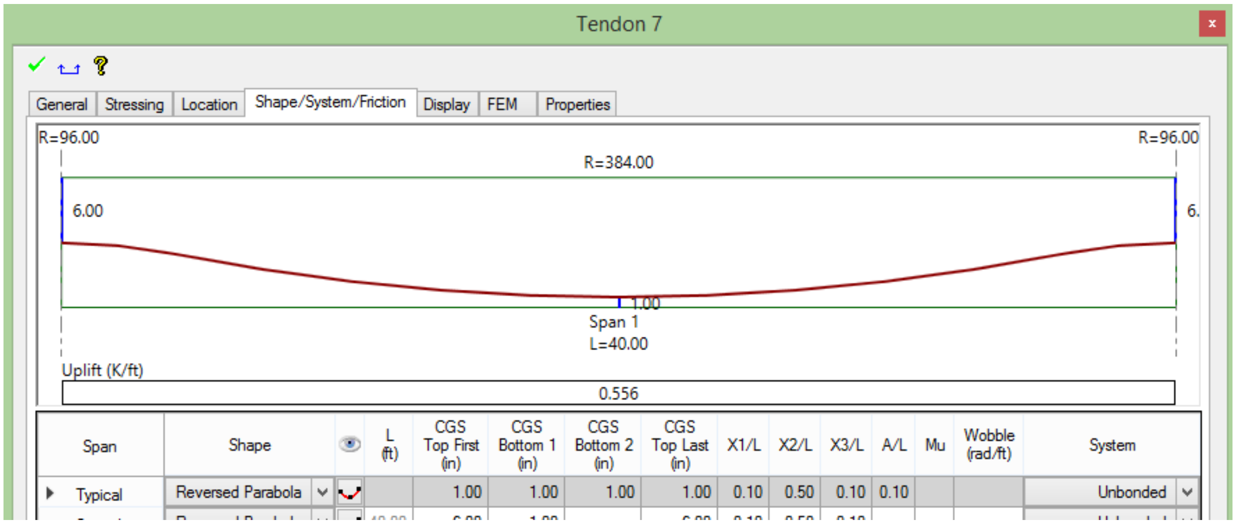


FIGURE 7 - Tendon Shape/System/Friction tab

In the example model we have 4 tendons (40 strands), so the total uplift is equal to 0.556 k/ft * 4 = 2.23 k/ft. Only self-weight is considered. The slab geometry is shown below. The slab is supported at both ends by line supports. The total slab self-weight (per ft basis) is 0.150 kcf * 12/12 * 10’ = 1.5 k/ft.

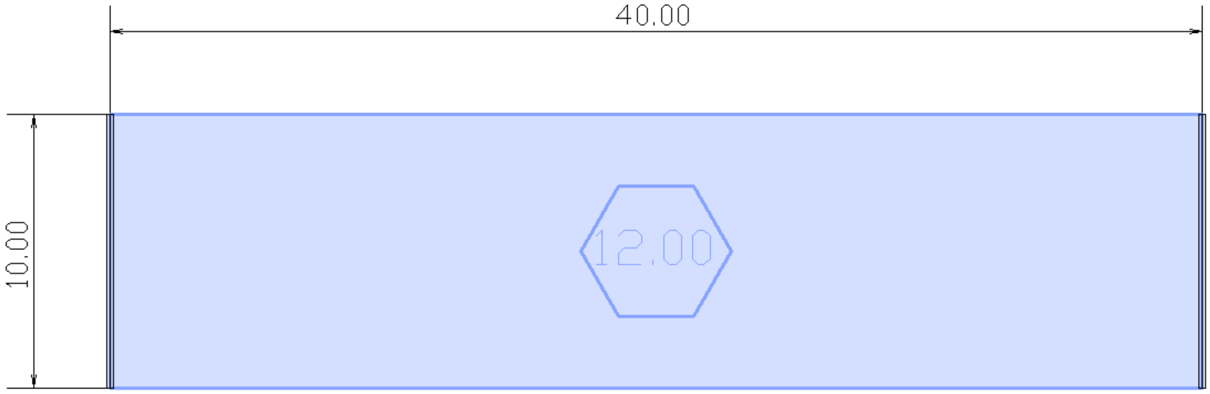


FIGURE 8 - Example Slab geometry

Balanced loading % = (2.23/1.5)*100 = **149%** - Note that this calculation is based on the approximate average uplift of the tendons assuming effective force and geometry of the cables.

