METAL DECK AND CONCRETE QUANTITIES

Prepared By
Richard B. Heagler, P.E.
SDI CONSULTANT

Steel Deck Institute
P.O. Box 25
Fox River Grove, IL 60021
Phone: (847) 458-4647
Fax: (847) 458-4648

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Director of Engineering, Nicholas J. Bouras, Inc.

A typical steel framed building has composite beams, composite girders, composite metal deck and a floor slab thickness which may have been selected to meet a fire rating requirement. In most cases the use of composite construction saves money, and with the use of available design aids and the AISC Specifications, the design is straight forward.

Since composite beams and girders will obviously be lighter than those designed non-compositely, the lighter units will deflect more under the concreting loads and this will affect the total concrete volume of the slab. The concrete contractor may be rudely surprised to find he has exceeded his estimate, and since the deck has been his working platform, his first reaction is to blame the steel deck for the overage. Indeed, some level shots may show that the deck at the center of the bay has "considerable deflection". However, no deck is strong enough to hold up the steel frame, and the reality of a deflection measurement is that it is the sum of the deflections of the girders, beams, and deck.

Deflection calculations are simple to perform so it would seem an easy task to arrive at an accurate prediction of the volume required to produce a reasonably level slab. While it is true the calculations are both simple and individually accurate, placing methods and tolerances of the system eliminate precision in the answer. (1) In the worst condition, a flexible frame could cause ponding, that is, as wet concrete is loaded onto the frame the deflection of the frame requires more concrete to be added in order to produce a level surface. Additional concrete means additional deflection so the process continues until some equilibrium is reached. At the other extreme one could imagine the beams and girders to be perfectly cambered, and as the concrete is gently snowed into place the system settles into a uniformly thick and level slab.(2) Both situations are unrealistic.

The object of this study is to find the additional concrete required because of the deck deflection. To do this the deck is assumed to be supported by non yielding supports; although the assumption would not be valid for most conditions, it is necessary because: (1) the frame flexibility is not the responsibility of the deck supplier; (2) the beams and girders may be cambered in order to take their own deflection into account; and (3) the beams may be shored.

The results are shown on the two nomographs; the difference between them being the concrete density. To find the increased volume for a deck application, one needs only to read the intersection of the span and the deck moment of inertia. (The deck spans are in feet and the inertia values for the deck are inches^4 per foot of width.) For example, a 20 gage (0.0358") 3" deep composite deck has an I of about 1 and a typical span could be 11 feet; the intersection of these variables (on the 145 pcf graph) shows a percent increase of approximately 3.25%; on the lightweight (115pcf) graph an increase of nearly 2.5% is found. If the total slab depth is 5.5", the undeflected volume would be 0.333 cubic feet per square foot. The real volume (increased because of deck deflection) would them be 0.333 x 1.0325 = 0.344 cubic feet per square foot for the 145 pcf concrete and 0.333 x 1.025 = 0.341 cubic feet per square foot for the 115 pcf concrete.

The graphs also show "shoring line". Generally, any combination of inertia and span that intersects above a shoring line would have shoring recommended by using the SDI formulas for construction loading.(3) **Intersections below**

the shoring line do not mean that shoring is not required. The lines are based on the thinnest slabs so a thicker slab may require shoring.

The graphs show the range of I values of the various deck patterns. Because of depth, profile, and gage variables there will, of course, be some overlapping of I values. Although the graphs are designed to cover the deck profiles shown in the SDI Composite Deck Design Handbook, they also apply to other (proprietary) deck sections – one simply must know the concrete volume required to fill the ribs of the deck so undeflected concrete volumes can be calculated.

It is apparent from the graphs that deck deflection will seldom cause as much as 5% increase in concrete. The designer is urged to check the frame deflection under the concrete weight, and to hold the frame deflection to a reasonable limit. The use of partial composite design methods as shown in the AISC Manuals for both ASD and LFRD can provide deflection control and still take advantage of the savings of composite design.

DERIVATION OF THE CHARTS:

"Exact" solutions were found by integrating under the deflection curves of both two and three span beams. Equal spans and constant I values were used.

The area bounded by the level (undeflected) beam (deck) and the deflection curve or a two span, uniformly loaded, beam was found to be:

$$A = \frac{3.125 \times 10^{-3} wL^5 \times 20736}{EI} ,$$

where w is the load in plf and L is in feet. The area is in square inches.

