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VULCRAFT/VERCO GROUP

Steel Floor Joist Presentation

for

SEAAK

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Presented By

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Business Dev Mgr.

Topics:

- ❑EOR & Joist Manufacturer’s responsibilities
- ❑Non-composite Joists
- ❑Composite Joists
- ❑Joist End Connection Options
- ❑Software Solutions for Floor Joists
- ❑Vibration Analysis Walking – free & online
- ❑MEP openings

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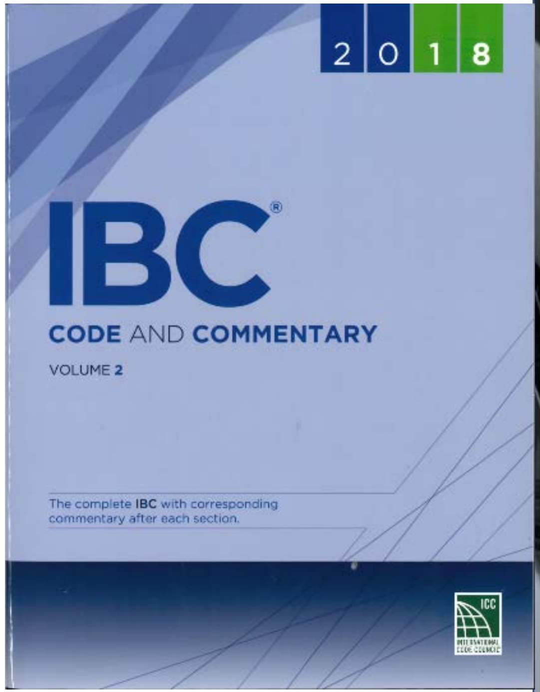
Specifying Joists:

Building Code:

- 2018 IBC Section 2207
  - References Steel Joist Institute (SJI) Specifications
  - SJI Specifications: included in Vulcraft Manual



- IBC Section 2207.4: “Steel joist placement plans do **not** require the seal and signature of the joist manufacturer’s registered design professional.”

- Vulcraft & the other manufacturers are SJI members

Specifying Joists:

Engineer's Responsibility:

- Depth of joist and joist girders
- Joist span
- Joist spacing & starting point for layout
- Support / end connection details
- All required loading
  - uniform, concentrated, axial, etc.
- Serviceability constraints
  - Deflection Criteria is most common.
- Any additional geometry considerations
  - Special sprinkler considerations, etc.

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Specifying Joists

Vulcraft’s Responsibility:

- Furnish Placement plans.
- Placement plans serve 2 purposes:
  - Shows all required loading, so Engineer can review & confirm.
  - Shows mark number & location for erection purposes.
- Determine sizes of all joist or joist girder members.
  - Top & Bottom Chord angles, Web sizes, Seat angles, etc.
  - Determine Weld sizes for webs
- Furnish stamped & signed joist calculations.
  - Calculation printed at time of fabrication.
- Fabricate the joists.

Non-composite SJI joists:

Floor Joist History:

- Original use – joists 2’ to 4’ o.c. with form deck
  - Joists initially limited end reactions, 9K and total load, 550 plf
  - Topping slab must fit occupancy use especially serviceability
  - Still good solution for 125 psf, 250 psf storage applications

Non-composite SJI joists:

- LH-Series with 1.5B Formlok deck (1970s)
  - Joist spacing increased to 6’ to 7’-6”
  - Common loading – 100 psf live load, 75 psf dead load
  - Joist girders used in lieu of steel beams as primary members
  - Load per foot designation, such as 32LH1050/600

Non-composite SJI joists:

- LH-Series with W2 or W3 decks (1980s)
  - Standard SJI Joist Tables – load range not adequate for wider spacings, tables were structured mostly around roof loadings
  - Load per foot joists used, TL/LL in plf after Depth
  - Bolted flush frames first used on joists

Non-composite SJI joists:

- LH-Series Joists with Expanded Load Tables (2020)
  - Joist spans from 12x depth to 24x depth
  - 18 inch joist has total load/ live load in plf listed from 18’ to 36’
  - Upper limit on loads is generally slightly above 2900 plf
  - Joist depths from 18 to 48 inches, spans 18’ to 96’

Uniform Load per Foot Designations:

30 LH 870/600 **(Uniform Load per Foot Designation)**

- 600 — Live Load (plf)
- 870 — Total Load (Dead + Live) (plf)
- LH — LH-Series SJI Specs to be Used in Design
- 30 — Depth (Inches)

- **Best** way to designate joist
- LH joists with Uniform Load per foot designation:
  - Available in full inch depths
  - 28LH, 29LH, 30LH,…

LH Expanded Load Tables:

ASD

STANDARD LOAD TABLE/OPEN WEB STEEL JOISTS, LH-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	18LH02	18LH03	18LH04	18LH05	18LH06	18LH07	18LH08	18LH09	18LH10	18LH11	18LH12	18LH13	18LH14	18LH15	18LH16	18LH17	18LH18	18LH19	18LH20
Depth (in.)	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Approx. Wt. (lbs./ft.)	10	11	12	14	15	17	19	21	23	25	28	33	36	39	44	50	57	62	83
Span (ft.) ↓																			
18	805 805	896 896	1039 1039	1175 1175	1438 1438	1529 1529	1728 1728	1989 1889	2231 2231	2489 2489	2751 2751								
19	748 748	833 833	966 966	1093 1093	1329 1329	1414 1414	1598 1500	1831 1601	2054 2054	2291 2291	2533 2533								
20	697 696	776 774	899 896	1018 1009	1231 1169	1310 1229	1480 1283	1688 1369	1895 1816	2114 2005	2337 2226	2805 2576							
21	649 600	723 667	838 772	949 870	1143 1008	1216 1059	1373 1105	1562 1180	1752 1565	1955 1728	2161 1918	2587 2220	2825 2413						
22	606 520	675 579	783 670	886 755	1063 874	1130 919	1277 959	1448 1024	1624 1358	1812 1500	2003 1664	2391 1926	2612 2094	2829 2276					
23	567 454	631 505	732 585	829 659	990 764	1053 803	1189 838	1345 894	1508 1186	1683 1310	1860 1454	2216 1683	2420 1829	2622 1987					
24	531 399	591 444	685 514	776 579	924 671	982 705	1110 736	1250 786	1403 1042	1566 1151	1732 1277	2059 1478	2248 1607	2436 1746	2811 1922				
25	497 353	554 392	643 454	728 511	863 593	918 623	1037 650	1167 694	1309 920	1461 1016	1615 1128	1916 1306	2093 1419	2268 1542	2587 1697	2950 1929			
26	468 313	521 348	604 403	684 454	809 526	840 553	876 577	936 616	1223 817	1365 902	1509 1001	1788 1159	1953 1260	2115 1369	2390 1506	2725 1712			
27	442 284	493 317	571 367	648 414	749 469	809 513	843 534	901 571	1145 728	1278 804	1413 893	1671 1033	1825 1123	1978 1220	2214 1343	2524 1526	2916 1739		
28	418 259	467 289	535 329	614 378	696 419	780 476	812 496	868 527	1074 652	1198 720	1325 799	1565 925	1710 1006	1852 1093	2057 1203	2345 1367	2709 1557		
29	391 234	438 262	500 296	581 345	648 377	726 428	784 462	838 491	1009 586	1126 647	1245 718	1469 832	1604 904	1738 982	1916 1081	2184 1229	2523 1400	2811 1538	
30	367 212	409 236	469 266	543 311	605 340	678 386	758 427	810 458	949 529	1059 584	1171 648	1380 750	1508 816	1634 886	1789 975	2039 1108	2356 1263	2624 1387	
31	345 193	382 213	440 242	508 282	566 307	635 349	717 387	783 418	894 479	996 529	1104 587	1300 679	1420 738	1538 802	1674 883	1909 1003	2205 1143	2456 1256	
32	324 175	359 194	413 219	476 256	531 280	595 317	680 351	759 380	844 435	934 480	1042 533	1226 617	1336 671	1451 729	1570 802	1790 911	2068 1038	2303 1141	2862 1402
33	306 160	337 177	388 200	448 233	499 254	559 288	641 320	713 346	798 396	878 437	980 485	1157 562	1255 611	1370 664	1475 731	1682 830	1943 946	2164 1039	2689 1277
34	289 147	317 161	365 182	421 212	470 232	526 264	604 292	671 316	754 362	826 399	923 443	1089 513	1182 558	1291 606	1389 667	1584 758	1829 864	2038 949	2532 1167
35	273 135	299 148	344 167	397 195	443 212	496 241	571 267	633 289	711 331	779 366	870 406	1027 470	1114 511	1217 555	1310 611	1494 695	1725 791	1922 869	2388 1068
36	259 124	283 136	325 153	375 179	418 195	469 222	540 246	598 266	672 304	736 336	822 373	970 432	1053 469	1150 510	1237 561	1411 638	1630 727	1816 798	2256 981

- Can be used to help approximate self-weight of joist

Uniform Load per Foot Designations:

24 K 240/128 **(Uniform Load per Foot Designation)**

- 128 — Live Load (plf)
- 240 — Total Load (Dead + Live) (plf)
- K — K-Series SJI Specs to be Used in Design
- 24 — Depth (Inches)

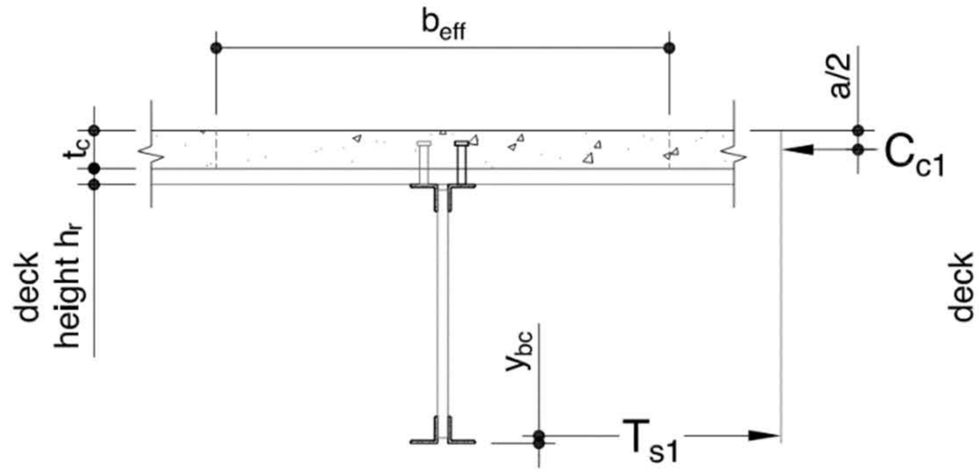
- Limited to 550plf total load
- K series depths:
  - Available in 2” depth increments from 10” to 30”

