Structural and Crane Load Design Criteria For Steel Building Systems

Canadian Sheet Steel Building Institute

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Preface

One of the objects of the CSSBI and its members is the development of standards that promote safety, performance and good practice. This bulletin is published as a guide for designers, specifiers and users of Steel Building Systems (SBS) and as a reference for building code officials and other authorities.

The material presented herein has been prepared for the general information of the reader and care has been taken to ensure that this Bulletin is a reasonable interpretation of the applicable code requirements. While the material is believed to be technically correct and in accordance with recognized practice at the time of publication, it does not obviate the need to determine its suitability for a given situation. Neither the CANADIAN SHEET STEEL BUILDING INSTITUTE nor its Members warrant or assume liability for the suitability of this bulletin for any general or particular application.

Reference Documents

Buildings Incorporating Steel Building Systems: Responsibilities of the Parties Involved, CSSBI B8-06, Canadian Sheet Steel Building Institute, Cambridge, ON

Crane Supporting Steel Structures: Design Guide, 2nd Edition, Canadian Institute of Steel Construction, Markham, ON, 2009

National Building Code of Canada 2005, National Research Council of Canada, Ottawa, ON

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Introduction

The objective of this bulletin is to present the structural and crane loading requirements in a format that is easy to understand. The structural loads are taken from the 2005 *National Building Code of Canada*. The focus is on Steel Building Systems, however, the loading criteria are applicable to most low rise building construction.

The *National Building Code of Canada* is a model document used by the provinces and territories of Canada in the preparation of their own building codes, which are the governing legislation for building construction. For specific designs, the loading criteria presented in this Bulletin should be checked against the requirements of the applicable building code.

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A. Structural Loads

The *National Building Code of Canada* outlines the minimum loads for which a building is to be designed to support. These loads are categorized as: Live, Dead and Environmental (snow, wind and earthquake).

A1: Live Loads due to Use and Occupancy

Live Loads are the expected variable loads on the building structure due to the intended use and occupancy. Crane loads and the pressure of liquids in containers are considered as Live Loads. The National Building Code of Canada specifies a minimum magnitude of Live Loads to cover the effect of ordinary load concentrations that may occur on the element being considered.

On roof surfaces, the minimum Live Load of 1 kPa (0.8 kPa for buildings in the Low Importance Category) represents the load during construction. Post construction, this load represents, maintenance workers and their equipment. On interior surfaces such as elevated floors, the Live Load is specified based on the occupancy or usage of the area(e.g. assembly areas, storage areas or libraries). For loads on surfaces not specifically defined in the National Building Code of Canada the designer of the structure (as defined in CSSBI B8) is responsible for defining the applicable load.

Examples of Live Load based on use and occupancy are:

Arenas, Churches, Gymnasia, other areas of similar use	4.8 kPa
Fixed seating Churches and Theaters, Classrooms	2.4 kPa
Equipment areas and service rooms	3.6 kPa

A2: Mezzanine Live Loads

Mezzanine means an intermediate floor assembly between the floor and ceiling of any room or storey and includes an interior balcony. (Ref. NBCC-05, 1.4.1.2, Division A)

Live Loads on mezzanines are based on the use and occupancy of the area. Where there is a corridor on the mezzanine floor the design load shall be the intended use of the room being served by the corridor. Where a mezzanine is to have multiple uses the design Live Load will be the greater load of the intended uses.

A3: Collateral and Dead Loads

Dead Load consists of the accumulation of the permanent self weight and collateral loads. Permanent weight is the sum of the self weight of the structural elements and all the weight of other material elements that would always exist throughout the life of the structure (e.g. insulation and lights).

Collateral load is the weight of any additional loads that may be in specific parts of the building, but may not be in all of the building (e.g. sprinklers, air handling units and other mechanical units). Listed below are several items or materials that would typically be considered as collateral loads

Sprinklers	0.24 kPa
Light ductwork	0.15 kPa
Acoustic ceiling tiles	0.10 kPa
Light aggregate plaster ceiling	0.19 kPa
Common glass window and framing	0.38 kPa
Glass Skylights and framing	0.58 kPa

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When designing the structural members for uplift loads (i.e. roof sheets, purlins and frames), the counter acting collateral loads are not included in the design. The collateral load is included when they act in the same direction as the dead load.