To replicate the solution shown along the the support line (FIGURE 5), the method using summation of forces, Fz, for the prestressing and dead load cases will be shown. To obtain the nodal force values (Fz) at nodes located within the tributary region, it is useful to graphically view the shell and node ID's. This is shown below in **Figure 9**.

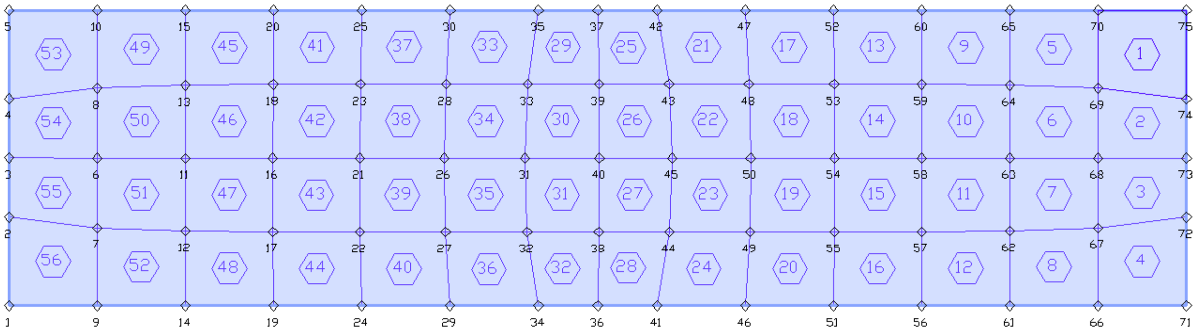


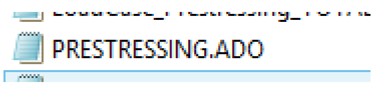
FIGURE 9 - FEM mesh shell and nodes

After the model analysis and design of design sections is complete, the model subfolder will contain solution files with the .ADO extension. These files are located in the path:

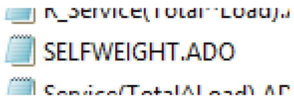
………\NAME_OF_MODEL\Databases\NAME_OF_MODELado\

"NAME OF MODEL" indicates the user-defined model file name. In this folder, the solution files of interested are:

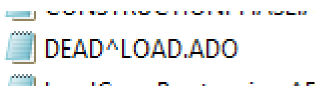
"PRESTRESSING.ADO"



"SELFWEIGHT.ADO"



"DEAD^LOAD.ADO"



The solution data block contain the information as shown in **Figure 10**. The data block contains nodal force and moment values for nodes assigned to each shell element in the system. Only those shell elements relevant to the span tributary in question are used in the calculation. The vertical force (Fz) values are of particular interest for the balanced loading check. The other values listed are not used. Note the values listed are in SI units, N and mm.

```
~DATA SHELL_FORCES
     11102   "SHELL_FORCES"

    // Forces given in global coordinates
    // Internal stress resultants (moments and forces) at the corners of shell elements
    //--ELEM---NODE---<---FX----------FY----------FZ---->------MXX---------MYY---------MZZ--->
             1       75 -3.9583E+05  4.3327E-04 -3.3032E+04  4.1862E+06  6.0325E+07  0.0000E+00
             1       74 -6.7593E+05  1.5870E+05  1.0157E+04  2.4268E+07  1.0356E+08  0.0000E+00
             1       69  5.8840E+05 -7.1399E+04 -4.7292E+03 -1.0435E+07 -1.0026E+08  0.0000E+00
             1       70  4.8336E+05 -8.7304E+04  2.7604E+04 -1.2534E+07 -8.4521E+07  0.0000E+00
             2       74 -7.0992E+05 -1.5870E+05 -1.2592E+04 -2.5312E+07  1.0764E+08  0.0000E+00
             2       73 -5.9519E+05  1.6843E+05 -5.7732E+03  2.4727E+07  9.0700E+07  0.0000E+00
             2       68  6.9064E+05  4.3562E+04  4.2489E+03  5.6630E+06 -1.1364E+08  0.0000E+00
             2       69  6.1447E+05 -5.3293E+04  1.4116E+04 -7.5619E+06 -1.0148E+08  0.0000E+00
             3       73 -5.9319E+05 -1.6843E+05 -5.7058E+03 -2.4727E+07  9.0411E+07  0.0000E+00
             3       72 -7.1083E+05  1.5854E+05 -1.2644E+04  2.5294E+07  1.0777E+08  0.0000E+00
             3       67  6.1245E+05  5.3316E+04  1.4101E+04  7.5599E+06 -1.0116E+08  0.0000E+00
             3       68  6.9157E+05 -4.3426E+04  4.2484E+03 -5.6597E+06 -1.1379E+08  0.0000E+00
             4       72 -6.7403E+05 -1.5854E+05  1.0198E+04 -2.4257E+07  1.0328E+08  0.0000E+00
             4       71 -3.9504E+05 -1.1642E-10 -3.3029E+04 -4.1795E+06  6.0204E+07  0.0000E+00
             4       66  4.8197E+05  8.7160E+04  2.7572E+04  1.2511E+07 -8.4299E+07  0.0000E+00
             4       67  5.8710E+05  7.1385E+04 -4.7416E+03  1.0411E+07 -1.0007E+08  0.0000E+00
```