The area, A, under the deflection curve of the outside span of a three span beam was found to be:

$$A = \frac{4.166 \times 10^{-3} wL^5 \times 20736}{EI}$$

The theoretical area under the middle span of a three span beam is zero so the average for all three spans is then:

$$A = \frac{4.166 \times 10^{-3} wL^5 \times 20736 \times 2/3}{EI}$$

The difference between three span and two span areas are obviously small so the average of the two is used and is taken as:

$$A = \frac{3 \times 10^{-3} wL^5 \times 20736}{EI}$$

The total weight increase W, is given by:

$$W = A(12)\, w_c / 1728$$

w_c is the density of the concrete in PCF – a 12" width of slab is used and 1728 converts cubic inches to cubic feet.

$$W = 0.432 wL^5 w_c / EI$$

$$w = V w_c$$

Where V is a factor (cubic feet per square foot) that represents the volume needed to produce a specific slab thickness on a given deck profile. (Volume constants are shown in TABLE I for the generic composite deck profiles. For proprietary sections the deck manufacturer can provide the number.)

The total volume increase: $\Delta V = W / w_c$,
$\Delta V = 0.432 w_c L^5 V / EI$.

The percent increase in volume (compared to an undeflected deck) is:

$$P = 100 \times 0.432 w_c L^5 V / (EIVL)$$

$$P = 43.2 w_c L^4 / EI; \qquad E = 29{,}500 \text{ ksi}$$

Since the volume increases (and the dead load increases) caused by deck deflection are seen to be generally small, it is not necessary to make iterations – that is the deck need not be considered to be in a ponding situation. If the frame is to be analyzed from a level starting position, iterations may be required for the frame but not the deck. The slab weight obtained from these calculations is suggested as the starting dead load for the frame calculations.

(1) Ruddy, John L, *Ponding of Concrete Deck Floors*, American Institute of Steel Construction Proceedings of the National Engineering Conference, 1986, AISC, Chicago, Illinois

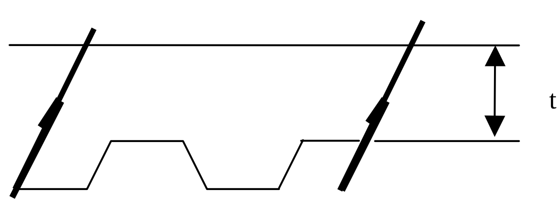
(2) Ricker, David T., *Cambering Steel Beams*, American Institute of Steel Construction Engineering Journal, 4th Quarter, 1989, Vol.26, No.4, AISC, Chicago, Illinois

(3) Heagler, Richard B., Luttrell, Larry D., Easterling W. Samuel, *Steel Deck Institute Composite Deck Design Handbook*, 1991, SDI, Canton, Ohio

TABLE I. SECTION PROPERTIES PER FOOT OF WIDTH

Profile	Type (gage)	Thickness (inches)	I, in.^{4}	S_p, in.^{3}	S_n, in.^{3}	Wt.* (psf)
3” x 12” C_v = 0.125	22	0.0295	0.797	0.454	0.500	1.7
	20	0.0358	0.993	0.583	0.620	2.1
	19	0.0418	1.158	0.708	0.726	2.4
	18	0.0474	1.324	0.832	0.832	2.7
	16	0.0598	1.666	1.045	1.045	3.4
2” x 12” C_v = 0.0833	22	0.0295	0.338	0.284	0.302	1.5
	20	0.0358	0.420	0.367	0.387	1.9
	19	0.0418	0.490	0.445	0.458	2.2
	18	0.0474	0.560	0.523	0.529	2.5
	16	0.0598	0.700	0.654	0.654	3.1
1 ½” x 6” C_v = 0.0469	22	0.0295	0.165	0.195	0.206	1.6
	20	0.0358	0.212	0.247	0.260	1.9
	19	0.0418	0.260	0.292	0.304	2.2
	18	0.0474	0.308	0.337	0.348	2.5
	16	0.0598	0.400	0.434	0.437	3.2
Inv. 1 ½” x 6” C_v = 0.0781	22	0.0295	0.165	0.206	0.195	1.6
	20	0.0358	0.212	0.260	0.247	1.9
	19	0.0418	0.260	0.304	0.292	2.2
	18	0.0474	0.308	0.348	0.337	2.5
	16	0.0598	0.400	0.437	0.434	3.2

The concrete volume, in cubic feet per square foot, is equal to the concrete thickness above the flutes divided by 12 plus C_v. $V = t / 12 + C_v$.