B. Crane Load Design Criteria

B1: Crane Types

Steel Building Systems can support several different types of crane systems when required. The typical crane types are Top Running, Under Hung and Jib cranes and are usually electric powered. Cranes can be provided in several styles based on the required capacity, span and service class.

Top Running cranes are supported by the crane bridge end trucks bearing on rails that are supported on top of their crane beams. These cranes have the greatest variation in capacity, span and service class and usually span the full width of the framing supports.

Figure B1: Top Running Crane

Under Hung cranes are supported by using a suspension type support which is connected to the bottom of a frame. The crane wheels are supported from the bottom flange of the crane beams which act as a crane rail and usually only span a portion of the column to column span of the structure. They are usually a small capacity of crane.

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Figure B2: Under Hung Crane

Figure B3: Jib Crane

Jib cranes are specialty cranes for a specific location and utility. They consist of a fixed length horizontal boom that can rotate about the supporting column. They are commonly used in areas of staged production to transfer work from station to station. Jib cranes are usually attached to a column flange allowing a rotation of more than 180 degrees. Considering the rotation of the load, Bi-axial bending usually governs the design of the supporting column.

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B2: Crane Service

Cranes are classified based on their frequency of operation called a *Duty Cycle* varying from Class A to F. A Class A crane is for more infrequently used moderate cranes and a Class F is for a heavy duty continuous severe service. The service of the crane is based on the quantity of partial and full lifts during a specified period of operation and does not limit the capacity of the crane.

Cranes that are usually supported by SBS buildings are often top running cranes of Class C. SBS buildings that support cranes greater than C must be evaluated based on the additional requirements set forth by the CISC *Crane-Supporting Steel Structures: Design Guide*.

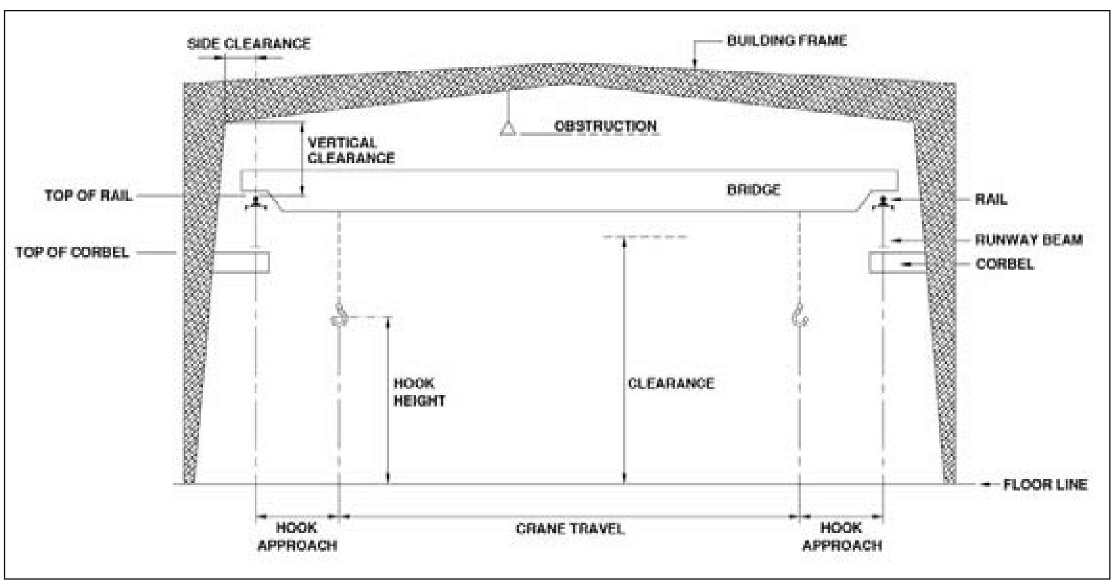
B3: Top Running Cranes

Top running cranes are the most common type of crane that a SBS building can be designed to support. The capacity of the crane is based on the magnitude of the Lifted Load. The *Lifted Load*, *Span* and *Service* define the crane member sizes, girder type and configuration. *Single Girder* cranes with a capacity of 10 tons usually span up to 50'. *Double Girder* cranes with a capacity of 25 tons usually span up to 65'. *Box Girder* cranes usually are required on longer spans.