Composite Joists:

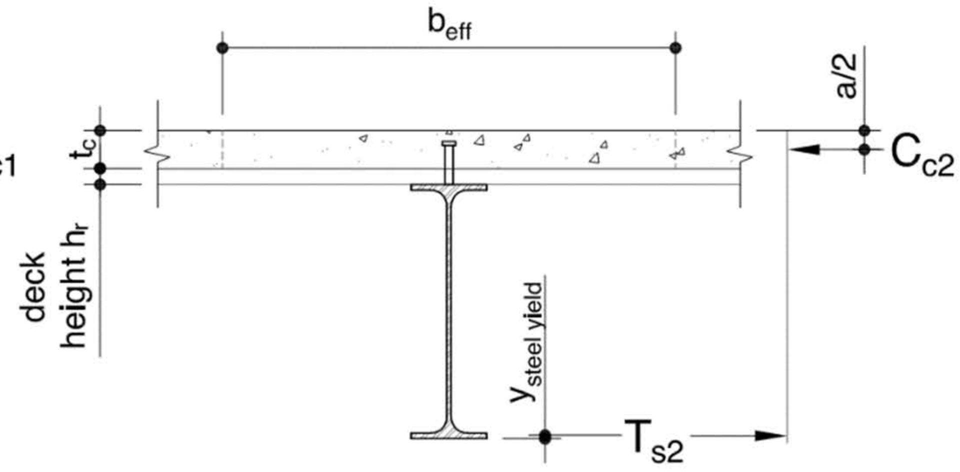
- There are 2 options for composite joists:
- CJ series composite joists:
  - Welded Shear Studs for composite action
- Ecospan E series composite joists:
  - Shearflex Screw for composite action
    - Self-drilling/Self-tapping screw
  - IAPMO ER 366

Composite Joists:

- Same design principles as Composite Beam
  - Concrete over steel deck used for compression
  - Bottom flange/chord steel used for tension
  - Nelson® studs used for shear transfer CJ Series
  - Shearflex screws used for shear transfer Ecospan



COMPOSITE JOIST



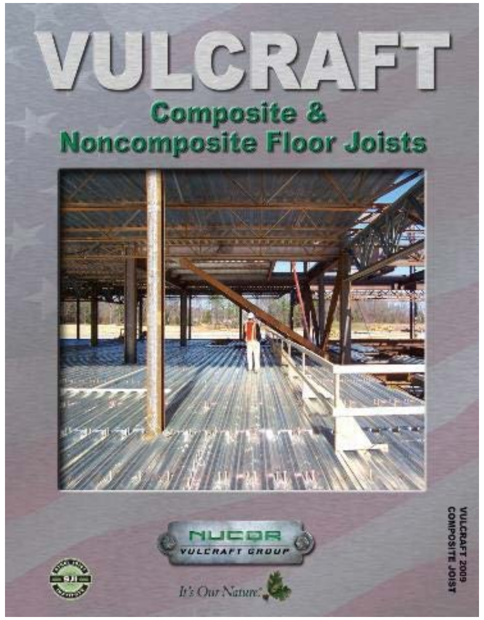
COMPOSITE BEAM

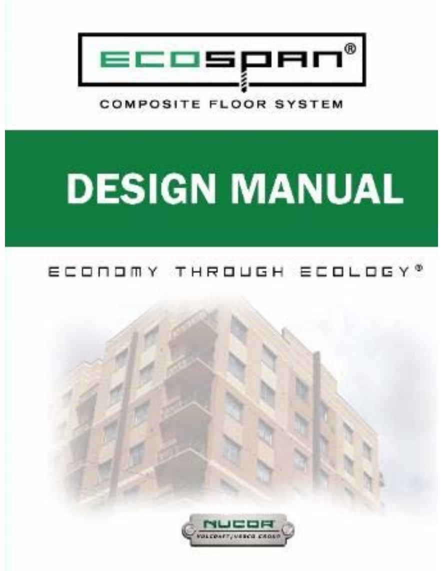
Composite Joists:

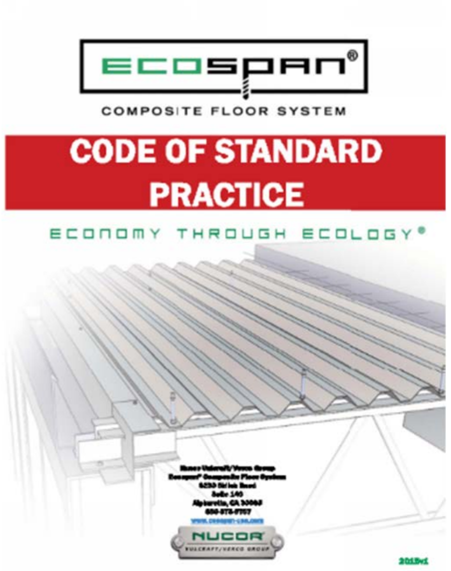
- Composite joists can be shallower than non-composite joists,
  - Composite Joists: span 30x depth
  - Non-Composite Joists: span 24x depth
- Lighter than same depth non-composite joist
  - Top chord less area, larger effective depth
- Weld Studs or Shearflex screws attached in staggered pattern
  - activates both chord angles