FIGURE 10 - Shell Forces data block (.ADO file)

See the Appendix for .ADO file data for “Prestressing” and “Selfweight” for the example model. The balanced loading check is carried out as follows:

WBal% = [∑ Fzpt / ∑ (Fzsw + Fzdl)]*100

WBal% = [375.8k/239.3k]*100 = **157%;** ADAPT reports **164%**

Shell Forces
PRESTRESSING

ELEMENT	NODE	Fz (N)	Fz,pos (K)
1	75	-33032.0	0.0
1	74	10157.0	2.3
1	69	-4729.2	0.0
1	70	27604.0	6.2
2	74	-12592.0	0.0
2	73	-5773.2	0.0
2	68	4248.9	1.0
2	69	14116.0	3.2
3	73	-5705.8	0.0
3	72	-12644.0	0.0
3	67	14101.0	3.2
3	68	4248.4	1.0
4	72	10198.0	2.3
4	71	-33029.0	0.0
4	66	27572.0	6.2
4	67	-4741.6	0.0
5	70	-32785.0	0.0
5	69	-7891.7	0.0
5	64	7745.5	1.7
5	65	32931.0	7.4
6	69	-26837.0	0.0
6	68	-16614.0	0.0
6	63	17293.0	3.9
6	64	26158.0	5.9
7	68	-16620.0	0.0
7	67	-26786.0	0.0
7	62	26099.0	5.9
7	63	17306.0	3.9
8	67	-7877.1	0.0
8	66	-32708.0	0.0
8	61	32844.0	7.4
8	62	7741.7	1.7
9	65	-32203.0	0.0
9	64	-5614.3	0.0
9	59	7832.8	1.8
9	60	29985.0	6.7
10	64	-24193.0	0.0
10	63	-15198.0	0.0
10	58	15997.0	3.6
10	59	23394.0	5.3
11	63	-15324.0	0.0
11	62	-24055.0	0.0
11	57	23273.0	5.2
11	58	16106.0	3.6
12	62	-5685.0	0.0
12	61	-32120.0	0.0
12	56	29885.0	6.7
12	57	7920.1	1.8
13	60	-28111.0	0.0
13	59	-1173.5	0.0
13	53	6780.2	1.5
13	52	22504.0	5.1
14	59	-19035.0	0.0
14	58	-10482.0	0.0
14	54	12570.0	2.8
14	53	16947.0	3.8
15	58	-10639.0	0.0
15	57	-18881.0	0.0
15	55	17827.0	4.0
15	54	11693.0	2.6