The function of a crane is to move the lifted load horizontally and longitudinally in the building. The lifted load is usually supported with a hook, which is cabled to a hoist. The hoist is supported by a trolley which moves the horizontally along the crane bridge. The crane bridge is connected to a number of crane trucks at each end depending on the capacity and span. The crane trucks can have 2, 4 or 8 wheels based on the capacity of the crane. The wheels ride along a crane rail which is supported by runway beams. The sketch in Figure B4 illustrates the basic crane components and some of the defined distances.

The crane span is defined as the horizontal distance from center to center of the crane wheel supports. The horizontal crane coverage is defined as the crane span less the left side hook approach and right side hook approach. Side clearances are measured from the center of the supporting rail to the face of the supporting column and are required for operation, safety, and wheel maintenance.

Figure B4 – Crane Components and Definitions



The hook height is the distance from the datum to the highest position of the hook. The crane must be able to travel within the building avoiding obstructions in the building such as lights, equipment and the structural framing. The vertical clearance is measured from the top of the crane rail to the underside of the structure. This clearance is based on the size of the crane bridge, location of the hoist and trolley, rail and a safety allowance.

B4: Deflections

Serviceability requirements of the crane system and crane supporting structural system are outlined in the CSA-S16 *Design of Steel Structures*. Unfactored crane loads without impact are used to calculate the deflections. The permissible vertical deflection limit for runway beams is L/600 for class A, B, and C cranes, L/800 for class D, and L/1000 for classes E and F. The permissible horizontal deflection limit of runway beams is L/400. The permissible lateral deflection of the crane supporting structural system is based on unfactored crane loads, or unfactored 1 in 10 wind loads, and shall not exceed 50mm for cab operated cranes. The permissible lateral deflection of the structure is CH/240 for class A, B and C cranes, and CH/400 for class D, E and F cranes, where CH is measured from the base to the top of the crane rail. There is an exception for frames supporting pendant-operated cranes, which has a limit of CH/100. "L" is the center to centre distance between crane runway beam supports.

B5: Crane Data

Crane Data for the design of crane systems is to be provided by the manufacturer of the crane to the designer of the crane supporting system. Listed below is the minimum required crane information to be used in the design of crane supporting systems.

Quantity of Cranes
New or Existing Crane
Capacity (tons or tonnes)
Class
Span
Power source (hand geared or electric)
Total weight of crane, weight of trolley and hoist
Maximum Wheel load (without impact)
Spacing, Diameter and Number of wheels
Vertical and Horizontal clearances
Hook approach
Special impact factors or serviceability requirements

B6: Loads on Frames

The sketch in Figure B5 shows the cross section of a steel building system with the associated crane loads. The sketch in Figure B6 shows the longitudinal loads applied to the building by the crane.

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Figure B5 - Building Section Showing Loads

