Sheet Steel Facts 5

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Understanding Limit States Design (LSD) Load Tables

Introduction

This Fact Sheet is written to provide guidance on the proper interpretation of Limit States Design (LSD) load tables for steel roof deck, floor deck, composite steel deck, and steel wall cladding. These are engineered products for which the manufacturer provides load tables. This Fact Sheet will describe the differences in these load tables and explain how they should be used.

In the transition from working stress design to limit states design, it is important that the person selecting the deck or cladding uses the correct loading conditions assumed in the creation of the load tables. Many manufacturers will publish both LSD and Working Stress Design (WSD) tables, so the user must be aware of the difference.

Limit States Design

Limit states design is a method of engineering that is mandated by all Canadian Building codes and design standards. LSD was adopted because it more accurately models the variability of loads and resistances that a structural member may experience.

Over the years many studies have measured actual loads, load patterns, material properties,fabrication tolerances and workmanship. Loads acting on a structural element, and the actual resistance of that element can only be defined statistically. In LSD the "factor of safety" is divided into two parts – a load factor and a resistance factor.

The National Building Code of Canada sets forth the fundamental safety criterion that must be met in LSD:

Factored Resistance ≥ Effect of Factored Loads

$$\phi R \geq \alpha \text{ (Loads)}$$

The load factor (α) is applied to the *specified loads* to recognize that loads higher than those anticipated may occur. It also takes into account the approximations used in the analysis of the effects these loads have on the structure. For example, wind loads are quite variable and consequently have a load factor of 1.5, whereas dead loads are much more predictable and have a load factor of only 1.25. The effect of the load factor is to <u>increase</u> the loads assumed in the design.

A resistance factor (ϕ) is applied to the theoretical member strength, or resistance (R) to recognize that the strength of the member cannot be predicted exactly due to variability in material properties, dimensions and workmanship. It is also used to take into account the significance of the failure mode and to reflect the uncertainty in the predictor equation. In general, the ϕ factor for steel members will be larger than for similar concrete members since the resistance of structural steel members in less sensitive to workmanship and therefore more predictable.The effect of the resistance factor is to <u>decrease</u> the strength of the member assumed in the design.

An advantage, therefore, of limit states design is that the different load factors and resistance factors more accurately predict the actual values and a greater degree of consistency against failure can be obtained than was provided by WSD.

In the practical design of steel deck and cladding,the resistance of a structural component is checked against different limit states (typically strength and deflection). For strength, the deck must have a capacity at least equal to the expected *factored load*. For deflection, the deck must not exceed a defection limit (i.e. L/240,L/360 etc.) at a *specified load*.

LSD has introduced the concepts of load factors,resistance factors, factored loads, specified loads,factored resistance plus other new terms. The following terminology is needed to understand LSD load tables.

Specified Load: those load prescribed by the National Building Code for the intended use and occupancy. There are a number of different types of specified loads: dead, live, temperature,earthquake, wind, snow, rain. These are equivalent to the working loads in WSD and might also be called allowable loads.

Superimposed Load: specified loads acting on the deck (live plus dead) excluding the self-weight of the deck or composite slab.

Factored Load: the product of the specified load and the appropriate load factor.

Load Factor: a factor used to account for the unpredictability of loads (e.g. for live load α_L = 1.5, for dead load α_D = 1.25, for wind load α_Q = 1.5). Resistance: the resistance of a member is the strength or capacity calculated in accordance with the governing design standard (i.e. CSA-S136 for cold formed steel).

Factored Resistance: the product of the nominal resistance and an appropriate resistance factor ≤ 1.0 which reduces the resistance to recognize variability in material properties, dimensions and workmanship.

Assumptions Used to Create Load Table

Load tables produced by the manufactures are developed by a Professional Engineer and are based on certain assumptions. These assumptions could include the following:

1) Factored resistances have been calculated in accordance with CSA Standard S136 "Cold Formed Steel Structural Members".

2) Tables are based on two limit states, strength and deflection, and assume a uniformly distributed load over the entire length.

3) Steel thicknesses listed are for the base steel, without metallic coatings, and are the design thicknesses.

4) Web crippling limitations assume a bearing length equal to the depth of the deck section.

5) All supports are assumed to be simple supports.

6) Minimum thicknesses are calculated by applying the tolerances specified in CSA-S136 to the design thickness. Steel deck and cladding manufactured by a CSSBI member company also comply with the following standards:
CSSBI 10M "Standard for Steel Roof Deck"
CSSBI 12M "Standard for Composite Steel Deck"
CSSBI 20M "Standard for Sheet Steel Cladding for Architectural and Industrial Applications"

NOTE: Read the load tables carefully to determine whether it is LSD or WSD. If in doubt, contact the manufacturer.

