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Serviceability Design Criteria for Low Rise Steel Building Systems

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PREFACE

The objective of the Canadian Sheet Steel Building Institute is the development of product standards and technical bulletins to promote safe and sound construction practices. This Bulletin gives guidance on the serviceability criteria for low rise steel building systems.

The material presented in this publication has been prepared for the general information of the reader. While the material is believed to be technically correct and in accordance with recognized good practice at the time of publication, it should not be used without first securing competent advice with respect to its suitability for any specific application. Neither the Canadian Sheet Steel Building Institute nor its members warrant or assume any liability for the suitability of the material for any general or particular purpose.

1. INTRODUCTION

Serviceability is an important aspect of design. It is only eclipsed by design for strength which is paramount. Design for serviceability addresses the performance of the structure with respect to its use, its interaction with non-structural elements, and maintenance.

According to NBC 2010, Part 4, Structural Design, Sentence 4.1.3.4. (1), a building and its structural components shall be checked for serviceability limit states (SLS) as defined in Clause 4.1.3.1. (1)(a) under the effect of service loads for serviceability criteria specified or recommended in Articles 4.1.3.5. and 4.1.3.6. and in the standards listed in Section 4.3.

The National Building Code lists *four* areas of consideration when sizing structural members for serviceability limit states:

(1) the intended use of the building or member;
(2) limiting damage to non-structural members made of materials whose physical properties are known at the time of design;
(3) limiting damage to the structure itself;
(4) creep, shrinkage, temperature changes and pre-stress.

2. DEFINITIONS

D	Dead load – a permanent load due to the weight of building components
L	Live load – a variable load due to intended use and occupancy (including live loads due to cranes and the pressure of liquids in containers)
S	Snow load – variable load due to snow, including ice and associated rain
W	Wind load – a variable load due to wind
T	Temperature effect – effect due to contraction, expansion or deflection caused by temperature changes, shrinkage, moisture changes, creep, ground settlement, or a combination thereof
α	Companion factor

3. SERVICEABILITY LIMIT STATES

The NBC 2010 Structural Commentaries (Part 4 of Division B) notes that loads and load combinations depend very much on the serviceability limit state and on the properties of structural materials (e.g. creep and cracking). The commentary goes on further to provide some guidance on the load combinations depending on the SLS to be considered. For example, three load combinations are suggested for displacement under the limit state of damage to non-structural components:

$$L+\alpha S$$
$$S+\alpha L$$
$$W$$

These are the recommended limit states for the short term effects that could cause undesirable effects on non-structural members. Note that S and W include an Importance Factor for the serviceability limit state (see Table 1.1 for SLS). The companion factor, α, is usually assumed to be 0.5 for live loads due to use and occupancy, except in the case of storage uses, where it is assumed to be 1.0, and 0.5 for snow loads.

Table 1.1-Importance Factors

Importance Category	Wind, I_w		Snow, I_s	
	ULS	SLS	ULS	SLS
Low	0.8	0.75	0.8	0.9
Normal	1.0	0.75	1.0	0.9
High	1.15	0.75	1.15	0.9
Post-disaster	1.25	0.75	1.25	0.9

Source: Table A-2, NBC 2010 Structural Commentaries-Commentary A

The following tables give recommendations for the serviceability limit states of metal roofing (Table 2.1), cladding (Table 2.2) and cranes (Table 2.3). The application of these limits is intended for low rise steel building systems, but may be used as a guide for other building types. The design professional is responsible for determining if these limits are appropriate for the specific building project.

Table 2.1
Serviceability Considerations for Metal Roofing

Roofing Type	Structural Element	Deformation	Recommended Serviceability Limit	Loading
Through Fastened (no interior finish)	Expansion joint	Horz. movement	100-200 ft. max (along slope of roof)	*T*
	Roof	Slope	0.5/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/150	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive Drainage[3]	*D+α*[2]*S*[1]
Standing Seam (no interior finish)	Expansion joint	Horz. movement	150-200 ft. max (along slope of roof)	*T*
	Roof	Slope	0.25/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/150	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]
Through Fastened (interior finish susceptible to cracking[4])	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.5/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/360	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]