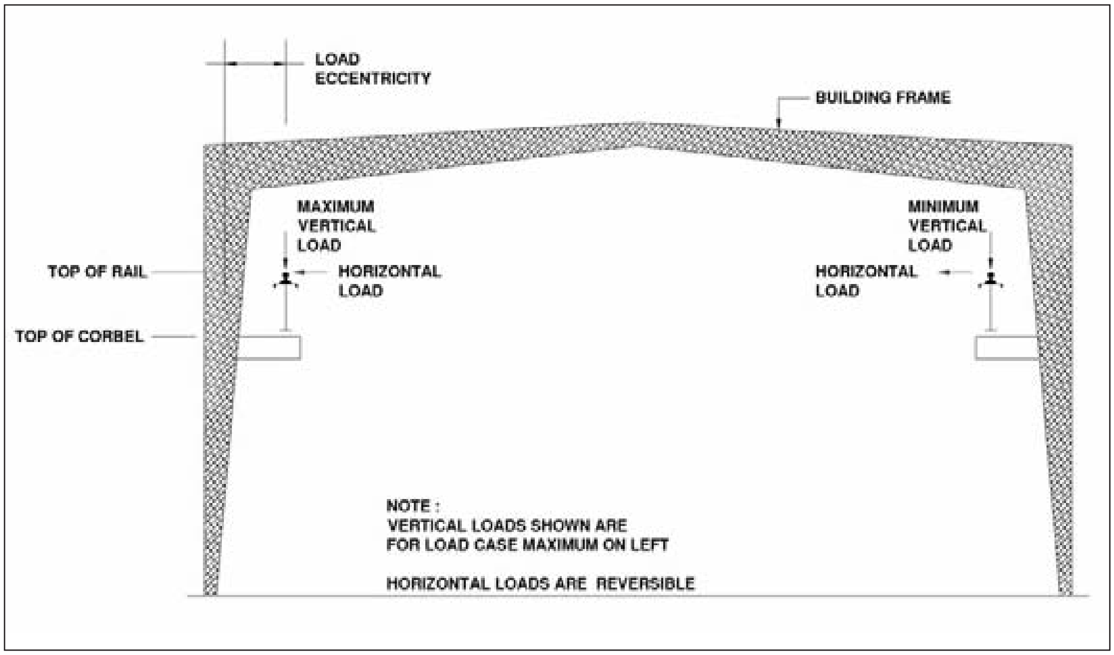
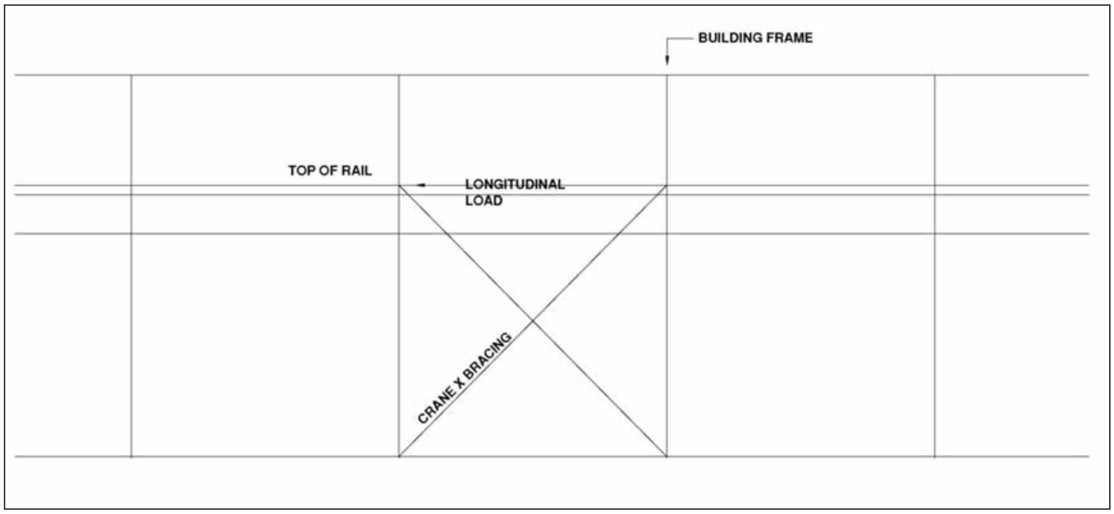


Figure B6 – Building Longitudinal Loads



B7: Load Directions

The vertical crane live loads are applied to the top of the rail at the centerline of the crane beams. The weight of the crane beam is applied at the top of the corbel bracket. The vertical loads are applied eccentric to the supporting frame column when a corbel attached to the column is used. The horizontal and longitudinal crane loads are considered as live loads. They are applied at the top of the crane rail as illustrated in Figure B7.