* The weights listed in the table should be used for calculating dead loads, not for pricing.

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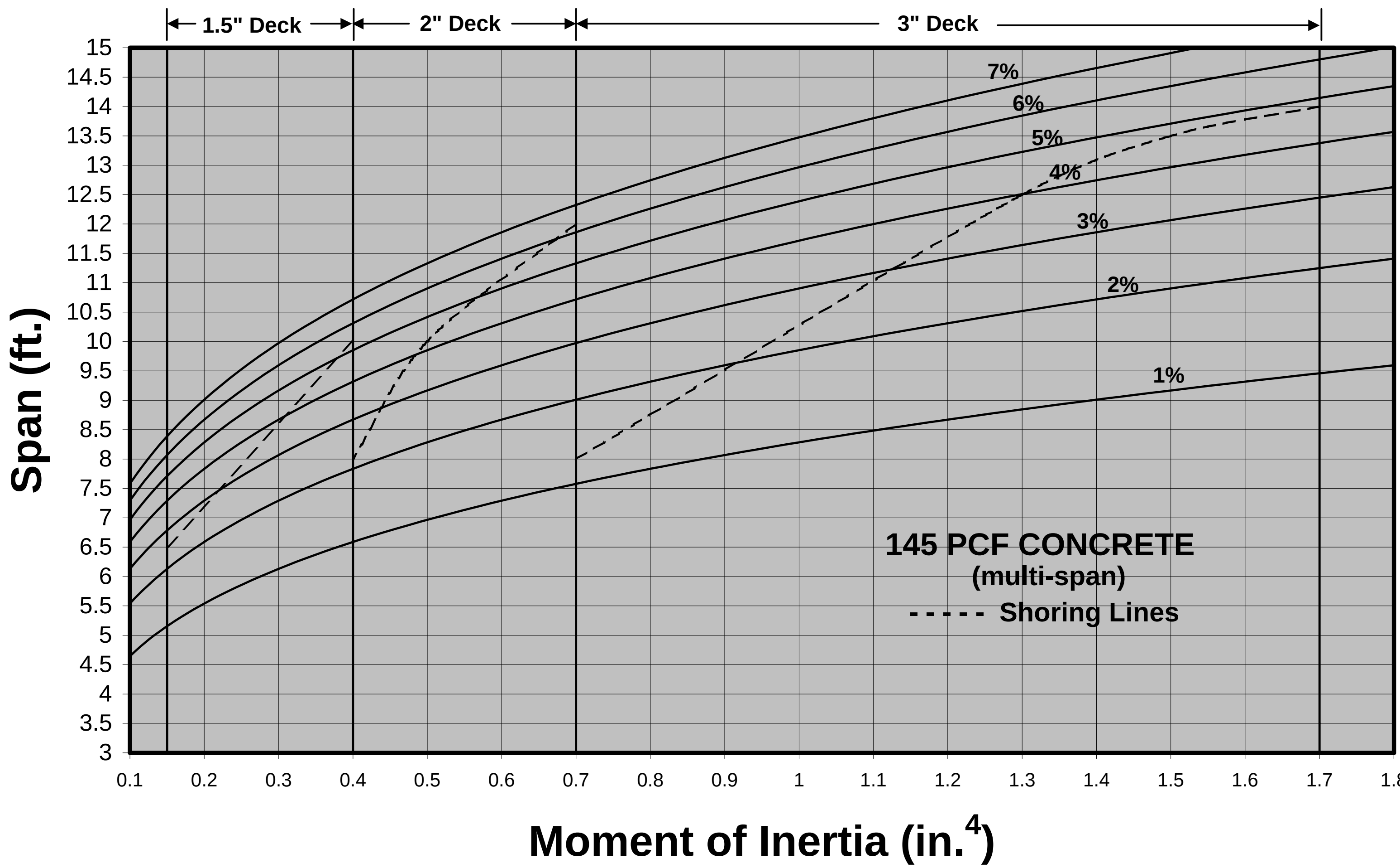

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