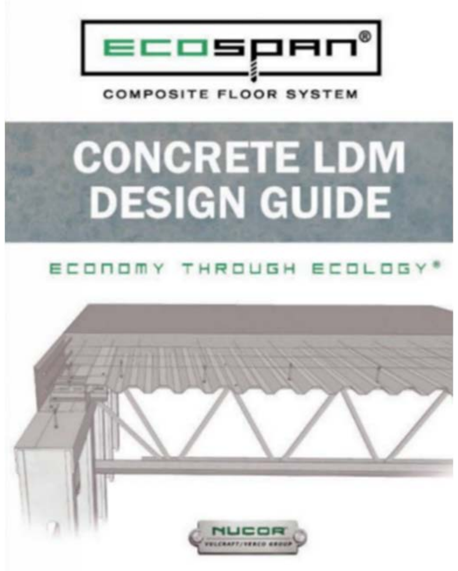
Composite Joists:

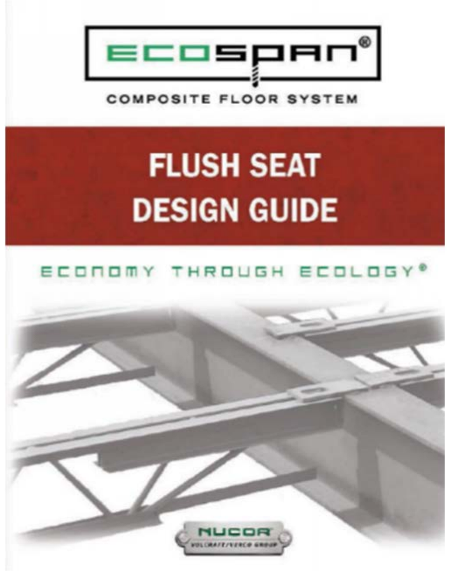
- Composite Joist & Ecospan catalogs available online
  - contains load tables, checklist, SJI specification for joists.
  - https://vulcraft.com/Literature