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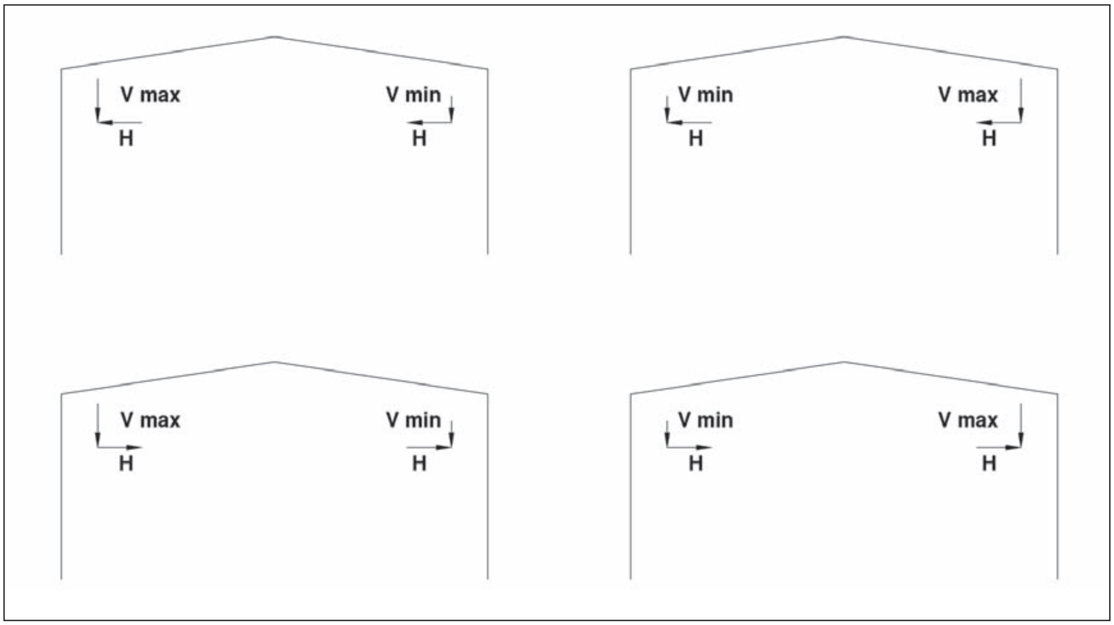
Figure B7 – Building Crane Loads



Note: Impact factor also applies for crane beam connection, fatigue check requirement for stress reversal on top flange, tension flange and welds at stiffeners.

B8: Crane Beam Loads

The design of the *Crane Beam* is to include all the loads imposed on the beam, which include the self weight of the beam, rail, all accessories, the loads induced from the crane and the lifted load. The design of the crane runway beams is to include the impact factor. The *Impact Factor* is applied to the lifted load and the weight of the crane including the trolley and hoist. For example, an electrically operated crane has an impact factor of 1.25; whereas pendant operated cranes have an impact factor of 1.10.

Crane beams are usually designed as simple span beams. Structural analysis of the beam is required to determine the location of the maximum design moments and shears due to the crane traveling along the length of the crane beam.

B9: Load combinations

Load combinations are specified in the *National Building Code of Canada*. The crane loads are considered to be live loads.

Consideration of the magnitude and direction of the crane must be taken into account when loading the frame. One combination is to include the maximum vertical loads on one side of the bridge with the horizontal loads going in one direction and then a combination with the horizontals going in the opposite direction. Frames should always be designed with the maximum load on one side and the minimum load on the other.

Multiple cranes can impact the quantity of load combinations greatly, especially for multi-span frames. For vertical loads, all combinations of maximum/minimum loads for each crane must be checked; all cranes are loaded simultaneously. This is not necessary for lateral and longitudinal loads, since there is a very low probability of multiple cranes imposing full lateral (or longitudinal) loads at the same time. Similarly, the vertical impact load is not required for all cranes simultaneously. Refer to the CISC *Crane-Supported Steel Structure Design Guide* for suggested load combinations for various situations.

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B10: Crane Beam Corbels

The design of the crane runway beam supporting corbel is to include the impact factor and fatigue loading. The design of the crane beam corbel is to include all the loads imposed on the corbel from the crane beam. Simple span crane beams impose loads in one direction. Continuous crane beam design causes stress reversals on the corbel.

B11: Crane Load Design Criteria Example

Building Size: 30m clear span building x 42m long x 9m high
7 - 6m bays

Crane Data: 1 new 10 tonne, Class C, electric operated crane
Crane span: to be determined
Crane weight: 11500 Kg
Trolley weight: 630 Kg
Hoist weight: combined with trolley
Maximum wheel load: 81.3 KN (without impact)
Number of wheels: 2 per end truck
Wheel spacing: 4980 mm
Vertical clearance: 1295 mm
Horizontal clearance: 203 mm
Crane approach: 1016 mm
Crane is electrically operated, and is not pendant operated
Code specified serviceability requirements

Determine the Crane Span:
The crane span is the building width, less the structure depth, less the horizontal clearances, and is illustrated in Figure B8.