Composite Deck

The LSD load tables for composite steel deck show the allowable SUPERIMPOSED LOAD (dead plus live). The tables are calculated incorporating the self-weight of the composite slab. The superimposed dead plus live loads (unfactored) are compared against the tabulated values.

The tables have been calculated assuming that the load factor for dead load equals the load factor for live load (i.e. 1.5). This is a conservative assumption which is practical for most composite slab designs. The strength of the composite slab does not usually govern the product selection, therefore a little conservatism in the load tables is done for simplicity.

NOTE: Allowable calculated superimposed loads are based on tested shear bond strength between deck and concrete. Design is based on single span only. The composite strength is also affected by the type of metallic coating: make sure that the correct load table is used.

If the strength of the composite slab is the limiting design state, the capacity of the slab can be determined exactly by taking the live load plus 0.833 times the dead load as the superimposed load. The 0.833 factor is a reduction to recognize that the load factor for dead load is 1.25, not the 1.5 assumed.

Wall Cladding

The LSD load tables for wall cladding are based on the SPECIFIED WIND LOAD. Since wall cladding systems have virtually no dead load, the only load acting on the cladding will be the wind load. The design procedure is simplified by listing the resistance to specified loads.

If a cladding product is installed on a slope inclined more than 200 from the vertical, this then becomes a roof cladding application and the same rules would apply as in steel roof deck.

Roof Deck and Non-Composite Floor Deck

The LSD load tables for steel roof and noncomposite floor deck show the SPECIFIED LOAD resistance. This means that the specified live load plus 0.833 times the specified dead load is compared to the load table to select the appropriate deck product.

NOTE: By using specified loads the LSD load table for steel deck will show capacities comparable to WSD load tables. This is done to prevent a factored load table from being used in a WSD design which would result in an unsafe overloading of the deck.

There are two design examples included to demonstrate the roof deck selection in both an LSD and WSD design.

For More Information

For more information on sheet steel building products, or to order any CSSBI publications, contact the CSSBI at the address shown below or visit the web site at www.cssbi.ca

ROOF DECK DESIGN EXAMPLE (LSD) – SPECIFIED

This example illustrates the design of a roof deck using a SPECIFIED LSD load table. The equivalent specified live load is compared to the load table to select the suitable deck section.

Given

3 continuous spans
L = 2.2m each span
L/240 deflection limit

Specified loads:

1) Dead load
   deck = 0.10 kPa
   superimposed = 0.50 kPa
2) Live load
   superimposed = 2.2 kPa

Solution:

1) Calculate total specified load
   (Live) + 0.833 (Dead)
   (2.2) + 0.833 (0.60) = 2.7 kPa

2) Select deck thickness for strength limit state:
   From table giving values for 3 continuous spans with L=2200 mm, look at column "B".
   For t = 0.76 mm the resistance in bending = 2.7 kPa = 2.7 kPa (total load). ∴O.K.

3) Check L/240 deflection criterion:
   For t = 0.76 mm, column "D" gives 2.3 kPa which is greater that the specified live load of 2.2 kPa. ∴O.K.

Summary:

In this example the only unknown was the thickness of the deck. A thickness of 0.76 mm satisfies the required strength and deflection limit states.

METRIC LOAD TABLE FOR STEEL ROOF DECK Limit States Design (LSD)

MATERIAL: Grade A. Steel
Min. Yield Stress: F_y = 230 MPa
DEFLECTION BASED ON L/240
PER METRE OF DECK WIDTH

ALL LOADS CALCULATED ACCORDING TO PROCEDURES OUTLINED IN THE CSSBI STANDARD CSSBI 10M-86 (REV. 88) AND CSA-136

SECTION PROPERTIES				FACTORED RESISTANCES			
				MOMENT		REACTIONS	
Base Steel Thickness (mm)	Section Modulus Mid-Span (10^3 mm^3)	Section Modulus Support (10^3 mm^3)	Moment of Inertia (10^3 mm^4)	Mid-Span (10^3 N-mm)	Support (10^3 N-mm)	End (kN)	Interior (kN)
0.76	9.61	10.35	201.1	1999.6	2059.6	6.2	12.8
0.91	11.76	12.33	262.4	2430.2	2542.0	9.1	18.3
1.22	16.30	16.37	366.5	3318.2	3372.0	16.6	32.8
1.52	20.20	20.20	455.9	4156.6	4156.6	26.1	50.9