Table 2.1 (Cont'd)
Serviceability Considerations for Metal Roofing

Roofing Type	Structural Element	Deformation	Recommended Serviceability Limit	Loading
Standing Seam (interior finish susceptible to cracking[4])	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.25/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/360	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]
Through Fastened (interior finish not susceptible to cracking[5])	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.5/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/150	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]
Standing Seam (interior finish not susceptible to cracking[5])	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.25/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/150	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1] *or D+5 psf*
Through Fastened (suspended ceiling)	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.5/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/240	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]
Standing Seam (suspended ceiling)	Expansion joint	Horz. movement	100-200 ft. max	*T*
	Roof	Slope	0.25/12 min.	*Drainage*
	Purlin	Vert. deflection	Span/240	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]
Insulated Metal Panels	Expansion joint	Horz. movement	Specified by panel manufacturer	*T*
	Roof	Slope	Specified by panel manufacturer	*Drainage*
	Purlin	Vert. deflection	Span/240 or specified by panel manufacturer	*S*[1] *or L or W*[1]
	Purlin	Vert. deflection	Positive drainage[3]	*D+α*[2]*S*[1]

Table Notes:

(1) S and W include an importance factor for serviceability (see Table 1.1)
(2) The companion factor, α, is usually assumed to be 0.5 for live loads due to use and occupancy, except in the case of storage uses, where it is assumed to be 1.0, and 0.5 for snow loads.
(3) For more information on positive drainage and ponding refer to NBC 2010 Structural Commentaries
(4) Interior finish susceptible to cracking would include gypsum drywall.
(5) Interior finish not susceptible to cracking would include metal liner panels.

Table 2.2
Serviceability Considerations for Cladding

Cladding Type/Support Type	Structural Element	Deformation	Recommended Serviceability Limit	Loading
Metal Panels/Foundation (no interior finish or interior finish not susceptible to cracking[5])	Bare frame	Drift perpendicular to wall	Height/60	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/100	*W*[1]
	Secondary structure	Horz. deflection	Span/90	*W*[1]
	Wind columns	Horz. deflection	Height/90	*W*[1]
Metal Panels/Foundation (interior finish susceptible to cracking[4])	Bare frame	Drift perpendicular to wall	Height/120	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/240	*W*[1]
	Secondary structure	Horz. deflection	Span/240	*W*[1]
	Wind columns	Horz. deflection	Height/240	*W*[1]
Insulated Metal Panels/Foundation	Bare frame	Drift perpendicular to all	Height/120	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/240	*W*[1]
	Secondary structure	Horz. deflection	Height/240	*W*[1]
	Wind columns	Horz. deflection	Height/240	*W*[1]
EIFS /Foundation (interior finish not susceptible to cracking[5])	Bare frame	Drift perpendicular to wall	Height/120	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/240	*W*[1]
	Secondary structure	Horz. deflection	Span/240	*W*[1]
	Wind columns	Horz. deflection	Height/240	*W*[1]
Tilt-Up Precast Panels/Foundation	Bare frame	Drift perpendicular to wall	Height/100	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/200	*W*[1]
	Secondary structure	Horz. deflection	Span/240	*W*[1]
	Wind columns	Horz. deflection	Height/240	*W*[1]
Unreinforced Masonry Wall/Foundation	Bare frame	Drift perpendicular to wall	1/16 in. crack in base of wall	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/360	*W*[1]
	Secondary structure	Horz. deflection	Span/240 ≤ 1.5 in.	*W*[1]
	Wind columns	Horz. deflection	span/240	*W*[1]
Reinforced Masonry Wall/Foundation	Bare frame	Drift perpendicular to wall	Height/100 with appropriate base details for max 1/16 in. crack in base of wall, or H/200 without	*W*[1]
	Wind frame	Drift parallel to wall (racking)	Height/240	*W*[1]
	Secondary structure	Horz. deflection	Span/240 ≤ 1.5 in.	*W*[1]
	Wind columns	Horz. deflection	Span/240	*W*[1]

