FLAWS IN DESIGN SPECIFICATIONS FOR STEEL STRUCTURES WITH POSSIBLE LINKS TO WORLD TRADE CENTER COLLAPSE

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The standard specifications for the design of steel structures in the USA and globally have been continuously evolving over the past eighty years or so. None of the current design specifications address many of the issues which are becoming increasingly apparent after the 9/11 events. The literature and the internet is increasingly becoming loaded with articles and opinions about a number of such issues, for example, the combined effects of fire, impact, sudden loss of one or more structural members, etc. The information available to the designers at the present is, at the best, patchy, incomplete, or questionable. A list of even the most pressing needs to fill this void would be quite long. For the designers to be able to design steel structures with a high probability of survival or for a time lapse for a 'controlled' progressive collapse, researchers need to address a vast number of issues. The presenter would like to give only a few examples of the flaws in the current specifications and the needed research to rectify these flaws.

Example 1:

The current design specifications assume that all of the applied loads and load-effects occur simultaneously. This is a flawed assumption when one may be interested in predicting the behavior of a steel structure approaching collapse conditions. Load-path dependent design formulas or procedures are needed for a reliable prediction of the structural behavior and collapse loads. The sequence of events during the collapse of the World Trade Center buildings clearly shows that, for example, the beam-columns forming the vertical support system were subjected to nonproportional loads which can result in a dramatic decrease in their load-carrying capacity.

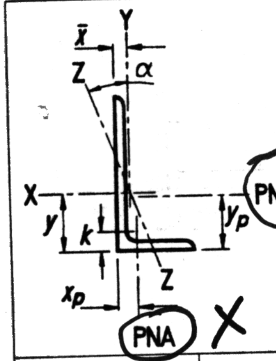
Example 2:

The current design specifications assume that the boundary conditions, such as at the ends of a column, beam, beam-column, truss, or a joist remain the same throughout the load-deformation process. Procedures need to be developed to account for the changing boundary conditions during a fire or due to an explosion or other reasons. The loss of several floors of the WTC towers increased the unsupported length of the core columns in addition to the weakening of the boundary conditions due to elasto-plastic deformations which became further accentuated due to the effects of fire. One may term the later as 'softening of the boundary conditions.' Presently, there appears to be a tendency among some investigators and code-writing bodies to 'Jerry Rig' the existing formulas and procedures to 'cook-up' hurriedly something that may capture the actual behavior of a structure. In the presenter's opinion, this will generally prove to be a futile approach. What is needed is a systematic theoretical and experimental research which can be cast into a reliable and useful form and then planted in formal design specifications.

Example 3:

Despite a number of research papers and apparent adequate coverage by a number of design specifications, the behavior and collapse load analysis of steel angle sections remains to be a relatively poorly understood topic. For example, one of the leading design specification in the USA provides wrong and unconservative plastic modulus values for predicting the collapse loads of single-angle sections. The locations of the indicated plastic neutral axes for single-angle sections are also completely wrong. Angle sections were indeed used in the bottom and top chords and at the end supports of the relatively long-span joists in the World Trade Center towers. The designers need to be given proper guidance and procedures for dealing with both single-, double-, quadruple- and multiple-angle section assemblies.