3 Continuous Spans – SPECIFIED Uniformly Distributed Live Load Equivalent (kPa)

SPAN (mm)	BASE STEEL DESIGN THICKNESS (mm)							
	0.76		0.91		1.22		1.52	
	B	D	B	D	B	D	B	D
1200	8.9	s	11.1	s	14.6	s	18.1	s
1400	6.6	s	8.1	s	10.8	s	21.2	s
1600	5.0	s	6.2	s	8.3	s	10.1	s
1800	4.0	4.2	4.9	s	6.5	s	8.0	s
2000	3.2	3.1	4.0	4.0	5.3	5.6	6.5	7.0
2200	2.7	2.3	3.3	3.0	4.4	4.2	5.4	5.3
2400	2.3	1.8	2.8	2.3	3.7	3.3	4.5	4.0
2600			2.4	1.8	3.1	2.6	3.8	3.2
2800					2.7	2.0	3.3	2.5
3000					2.3	1.7	2.9	2.1
3200							2.6	1.7

NOTES TO TABLES:
1) Column "B" gives the total specified load (kPa) that can be resisted by the deck calculated on the basis of strength limitations. (Specified live load + 0.833 x specified dead load)
2) Column "D" gives the total specified live load (kPa) that can be resisted by the deck calculated on the basis of an L/240 deflection criteria.
3) 's' in column D indicates strength governs.

ROOF DECK DESIGN EXAMPLE (LSD) – FACTORED

This example illustrates the design of a roof deck using a FACTORED LSD load table. The total factored load is compared to factored resistance given in the load table to select the deck section.

Given

3 continuos spans
L = 2.2 m each span
L/240 deflection limit

Loads:

1) Dead load
   deck = 0.10 kPa
   superimposed = 0.50 kPa
2) Live load
   superimposed = 2.2 kPa

Solution:

1) Calculate total factored load
   1.5 (Live) + 1.25 (Dead)
   1.5 (2.2) + 1.25 (0.60) = 4.1 kPa

2) Select deck thickness for strength:
   From table giving values for 3 continuous spans with L=2200 mm. Look at column “B”. For t = 0.76 mm the factored resistance in bending = 4.3 kPa> 4.1 kPa (factored load) ∴O.K.

3) Check L/240 deflection criterion: For t = 0.76 mm column “D” gives 2.3 kPa which is greater than the specified live load of 2.2 kPa. ∴O.K.

Summary:

In this example the only unknown was the thickness of the deck. A thickness of 0.76 mm satisfies the required strength and deflection limit states.

METRIC LOAD TABLES FOR STEEL ROOF Limit States Design (LSD)

MATERIAL: Grade A, Steel
MIN. YIELD STRESS; F_y = 230 MPa
DEFLECTION BASED ON L/240
PER METRE OF DECK WIDTH

ALL LOADS CALCULATED ACCORDING TO PROCEDURES OUTLINED IN THE CSSBI STANDARD CSSBI 10M-86 (Rev. 88) and CSA-S136

SECTION PROPERTIES				FACTORED RESISTANCES			
				MOMENT		REACTIONS	
Base Steel Thickness (mm)	Section Modulus Mid-Span (10^3 mm^3)	Section Modulus Support (10^3 mm^3)	Moment of Inertia (10^3 mm^4)	Mid-Span (10^3 N-mm)	Support (10^3 N-mm)	End (kN)	Interior (kN)
0.76	9.61	10.35	201.1	1999.6	2059.6	6.2	12.8
0.91	11.76	12.33	262.4	2430.2	2542.0	9.1	18.3
1.22	16.30	16.37	366.5	3318.2	3372.0	16.6	32.8
1.52	20.20	20.20	455.9	4156.6	4156.6	26.1	50.9

3 Continuous Spans – FACTORED Uniformly Distributed Load (kPa)

SPAN (mm)	BASE STEEL DESIGN THICKNESS (mm)							
	0.76		0.91		1.22		1.52	
	B	D	B	D	B	D	B	D
1200	14.3	s	17.7	s	23.4	s	28.9	s
1400	10.5	s	13.0	s	17.2	s	21.2	s
1600	8.0	s	9.9	s	13.2	s	16.2	s
1800	6.4	4.2	7.8	s	10.4	s	12.8	s
2000	5.1	3.1	6.4	4.0	8.4	5.6	10.4	7.0
2200	4.3	2.3	5.3	3.0	7.0	4.2	8.6	5.3
2400	3.6	1.8	4.4	2.3	5.9	3.3	7.2	4.0
2600			3.0	1.8	5.0	2.6	6.1	3.2
2800					4.3	2.0	5.3	2.5
3000					3.7	1.7	4.6	2.1
3200							4.1	1.7

NOTES TO TABLES:
1) Column “B” gives the total FACTORED load (kPa) that can be resisted by the deck calculated on the basis of strength limitations.
2) Column “D” gives the total SPECIFIED (unfactored) live load (kPa) that can be resisted by the deck calculated on the basis of an L/240 deflection criteria
3) ‘s’ in column D indicates strength governs.