Understanding Metric Data Center Ceiling Load Requirements and Determining if Suspension System Meets Design Loads

May 18, 2022

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Purpose

The purpose of this paper is to identify the unique loading requirements of Data Center Ceiling Systems and standardize a methodology for determining which Ceiling Suspension System is the best choice for meeting the Data Center project's design loads.

This standardization provides:

I. Definition of Static Point and Uniform Loads
II. Acceptable Deflection of Ceiling Suspension System
III. Method of Calculating Deflection for Static Point and Uniform Loads
IV. Explanation of Loads Transferred to the Deck

Background

Today's data centers require Ceiling Suspension Systems to provide both flexibility and increasingly greater load carrying capabilities for end users to support operations today and in the future. The current trend of eliminating raised floors will require greater loads to be transferred to the Ceiling Suspension System in order to carry more service equipment. For this reason, it is important to understand the key features required of the Data Center Ceiling Suspension System and how to determine which Suspension System to best for your project's design loads.

Today's Data Center Ceilings must provide the following features:

- The ceiling design serves the dual purpose of both a Drop Ceiling System and structural Ceiling Suspension System for overhead utility distribution.
- The Ceiling Suspension System provides an attachment or suspension platform for containment barriers, partitions, or surface mounted equipment.
- Greater installation and routing flexibility of distribution systems and partitions are required to adapt to changes in the Data Center market.
- Totally accessible overhead Data Center Ceiling Suspension System allows for simple expansion, upgrade or distribution system changes.
- Ceiling Suspension System components must be non-progressive and removable, without compromising the structural integrity of the installed Ceiling System.

A properly designed Ceiling Suspension System eliminates the need for separate strut grids to handle overhead distribution suspension with an acoustical tile drop ceiling below the struts.

Design parameters and loading requirements vary between Data Centers. For this reason it is important to understand how loading is applied to the Ceiling Suspension System and how to determine which Ceiling Suspension System is right for your project.

Load Definitions

There are two types of Loads applied to the Data Center Ceiling: 1) Static Point Loads; and 2) Uniform Loads. Shown below is a definition for each type of Load and an example of how this applies to a Data Center Suspension System.

1) Static Point Loads: A Load or Force applied to a specific point on a supporting structure.

   Example: A cable tray may be suspended from a Ceiling Suspension System every 1200mm. The cable tray's suspension points connected to the Ceiling Suspension System is where its Static Point Loads are applied. The total load over the 1200mm of the cable tray is transferred to the Ceiling Suspension System at these specific points.

2) Uniform Loads: A Load or Force evenly distributed along a supporting structure.

   Example: A lay-in light fixture distributes its weight (Load) along all suspension tee profiles that it is contacting. The total Load applied to the Ceiling Suspension System is evenly distributed over the entire LM of the suspension tees and not applied to only one point.

Acceptable Deflection

(American Society for Testing and Materials) ASTM C 635, Standard Specification for the Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings, specifies the maximum allowable deflection for the Ceiling Suspension to be 1/360 of its span.

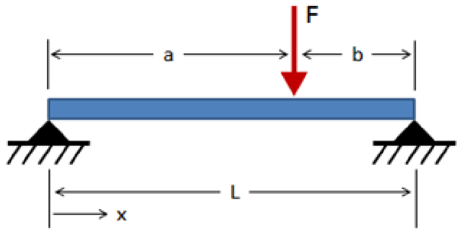
For example, if the Ceiling Suspension Hangers are located 1200mm on center, the maximum allowable deflection, per ASTM C 635, is 1200mm/360 = 3.33mm.

In a Data Center Ceiling application, where the main function of the Ceiling Suspension System is its Load carrying capability, it is recommended that maximum deflection be limited to 1/360 of its span. However, the maximum deflection can be increased to 1/180 of its span, if the aesthetic appearance of the Ceiling System at this deflection is acceptable to the end user.

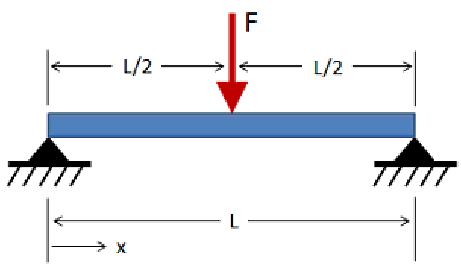
It should be noted that deflection greater than 1/360 of its span is most evident where lay-in panels and light fixtures can highlight the visual deflection.

Static Point Loads and Deflection

If the Point Load (Force) is known, the amount of deflection to the Suspension Tee can be calculated based on the position of the Point Load from the Hanger that supports the Suspension Tee.



However, when selecting the right Ceiling Suspension System for the Loads in your Data Center project, the exact location of the Point Loads are not always known and will vary over the entire system. For this reason, it is recommended to look at the worst-case loading point, which is at the mid-point between the Hangers that support the Suspension Tee.