Building Width = BWD = 30000 mm
Assumed Frame Width = AFWD = 1070 mm
Horizontal Clearance = HCD = 203 mm
Crane span = SPD = BWD – 2 (AFWD + HCD)
SPD = 30000 – 2(1072 + 203) = 27450 mm

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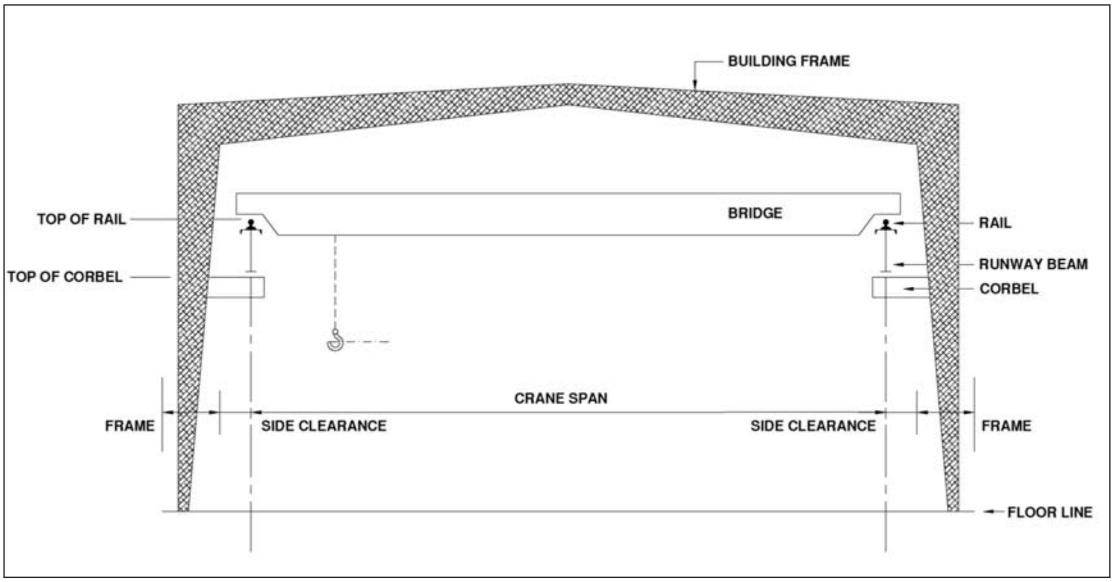
Figure B8 – Crane Span



Calculate the Crane Loads:

Lifted Crane Load = LCL = 10 tonnes = 97.90 KN
Crane Weight = CW = 112.87 KN
Trolley and Hoist Weight = THW = 6.19 KN

When the lifted load is hoisted and is as far to the left as physically possible, it is at the closest position to the left support. This is equal to the crane approach. The crane approach is the smaller distance of the left or right side approach.

Crane Approach = CAD = 1016 mm
The Maximum Load Factor for this span based on the side approach is
MXLF = (SPD –CAD) /SPD = (27450 – 1016)/ 27450 = 0.96

The Minimum Load Factor for this span based on the side approach is
MNLF = 1 – MXLF = 1 – 0.96 = 0.04

There are 2 wheels per truck and 2 trucks per crane for a total of 4 wheels for this crane.
Wheels per Truck = TrW = 2
Total number of Wheels = TTrW = 4