Shell Forces
SELFWEIGHT

ELEMENT	NODE	Fz (N)	Fz,pos (K)
1	75	29810.0	6.7
1	74	2360.1	0.5
1	69	-3260.6	0.0
1	70	-28910.0	0.0
2	74	21248.0	4.8
2	73	8354.9	1.9
2	68	-11308.0	0.0
2	69	-18295.0	0.0
3	73	8276.8	1.9
3	72	21289.0	4.8
3	67	-18249.0	0.0
3	68	-11317.0	0.0
4	72	2292.3	0.5
4	71	29801.0	6.7
4	66	-28847.0	0.0
4	67	-3246.1	0.0
5	70	26229.0	5.9
5	69	-877.9	0.0
5	64	-1300.5	0.0
5	65	-24050.0	0.0
6	69	17430.0	3.9
6	68	8974.4	2.0
6	63	-9230.3	0.0
6	64	-17174.0	0.0
7	68	9008.6	2.0
7	67	17370.0	3.9
7	62	-17126.0	0.0
7	63	-9252.0	0.0
8	67	-871.1	0.0
8	66	26171.0	5.9
8	61	-23978.0	0.0
8	62	-1321.7	0.0
9	65	21500.0	4.8
9	64	-1041.2	0.0
9	59	-1111.9	0.0
9	60	-19346.0	0.0
10	64	14513.0	3.3
10	63	6739.2	1.5
10	58	-7414.5	0.0
10	59	-13837.0	0.0
11	63	6840.5	1.5
11	62	14415.0	3.2
11	57	-13741.0	0.0
11	58	-7514.1	0.0
12	62	-961.7	0.0
12	61	21434.0	4.8
12	56	-19272.0	0.0
12	57	-1199.4	0.0
13	60	16834.0	3.8
13	59	-1159.2	0.0
13	53	-1844.0	0.0
13	52	-13831.0	0.0
14	59	11119.0	2.5
14	58	4926.2	1.1
14	54	-6192.0	0.0
14	53	-9853.1	0.0
15	58	5051.1	1.1
15	57	11010.0	2.5
15	55	-10498.0	0.0
15	54	-5563.7	0.0

16	57	-1321.3	0.0
16	56	-28027.0	0.0
16	51	21367.0	4.8
16	55	7981.6	1.8
17	52	-20682.0	0.0
17	53	229.7	0.1
17	48	12935.0	2.9
17	47	7517.8	1.7
18	53	-13141.0	0.0
18	54	-7226.4	0.0
18	50	12626.0	2.8
18	48	7741.2	1.7
19	54	-6336.2	0.0
19	55	-14021.0	0.0
19	49	10340.0	2.3
19	50	10017.0	2.3
20	55	-1035.5	0.0
20	51	-19563.0	0.0
20	46	4640.0	1.0
20	49	15959.0	3.6
21	47	-5797.5	0.0
21	48	-6204.8	0.0
21	43	34274.0	7.7
21	42	-22272.0	0.0
22	48	-4294.8	0.0
22	50	-7673.6	0.0
22	45	13727.0	3.1
22	43	-1758.5	0.0
23	50	-5044.9	0.0
23	49	-6899.6	0.0
23	44	-227.4	0.0
23	45	12172.0	2.7
24	49	-9223.3	0.0
24	46	-2922.2	0.0
24	41	-23966.0	0.0
24	44	36111.0	8.1
25	42	23636.0	5.3
25	43	-28527.0	0.0
25	39	7352.6	1.7
25	37	-2461.8	0.0
26	43	4369.1	1.0
26	45	-9366.1	0.0
26	40	3751.4	0.8
26	39	1245.5	0.3
27	45	-7799.2	0.0
27	44	2820.7	0.6
27	38	203.4	0.0
27	40	4775.1	1.1
28	44	-30272.0	0.0
28	41	25344.0	5.7
28	36	-1689.0	0.0
28	38	6617.1	1.5
29	37	4412.0	1.0
29	39	256.2	0.1
29	33	-24877.0	0.0
29	35	20209.0	4.5
30	39	2825.6	0.6
30	40	2076.4	0.5
30	31	-7557.6	0.0
30	33	2655.7	0.6
31	40	1051.2	0.2
31	38	3816.2	0.9
31	32	804.1	0.2
31	31	-5671.5	0.0
32	38	1089.6	0.2