The formula below is used to calculate the maximum deflection at a given Load (Force):

$$\Delta \text{ max. (at point load)} = \frac{Fl^3}{48EI}$$

X = L/2

F = Force applied to Suspension Tee

L = Length of Suspension Tee between Hangers

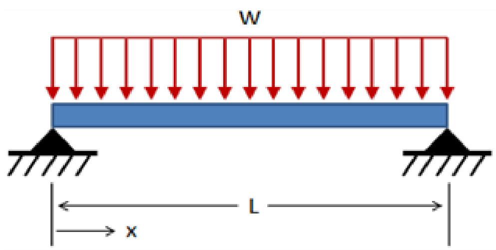
E = Young’s Modulus

I = Moment of Inertia

NOTE: When reviewing allowable Loads and Deflection, one should ensure that the Stresses developed in the Suspension Tee, due to the applied Loads, do not exceed the Yield Strength of the Suspension Tee material.

Uniform Loads and Deflection

If an evenly distributed Load (Force) along the Suspension Tee is known (for example, the weight of a light fixture), the amount of deflection to the Suspension Tee can be calculated.



Per ASTM C 635, Standard Specification for the Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings, Uniform Load for Ceiling Suspension Systems is defined as weight per linear measurement. For metric ceiling systems the uniform load is defined in kilograms per linear meter (Kg/LM).

As stated previously, when looking at devices (e.g., light fixtures) that distribute a Uniform Load along the Suspension Tee, any deflection greater than 1/360 of span will highlight the visual deflection.

The formula below is used to calculate the maximum deflection at a given Uniform Load (Force):

$$\Delta \textbf{ max. (at center)} = \frac{5\,wl^4}{384\,EI}$$

L = Length of Suspension Tee between Hangers

W = Line Pressure Load applied to Suspension Tee

E = Young’s Modulus

I = Moment of Inertia

Loads Transferred to Deck

When designing a Data Center, it is important to keep in mind the effects of the Ceiling Suspension System Loads that are transferred to the Roof / Floor Deck. All Loads applied to the Ceiling Suspension System are transferred to the Deck at the Ceiling Suspension Hanger locations.

With the heavy Static Point Loads, which are characteristic of Data Center Suspension Systems and which vary across the Data Center Ceiling System, a simple Uniform Load designated in Kilograms per Square Meter (kg/m^2) cannot consistently be applied to the overall Ceiling Suspension System.

For this reason, most Data Center Ceiling Manufacturer's will provide a worst-case Load being transferred to the Deck. They use the Static Point Load that can be applied at the Ceiling Suspension Hanger location and apply this Load across the 1.44 m^2 area supported by that Suspension Hanger, based on a 1200mm X 1200mm Hanger layout.

For example, Gordon, Inc. Data Center Ceiling Suspension Systems can support up to 544 kg. directly below the Ceiling Suspension System Hanger. Using a typical 1200mm X 1200mm Hanger Suspension Layout, this 544 kg divided by 1.44 m^2 would equate to 378 kg/m^2. As stated previously, this 378 kg/m^2 is a worst-case condition and should not be consistently applied across the Ceiling System.

For this reason, <u>it is not recommended to specify the Data Center Ceiling Suspension System based on a kg/m^2 Uniform Load</u>. This information can be misleading and lead to poor design choices, such as overcompensation for Seismic Bracing.

It is recommended that the Project Structural Engineer understand the locations of Static Point Loads and how they transfer to the Deck at their associated Ceiling Suspension System Hangers.

To assist the Project Structural Engineer with his/her review, it is recommended that the Data Center Ceiling Manufacturer provide project specific Professional Engineer Calculations for both Ceiling Suspension System Loading and locations for Seismic Bracing.

Summary

As explained in the previous pages, the most important performance criteria of the Data Center Ceiling Suspension System is its Static Point Load capabilities based on the acceptable Ceiling Deflection for your project.

To ensure an accurate comparison is made between all Ceiling Suspension Systems being considered, the same methodology should be used for each system. The mid-span deflection formula shown below, as fully described on page 7 of this report, is the best method of comparison between systems:

$$\Delta \text{ max. (at point load)} = \frac{Fl^3}{48EI}$$

$$X = L/2$$

Since each Data Center project has its own unique loading requirements, Gordon, Incorporated offers 3 different Ceiling Suspension options:

1. **DG 1.5M Structural Suspension**
    a. Heavy Load Suspension
    b. Load support for overhead cable and power distribution
    c. Support for walls and containment barriers
    d. See Load Specification Sheet in Appendix A
2. **DG 3.0M Structural Suspension**
    a. Extreme Load Suspension
    b. Provides greater Load support for overhead utilities than DG1.5M
    c. Maintains same platform as DG1.5M for support of walls and containment barriers
    d. See Load Specification Sheet in Appendix B
3. **DG X-SPAN M Enhanced Performance Ceiling System**
    a. Highest mid-span Load capacity
    b. Exceeds the application requirements required for hyper scale and Cloud Data Center operations.
    c. Capable of greater hanger spans than other Data Center Suspension Systems. Ideal product when utilizing stem anchors placed on 1800mm centers in precast concrete roofs.
    d. Maintains same platform as DG1.5M for support of walls and containment barriers
    e. See Load Specification Sheet in Appendix C

Appendix A: DG 1.5M Load Data Specifications

Physical Properties

Material: Extruded Aluminum

Alloy: 6060

Temper: T66

Weight: .9479 kg / m

Modulus of Elasticity: 69 GPa

Ultimate Tensile Strength: 220 MPa

Tensile Yield Strength: 170 MPa

Shear Strength: 152 MPa

Fatigue Strength: 68.9 MPa

Structural Properties

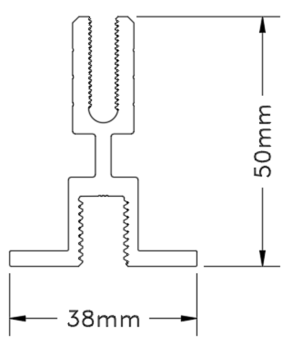
Moment of Inertia:
I_x 0.106 x 10^6
I_y 0.0208 x 10^6

Section Modulus:
S_x 3.654 X 10^3
S_y 1.092 x 10^3

Center of Gravity:
CG_x 28.93
CG_y 19.05

Load Data

Main Tee Spacing	Hanger Spacing	Max. Allow Deflection	Max. Concentrated Static Load at mid-span
1200mm	1200mm	L/360 (3.33mm)	68.77 kg
1200mm	1200mm	L/180 (6.66mm)	137.75 kg



Appendix B: DG 3.0M Load Data Specifications

Physical Properties

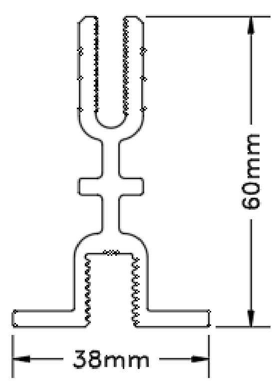
Material: Extruded Aluminum
Alloy: 6060
Temper: T66
Weight: 1.256 kg / m
Modulus of Elasticity: 69 GPa
Ultimate Tensile Strength: 120 MPa
Tensile Yield Strength: 170 MPa
Shear Strength: 152 MPa
Fatigue Strength: 68.9 MPa

Structural Properties

Moment of Inertia:	Section Modulus:	Center of Gravity:
I_x 0.169 x 10^6	S_x 4.980 x 10^3	CG_x 33.93
I_y 0.0208 x 10^6	S_y 1.092 x 10^3	CG_y 19.05

Load Data

Main Tee Spacing	Hanger Spacing	Max. Allow Deflection	Max. Concentrated Static Load at mid-span
1200mm	1200 mm	L/360 (3.33 mm)	109.93 kg
1200 mm	1200 mm	L/180 (6.67 mm)	220.19 kg



Appendix C: DG X-SPAN M Load Data Specifications

Physical Properties

Material: Extruded Aluminum

Alloy: 6060

Temper: T66

Weight: 2.080 kg / m

Modulus of Elasticity: 69 GPa

Ultimate Tensile Strength: 220 MPa

Tensile Yield Strength: 170 MPa

Shear Strength: 152 MPa

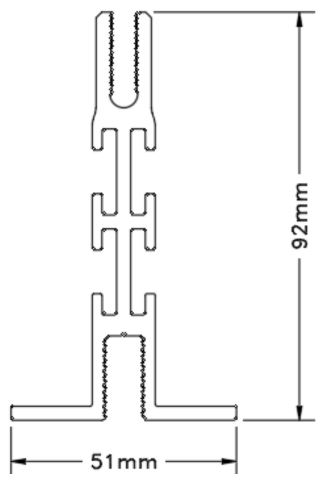
Fatigue Strength: 68.9 MPa

Structural Properties

Moment of Inertia:	Section Modulus:	Center of Gravity:
I_x 0.64 X 10^6	S_x 12.316 X10^3	CG_x 51.94 mm
I_y 0.0466 X 10^6	S_y 1.835 X 10^3	CG_y 25.40 mm

Load Data

Main Tee Spacing	Hanger Spacing	Max. Allow Deflection	Max. Concentrated Static Load at mid-span
1200 mm	600 mm	L/360 (1.44 mm)	1443 kg
1200 mm	1200 mm	L/360 (3.33 mm)	415.73 kg
1200 mm	1800 mm	L/360 (5 mm)	183 kg
1200 mm	2400 mm	L/360 (6.66 mm)	104 kg



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