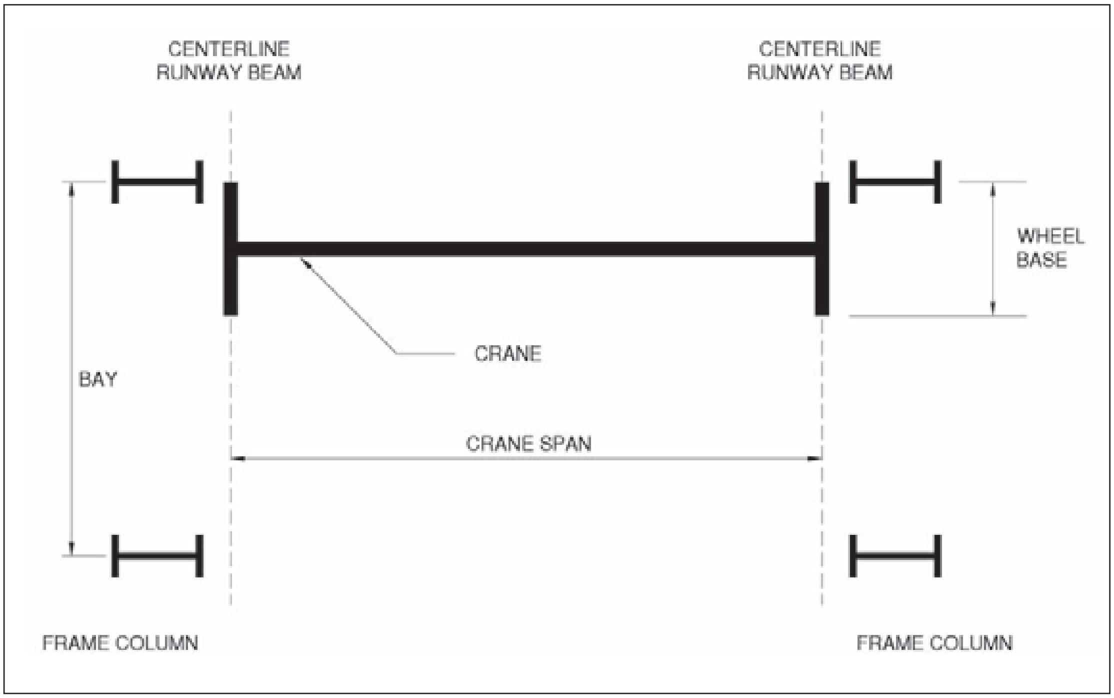
The calculated Wheel Loads are:
Maximum Wheel Load = MXWL = CW/TTrW + MXLF (THW + LCL) / TrW
MXWL = 112.87 / 4 + 0.96 (6.19 + 97.90) / 2 = 78.18 KN

Minimum Wheel Load = MNWL=CW/ TTrW + MNLF (THW + LCL) / TrW
MNWL = 112.87 / 4 + 0.04 (6.19 + 97.90) / 2 = 30.30 KN

The sum of all wheel loads is 2 (78.18) + 2 (30.30) = 216.96 KN
Check the sum of the lifted load + the crane, trolley and hoist weight.
112.87 + 6.19 + 97.90 = 216.96 KN

The maximum load of the crane on any one frame will be when a crane wheel is directly in line with the frame centerline as illustrated in Figure B9.

Figure B9 – Configuration Causing Maximum Crane Load on a Frame



The distance between frames is the bay size, BAYD = 6000 mm
The Wheel Spacing = WSD = 4980 mm
Truck Wheel Factor = TWF = (2 – WSD/ BAYD)
= 2 – 4980/6000 = 1.17

Vertical Frame Load:

Maximum Live Load:

MXVFL = MXWL * TWF = 78.18 * 1.17 = 91.47 KN

Minimum Live Load:

MNVFL = MNWL * TWF = 30.30 * 1.17 = 35.45 KN

Assume the crane beam, rail and accessories weighs 7 KN per 6m bay

Horizontal Load:
The horizontal load is 20% of the sum of the lifted load, weight of the trolley and hoist weight applied at the top of the rail and is equally divided between each side of the crane.

The horizontal load will then be distributed to each frame proportional to the relative stiffness and support conditions.

CLHL = CRHL = (0.20 (THW + LCL) /2) TWF
= (0.20 (6.19 + 97.90) /2) 1.17 = 12.18 KN

Longitudinal Load:
The longitudinal load is to be 10% of the maximum wheel load (on driving wheels) at the top of the rail.

CLLL = CRLL = 0.10 (Maximum Wheel Load) * Number of Wheels
= 0.10 (81.3) * 2 = 16.26 KN