Table 1-7. Angles (L-Shapes) Properties



Shape	k	Wt.	Area, A	Axis X-X					
				I	S	r	$\bar{y}$	Z	y_p
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.
L8×8×1 1/8	1 3/4	57.2	16.8	98.1	17.5	2.41	2.40	31.6	1.05
×1	1 5/8	51.3	15.1	89.1	15.8	2.43	2.36	28.5	0.943
×7/8	1 1/2	45.3	13.3	79.7	14.0	2.45	2.31	25.3	0.832
×3/4	1 3/8	39.2	11.5	69.9	12.2	2.46	2.26	22.0	0.720
×5/8	1 1/4	33.0	9.69	59.6	10.3	2.48	2.21	18.6	0.606
×9/16	1 3/16	29.8	8.77	54.2	9.33	2.49	2.19	16.8	0.548
×1/2	1 1/8	26.7	7.84	48.8	8.36	2.49	2.17	15.1	0.490
L8×6×1	1 1/2	44.4	13.1	80.9	15.1	2.49	2.65	27.3	1.47
×7/8	1 3/8	39.3	11.5	72.4	13.4	2.50	2.60	24.3	1.41
×3/4	1 1/4	34.0	9.99	63.5	11.7	2.52	2.55	21.1	1.34
×5/8	1 1/8	28.6	8.41	54.2	9.86	2.54	2.50	17.9	1.27
×9/16	1 1/16	25.9	7.61	49.4	8.94	2.55	2.48	16.2	1.23
×1/2	1	23.2	6.80	44.4	8.01	2.55	2.46	14.6	1.20
×7/16	15/16	20.4	5.99	39.3	7.06	2.56	2.43	12.9	1.16
L8×4×1	1 1/2	37.6	11.1	69.7	14.0	2.51	3.03	24.3	2.47
×7/8	1 3/8	33.3	9.79	62.6	12.5	2.53	2.99	21.7	2.41
×3/4	1 1/4	28.9	8.49	55.0	10.9	2.55	2.94	18.9	2.34
×5/8	1 1/8	24.4	7.16	47.0	9.20	2.56	2.89	16.1	2.27
×9/16	1 1/16	22.1	6.49	42.9	8.34	2.57	2.86	14.6	2.23
×1/2	1	19.7	5.80	38.6	7.48	2.58	2.84	13.1	2.20
×7/16	15/16	17.4	5.11	34.2	6.59	2.59	2.81	11.6	2.16
L7×4×3/4	1 1/4	26.2	7.70	37.8	8.39	2.21	2.50	14.8	1.87
×5/8	1 1/8	22.1	6.50	32.4	7.12	2.23	2.45	12.5	1.80
×1/2	1	17.9	5.26	26.6	5.79	2.25	2.40	10.2	1.74
×7/16	15/16	15.8	4.63	23.6	5.11	2.26	2.38	9.0	1.70
×3/8	7/8	13.6	4.00	20.5	4.42	2.27	2.35	7.8	1.67
L6×6×1	1 1/2	37.5	11.0	35.4	8.55	1.79	1.86	15.4	0.918
×7/8	1 3/8	33.2	9.75	31.9	7.61	1.81	1.81	13.7	0.813
×3/4	1 1/4	28.8	8.46	28.1	6.64	1.82	1.77	11.9	0.705
×5/8	1 1/8	24.3	7.13	24.1	5.64	1.84	1.72	10.1	0.594
×9/16	1 1/16	22.0	6.45	22.0	5.12	1.85	1.70	9.18	0.538
×1/2	1	19.6	5.77	19.9	4.59	1.86	1.67	8.22	0.481
×7/16	15/16	17.3	5.08	17.6	4.06	1.86	1.65	7.25	0.423
×3/8	7/8	14.9	4.38	15.4	3.51	1.87	1.62	6.27	0.365
×5/16	13/16	12.5	3.67	13.0	2.95	1.88	1.60	5.26	0.306
L6×4×7/8	1 3/8	27.1	7.95	27.6	7.13	1.86	2.12	12.7	1.46
×3/4	1 1/4	23.5	6.90	24.4	6.23	1.88	2.08	11.1	1.40
×5/8	1 1/8	19.8	5.83	21.0	5.29	1.90	2.03	9.42	1.34
×9/16	1 1/16	17.9	5.27	19.2	4.81	1.91	2.01	8.57	1.31
×1/2	1	16.0	4.72	17.3	4.31	1.92	1.99	7.69	1.28
×7/16	15/16	14.1	4.15	15.4	3.81	1.92	1.97	6.79	1.26
×3/8	7/8	12.2	3.58	13.4	3.3	1.93	1.94	5.87	1.23
×5/16	13/16	10.2	2.99	11.3	2.77	1.94	1.92	4.93	1.21
L6×3 1/2×1/2	1	15.3	4.48	16.6	4.23	1.92	2.08	7.46	1.52
×3/8	7/8	11.6	3.41	12.8	3.24	1.94	2.04	5.71	1.46
×5/16	13/16	9.72	2.86	10.9	2.72	1.95	2.02	4.81	1.43
L5×5×7/8	1 3/8	27.3	8.02	17.8	5.16	1.49	1.56	9.31	0.802
×3/4	1 1/4	23.7	6.98	15.7	4.52	1.50	1.52	8.14	0.698
×5/8	1 1/8	20.1	5.90	13.6	3.85	1.52	1.47	6.93	0.590
×1/2	1	16.3	4.79	11.3	3.15	1.53	1.42	5.66	0.479
×7/16	15/16	14.4	4.22	10.0	2.78	1.54	1.40	5.00	0.422
×3/8	7/8	12.4	3.65	8.76	2.41	1.55	1.37	4.33	0.365
×5/16	13/16	10.4	3.07	7.44	2.04	1.56	1.35	3.65	0.307