16	57	-1044.1	0.0
16	56	16766.0	3.8
16	51	-12992.0	0.0
16	55	-2730.4	0.0
17	52	11343.0	2.6
17	53	-497.0	0.0
17	48	-6889.1	0.0
17	47	-3956.7	0.0
18	53	7282.0	1.6
18	54	3769.9	0.8
18	50	-7028.5	0.0
18	48	-4023.4	0.0
19	54	3129.4	0.7
19	55	7936.3	1.8
19	49	-5876.0	0.0
19	50	-5189.7	0.0
20	55	405.5	0.1
20	51	10512.0	2.4
20	46	-1907.8	0.0
20	49	-9009.3	0.0
21	47	1509.6	0.3
21	48	4569.9	1.0
21	43	-21779.0	0.0
21	42	15699.0	3.5
22	48	1625.8	0.4
22	50	4728.6	1.1
22	45	-8223.2	0.0
22	43	1868.8	0.4
23	50	2871.7	0.6
23	49	3490.8	0.8
23	44	785.8	0.2
23	45	-7148.3	0.0
24	49	6682.4	1.5
24	46	-537.4	0.0
24	41	16886.0	3.8
24	44	-23031.0	0.0
25	42	-17800.0	0.0
25	43	19695.0	4.4
25	39	-3223.9	0.0
25	37	1328.8	0.3
26	43	-4024.0	0.0
26	45	6092.6	1.4
26	40	-1549.5	0.0
26	39	-519.1	0.0
27	45	5002.3	1.1
27	44	-2932.0	0.0
27	38	192.6	0.0
27	40	-2262.9	0.0
28	44	20910.0	4.7
28	41	-18994.0	0.0
28	36	790.9	0.2
28	38	-2707.4	0.0
29	37	-3116.4	0.0
29	39	1290.8	0.3
29	33	17596.0	4.0
29	35	-15770.0	0.0
30	39	-1468.5	0.0
30	40	-502.8	0.0
30	31	4983.1	1.1
30	33	-3011.8	0.0
31	40	198.5	0.0
31	38	-2165.8	0.0
31	32	-1700.4	0.0
31	31	3667.7	0.8
32	38	734.0	0.2

32	36	3648.2	0.8
32	34	21754.0	4.9
32	32	-26492.0	0.0
33	35	-18830.0	0.0
33	33	30766.0	6.9
33	28	-6826.2	0.0
33	30	-5110.4	0.0
34	33	-98.2	0.0
34	31	11961.0	2.7
34	26	-7041.4	0.0
34	28	-4821.8	0.0
35	31	10065.0	2.3
35	32	1767.8	0.4
35	27	-6295.7	0.0
35	26	-5537.1	0.0
36	32	32389.0	7.3
36	34	-20370.0	0.0
36	29	-3858.4	0.0
36	27	-8160.8	0.0
37	30	6855.2	1.5
37	28	13736.0	3.1
37	23	-278.0	0.0
37	25	-20314.0	0.0
38	28	8292.7	1.9
38	26	12143.0	2.7
38	21	-7610.5	0.0
38	23	-12826.0	0.0
39	26	10635.0	2.4
39	27	9771.2	2.2
39	22	-13689.0	0.0
39	21	-6717.1	0.0
40	27	15048.0	3.4
40	29	5599.5	1.3
40	24	-19679.0	0.0
40	22	-968.4	0.0
41	25	22123.0	5.0
41	23	7174.4	1.6
41	18	1606.7	0.4
41	20	-30904.0	0.0
42	23	16748.0	3.8
42	21	12745.0	2.9
42	16	-9429.2	0.0
42	18	-20064.0	0.0
43	21	12317.0	2.8
43	22	17509.0	3.9
43	17	-20291.0	0.0
43	16	-9535.3	0.0
44	22	7947.0	1.8
44	24	21484.0	4.8
44	19	-30681.0	0.0
44	17	1250.1	0.3
45	20	32758.0	7.4
45	18	5330.4	1.2
45	13	1603.4	0.4
45	15	-39692.0	0.0
46	18	24100.0	5.4
46	16	15127.0	3.4
46	11	-12013.0	0.0
46	13	-27214.0	0.0
47	16	14755.0	3.3
47	17	24288.0	5.5
47	12	-27045.0	0.0
47	11	-11998.0	0.0
48	17	5691.3	1.3
48	19	32524.0	7.3