Table 2.2 (Cont'd)
Serviceability Considerations for Cladding

Cladding Type/Support Type	Structural Element	Deformation	Recommended Serviceability Limit	Loading
Glass Curtain Wall/Foundation	Bare frame	Drift perpendicular to all	Height/240	*W*[(1)]
	Wind frame	Drift parallel to wall (racking)	Height/360	*W*[(1)]
	Secondary structure	Horz. deflection	Span/360 or specified by curtain wall manufacturer	*W*[(1)]
	Wind columns	Horz. deflection	Span/360 or specified by curtain mfg	*W*[(1)]
Glass Curtain Wall/Spandrel Beams	Bare frame	Drift perpendicular to wall	Height/240	*W*[(1)]
	Wind frame	Drift parallel to wall (racking)	Height/240	*W*[(1)]
	Secondary structure	Horz. deflection	Span/360 or specified by curtain wall manufacturer	*W*[(1)]
	Wind columns	Horz. deflection	Span/360 or specified by curtain wall manufacturer	*W*[(1)]
	Spandrels	Vert. deflection	Span/400 or specified by curtain wall manufacturer	*D*

Technical Notes:

(1) S and W include an importance factor for serviceability (see table 1.1)
(2) The companion factor, α, is usually assumed to be 0.5 for live loads due to use and occupancy, except in the case of storage uses, where it is assumed to be 1.0, and 0.5 for snow loads.
(3) For more information on positive drainage and ponding refer to NBC 2010 Structural Commentaries
(4) Interior finish susceptible to cracking would include gypsum drywall.
(5) Interior finish not susceptible to cracking would include metal liner panels.

Table 2.3
Serviceability Considerations for Cranes

Crane Type	Structural Element	Deformation	Recommended Serviceability Limit	Loading
Top Running Cranes	Runway supports	Relative lateral deflection of runway rails (change in gauge)	1.0 in. max.	$D + \alpha S$
	Runway beam Structural class of service 'A','B','C','D','E','F'	Horz. deflection	Span/400	$C_{SS}^{(3)}$ *or* $0.5C_{SM}^{(4)}$
	Runway Beam Structural class of service 'A','B'&'C',	Vert. deflection	Span/600	$C_{VS}^{(5)}$ *or* $C_{VM}^{(6)}$
	Runway beam Structural class of service 'D'	Vert. deflection	Span/800	$C_{VS}^{(5)}$ *or* $C_{VM}^{(6)}$
	Runway beam Structural class of service 'E'&'F'	Vert. deflection	Span/1000	$C_{VS}^{(5)}$ $C_{VM}^{(6)}$
Top Running Cab Operated or Radio Operated Cranes	Bare frame Structural class of service 'A','B'&'C'	Lateral drift at runway elev.	Height/240 ≤ 2 in. max.	$C_{SS}^{(3)}$ *or* $0.5C_{SM}^{(4)}$*or* $q_{1/10}$
	Bare frame Structural class of service 'D','E'&'F'	Lateral drift at runway elev.	Height/400 ≤ 2 in. max.	$C_{SS}^{(3)}$*or* $0.5C_{SM}^{(4)}$*or* $q_{1/10}$
Top Running Pendant Operated Cranes	Bare frame Structural class of Service 'A','B','C','D'	Lateral drift at runway elev.	Height/100 ≤ 2 in. max.	$C_{SS}^{(3)}$*or* $0.5C_{SM}^{(4)}$*or* $q_{1/10}$
Underhung Crane (supported by frames)	Runway supports	Relative lateral deflection of runway rails (change in gauge)	1.0 in. max.	$D + \alpha S$
	Runway beam Structural class of service 'A','B'&'C',	Vert. deflection	Span/450	$C_{VS}^{(5)}$*or* $C_{VM}^{(6)}$
	Bare frame Structural class of service 'A','B','C','	Lateral drift at runway elev.	Height/100	$C_{SS}^{(3)}$*or* $0.5C_{SM}^{(4)}$*or* $q_{1/10}$
	Bare frame Structural class of service 'A','B','C',	Vertical deflection at runway	Span/240	$C_{VS}^{(5)}$*or* $C_{VM}^{(6)}$

Technical Notes:

(1) S and W include an importance factor for serviceability (see Table 1.1)
(2) S and W include an importance factor for serviceability (see Table 1.1)
(3) The companion factor, α, is usually assumed to be 0.5 for live loads due to use and occupancy, except in the case of storage uses, where it is assumed to be 1.0, and 0.5 for snow loads.
(4) C_{SS} refers to the side-thrust due to a single crane.
(5) C_{SM} refers to the side-thrust due to multiple cranes.
(6) C_{VS} refers to the vertical load due to a single crane, not including impact.
(7) C_{VM} refers to the vertical load due to multiple cranes, not including impact.