32	36	-2584.9	0.0
32	34	-16856.0	0.0
32	32	18707.0	4.2
33	35	13655.0	3.1
33	33	-19753.0	0.0
33	28	5663.9	1.3
33	30	434.2	0.1
34	33	853.5	0.2
34	31	-7166.8	0.0
34	26	4573.7	1.0
34	28	1739.6	0.4
35	31	-5853.5	0.0
35	32	-457.3	0.0
35	27	2797.3	0.6
35	26	3513.4	0.8
36	32	-20869.0	0.0
36	34	14739.0	3.3
36	29	-466.6	0.0
36	27	6596.3	1.5
37	30	-2890.7	0.0
37	28	-8070.8	0.0
37	23	1098.5	0.2
37	25	9863.1	2.2
38	28	-4108.3	0.0
38	26	-6927.5	0.0
38	21	4541.1	1.0
38	23	6494.7	1.5
39	26	-5865.0	0.0
39	27	-5167.0	0.0
39	22	7131.9	1.6
39	21	3900.1	0.9
40	27	-8995.9	0.0
40	29	-1988.3	0.0
40	24	9384.3	2.1
40	22	1599.9	0.4
41	25	-12347.0	0.0
41	23	-3345.5	0.0
41	18	-715.7	0.0
41	20	16408.0	3.7
42	23	-9158.8	0.0
42	21	-6795.2	0.0
42	16	5166.9	1.2
42	18	10787.0	2.4
43	21	-6516.8	0.0
43	22	-9710.3	0.0
43	17	10979.0	2.5
43	16	5248.3	1.2
44	22	-3923.2	0.0
44	24	-11866.0	0.0
44	19	16223.0	3.6
44	17	-433.9	0.0
45	20	-18914.0	0.0
45	18	-1435.4	0.0
45	13	-1605.8	0.0
45	15	21955.0	4.9
46	18	-13606.0	0.0
46	16	-7801.6	0.0
46	11	6582.6	1.5
46	13	14825.0	3.3
47	16	-7541.2	0.0
47	17	-13746.0	0.0
47	12	14734.0	3.3
47	11	6553.3	1.5
48	17	-1753.2	0.0
48	19	-18724.0	0.0

48	14	-39585.0	0.0
48	12	1369.4	0.3
49	15	40416.0	9.1
49	13	5975.4	1.3
49	8	-3298.1	0.0
49	10	-43093.0	0.0
50	13	23687.0	5.3
50	11	14109.0	3.2
50	6	-13286.0	0.0
50	8	-24510.0	0.0
51	11	13897.0	3.1
51	12	23772.0	5.3
51	7	-24707.0	0.0
51	6	-12962.0	0.0
52	12	5923.6	1.3
52	14	40294.0	9.1
52	9	-43098.0	0.0
52	7	-3118.9	0.0
53	10	37920.0	8.5
53	8	16674.0	3.7
53	4	21482.0	4.8
53	5	-76077.0	0.0
54	8	-14202.0	0.0
54	6	817.7	0.2
54	3	2394.6	0.5
54	4	10990.0	2.5
55	6	687.8	0.2
55	7	-14149.0	0.0
55	2	11059.0	2.5
55	3	2402.6	0.5
56	7	16658.0	3.7
56	9	37952.0	8.5
56	1	-76061.0	0.0
56	2	21450.0	4.8
		SUM PT	**375.8**

48	14	21878.0	4.9
48	12	-1401.0	0.0
49	15	-24503.0	0.0
49	13	-1438.8	0.0
49	8	-816.6	0.0
49	10	26759.0	6.0
50	13	-16773.0	0.0
50	11	-9129.7	0.0
50	6	8811.9	2.0
50	8	17091.0	3.8
51	11	-8890.6	0.0
51	12	-16913.0	0.0
51	7	17214.0	3.9
51	6	8590.0	1.9
52	12	-1396.5	0.0
52	14	-24418.0	0.0
52	9	26762.0	6.0
52	7	-947.5	0.0
53	10	-29439.0	0.0
53	8	-5467.5	0.0
53	4	320.8	0.1
53	5	34585.0	7.8
54	8	-15806.0	0.0
54	6	-11045.0	0.0
54	3	6210.2	1.4
54	4	20640.0	4.6
55	6	-10992.0	0.0
55	7	-15832.0	0.0
55	2	20720.0	4.7
55	3	6104.2	1.4
56	7	-5423.2	0.0
56	9	-29437.0	0.0
56	1	34598.0	7.8
56	2	262.3	0.1
		SUM SW	**239.3**