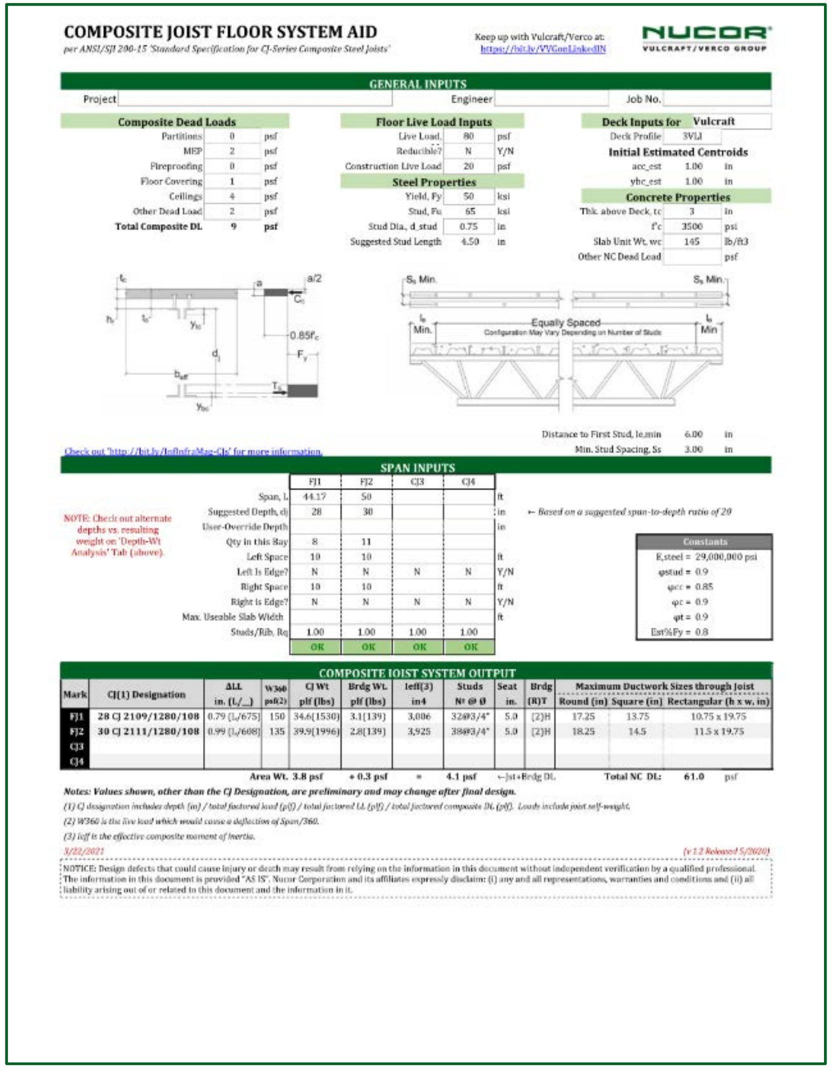


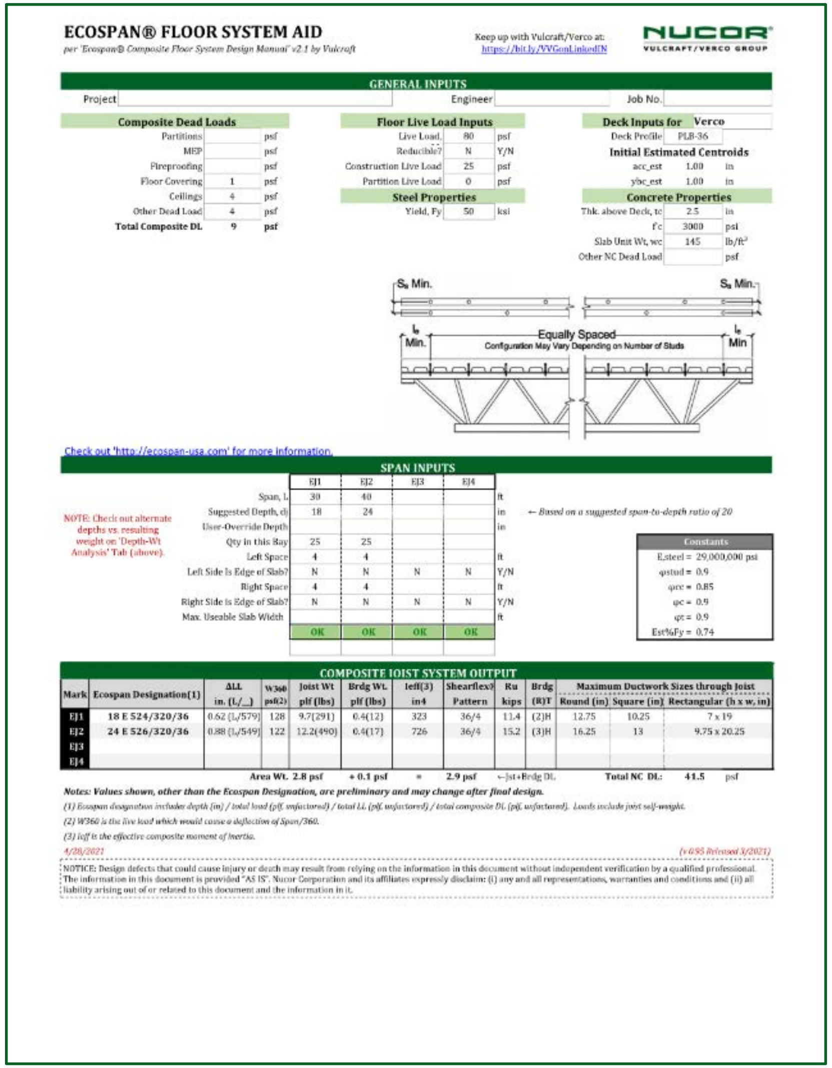




Composite Joist Online Tools:

- ❑CJ Series: Composite Joist Floor System Aid
- ❑Ecospan: Ecospan Floor System Estimating Aid





Additional Info on Plans:

- Deck spec:
  - Ecospan: Verco BFormlok deck
  - CJ: Verco B, W2, or W3 deck

- Concrete spec:
  - Slab Thickness above the deck
  - Concrete unit weight (pcf)
  - Concrete Compressive Strength f'_c
    - 3.0ksi-5ksi typical

Additional Info on Plans:

For both Ecospan & CJ series:

- Construction Live Load:
  - Call out the psf loading.
  - 20 psf to 75 psf.
  - Live Load depends on how slab finished.
    - Manual Tools vs. Motorized Equipment

- Needed for Pre-Composite check

Add'l Info: Deflection Criteria:

- ❑Live Load Deflection Criteria Only

- ❑SJI Specifications only require LL deflection

- ❑IBC Table 1604.3:
  - Per footnote d & g: D+L check is for creep
  - Steel Structural Members, D = 0 for creep
  - So only LL deflection needed for steel joists or joist girders

- ❑Specialty cases may have add'l deflection criteria

- ❑Camber can be used to offset most/all Dead Load Deflection

Composite Joist Camber:

CJ Series Camber:

- Engineer to specify % of load for camber:
  - Non-Composite Dead Load (typically 100%)
  - Composite Dead Load (typically 0%-50%)
  - Composite Live Load (typically 0%-25%)

Ecospan Camber:

- Standard SJI Camber common due to shorter spans

CJ-Series Designations:

- Joist Designation:

  24 CJ 2188/1168/420 **(LRFD Uniform Load per Foot Designation)**

  Factored Composite Dead Load (plf) (Superimposed, post composite)

  Factored Composite Live Load (plf)

  Total Factored Design Load (plf)

  CJ-Series Composite Joist

  Depth (Inches)

- CJ joists use factored loads for designation
- Online Design tool to help specify

CJ Series: Shear Studs:

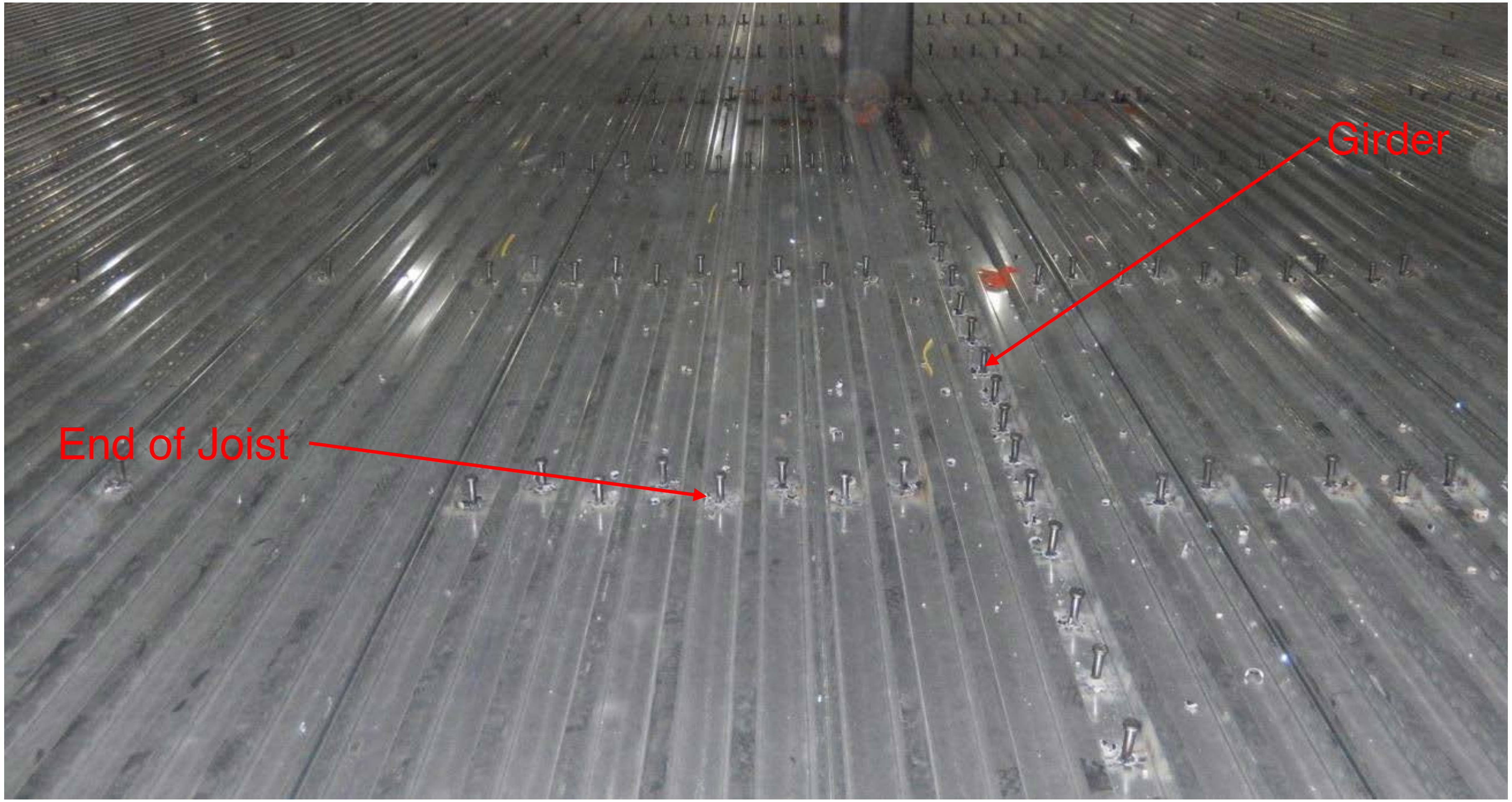
TABLE 103.5-1

MINIMUM TOP CHORD SIZES FOR INSTALLING WELDED SHEAR STUDS

Shear Stud Diameter in. (mm)	Minimum Horizontal Flat Leg Width in. (mm)	Minimum Leg Thickness in. (mm)
0.375 (10)	1.50 (38)	0.125 (3.2)
0.500 (13)	1.75 (44)	0.167 (4.2)
0.625 (16)	2.00 (51)	0.209 (5.3)
0.750 (19)	2.50 (64)	0.250 (6.3)

- Top chord angle size & thickness also dependent on stud diameter
  - SJI allows: Stud diameter / 3 for min. thickness
  - Less stringent than AISC, SJI controls for joist

CJ Series: Shear Studs



CJ Joists:

Ecospan Composite Joist System:

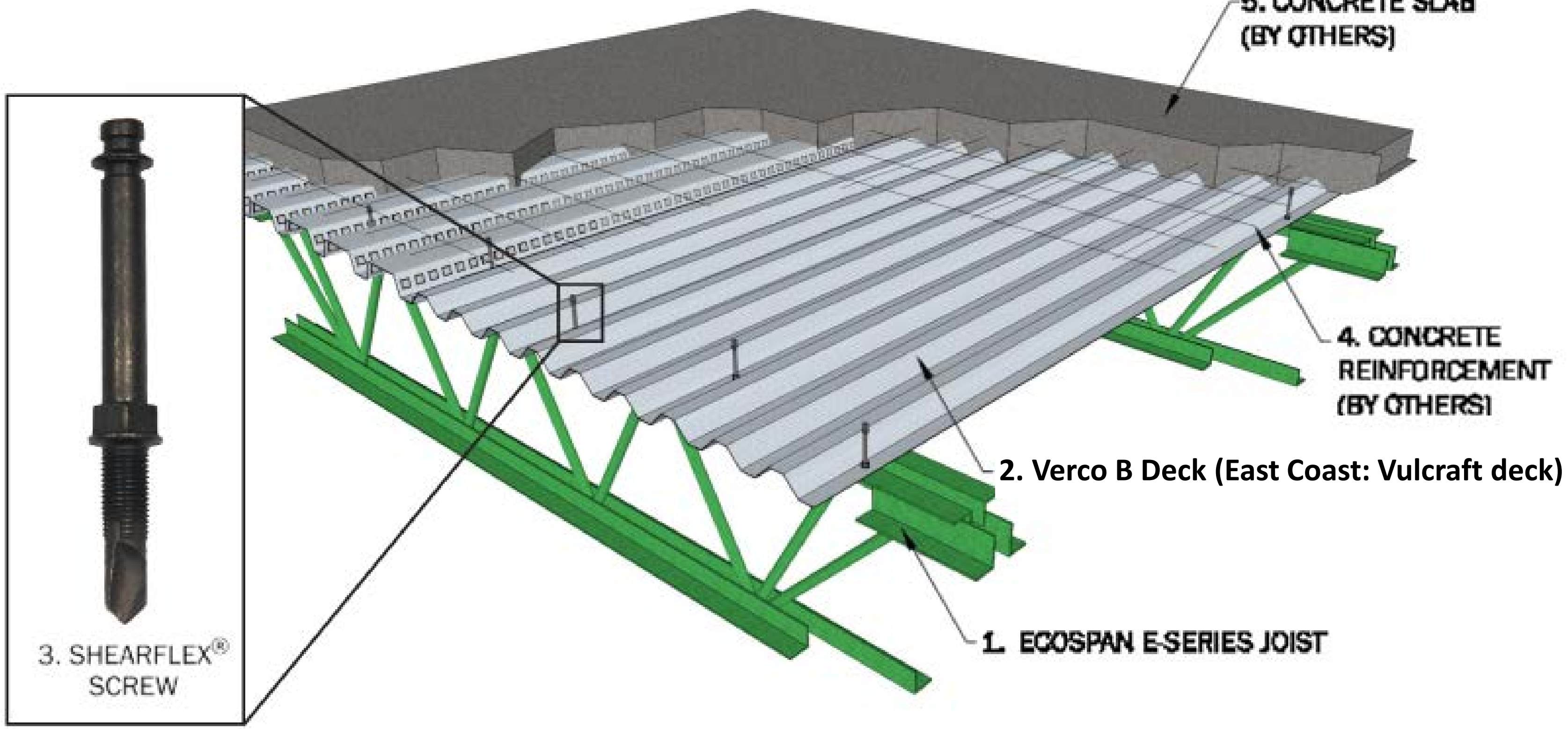


Figure 1-1: The Ecospan® Composite Floor System

Common Ecospan Projects:

MULTI-STORY RESIDENTIAL

APARTMENTS / CONDOS
SENIOR HOUSING
HOTELS / RESORTS
DORMITORIES / MILITARY HOUSING

OFFICE - COMMERCIAL

OFFICE BUILDINGS
SCHOOLS (Private or outside California)
MEZZANINES

Ecospan Composite Joists:

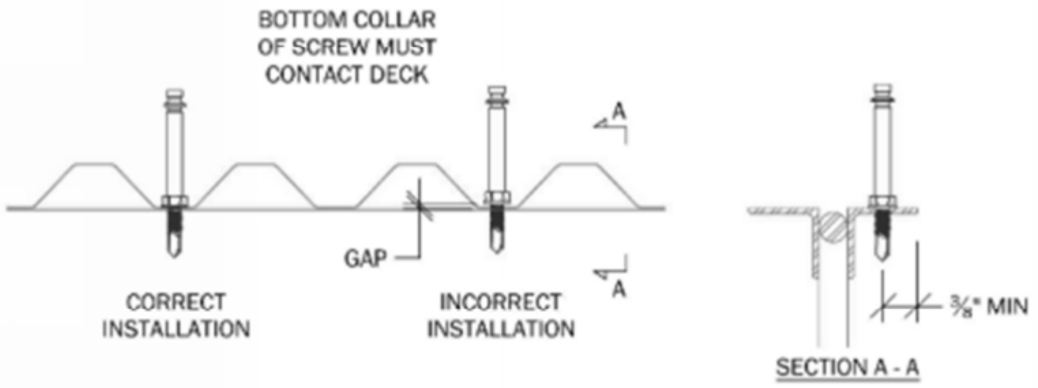
- ❑Joists from Exterior Wall to Corridor Wall
  - Partitions are non-bearing
  - W deck at corridor

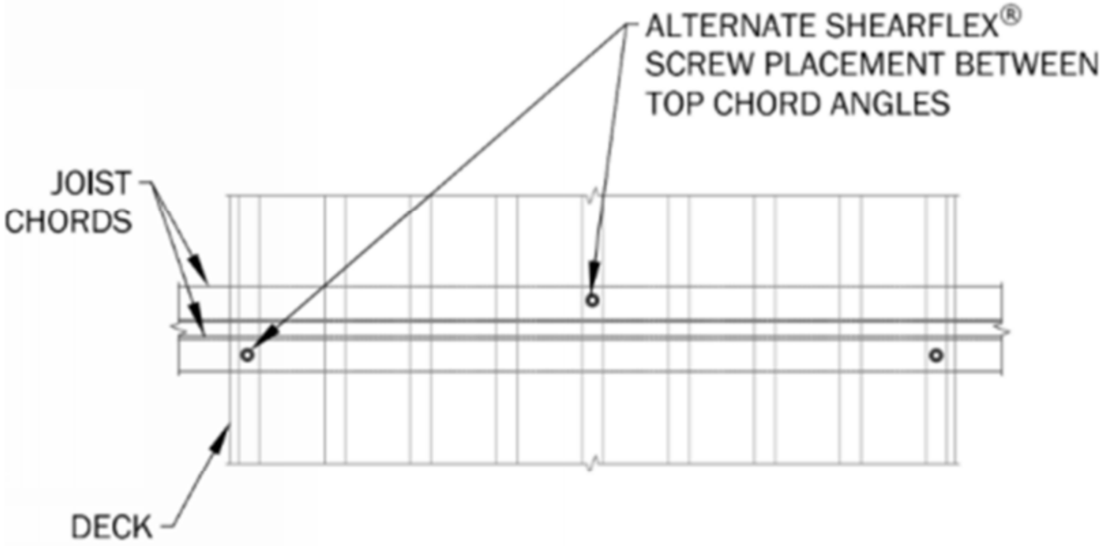
Ecospan Composite Joists:

Ecospan joists with shearflex screws

Corridor with just ‘W’ deck

Ecospan Composite Joist System:





Ecospan Composite Joist System:

E-Series Designations:

- Joist Designation:

  24 E 488/220/60 **(Uniform Load per Foot Designation, unfactored)**

  Composite Dead Load (plf) (Superimposed, post composite) — 60

  Composite Live Load (plf) — 220

  Total Design Load (plf) — 488

  Ecospan E-Series Composite Joist — E

  Depth (Inches) — 24

- Ecospan E joists use unfactored loads
- Number of Shearflex Screws by Vulcraft
- Online Design Tool to help specify

Ecospan Composite Joists:

$$\text{span to depth } (d) \leq \frac{L}{30} = \frac{\text{span (inches)}}{30}$$

E-Series Joist Maximum Span Chart (ft)						
Typical Loading	Residential Loading Total Load = 112 PSF Live Load = 55 PSF NC Dead Load = 42 PSF Composite Dead Load = 15 PSF			Commercial Loading Total Load = 158 PSF Live Load = 100 PSF NC Dead Load = 43 PSF Composite Dead Load = 15 PSF		
Depth (in)	On Center Joist Spacing					
	4'-0"	4'-6"	5'-0"	4'-0"	5'-0"	6'-0"
Typical Loading (plf)	448/220/60	505/248/68	560/275/75	632/400/60	790/500/75	948/600/90
10E	25'	25'	25'	25'	21'	17'
12E	30'	30'	30'	30'	25'	21'
14E	35'	35'	35'	35'	29'	24'
16E	40'	40'	39'	37'	33'	27'
18E	45'	44'	42'	39'	35'	31'
20E	50'	47'	44'	41'	37'	32'
22E	52'	49'	46'	43'	38'	33'
24E	54'	51'	48'	45'	40'	36'
26E	57'	53'	50'	47'	41'	38'
28E	59'	55'	52'	49'	43'	39'
30E	60'	57'	54'	50'	45'	41'

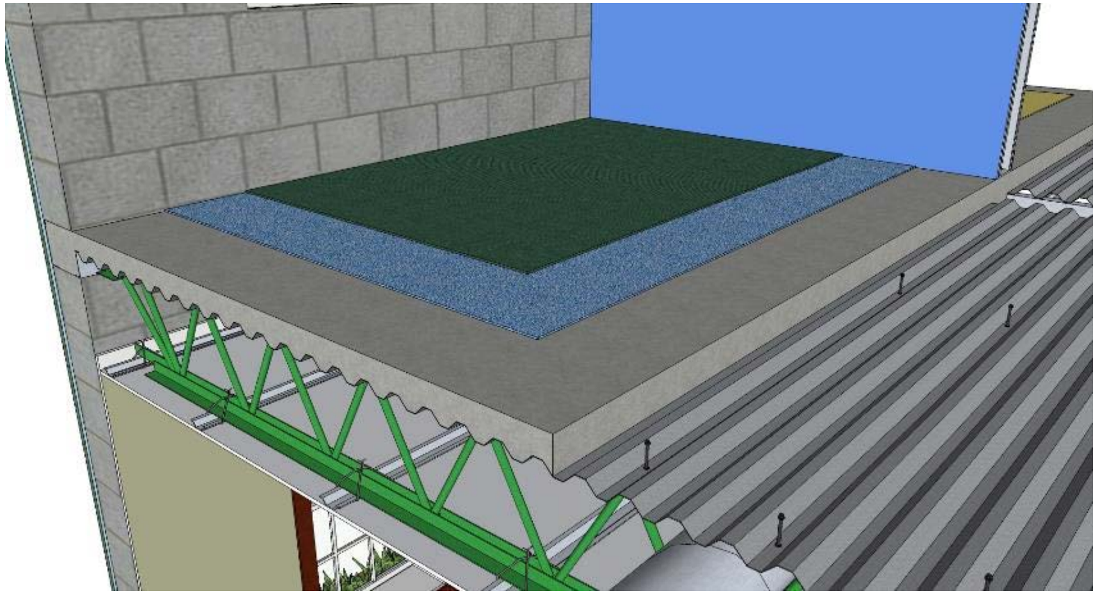
Table 2-2

Notes:

1. Assumed 36/4 attachment pattern
2. Assumed 1.0C24 (3.5" total) for Residential
3. Assumed 1.5VL22 (4.0" total) for Commercial
4. Joists ranging from 10"-14" deep are assumed rod web joists, while joists 16"-30" may be crimped or uncrimped angle web joists

Ecospan Sound Ratings:

- Sound Attenuation
  - Sound Transmission Classification (STC)
  - Impact Insulation Classification (IIC)
  - Meets or Exceed IBC req'ts with common materials



Full Scale Tests		
Flooring Materials/Thickness	IIC	STC
Bare Concrete	26, 30*	57
Carpet 1. 6PCF Pad (0.4") 2. 100% Pet Polyester Carpet (0.438")	77	57
Ceramic Tile 1. Loose-laid Cork (0.235") 2. Thinset Mortar 3. Glazed Ceramic Tile (0.3")	51, 54*	Not Tested
Wood Laminate 1. Underlayment (0.07") 2. Wood Laminate Floor (0.38")	54	Not Tested

*Resilient sound isolation clips (RSIC-1) used in place of wire ties.

Table 4-2

Ecospan UL Ratings:

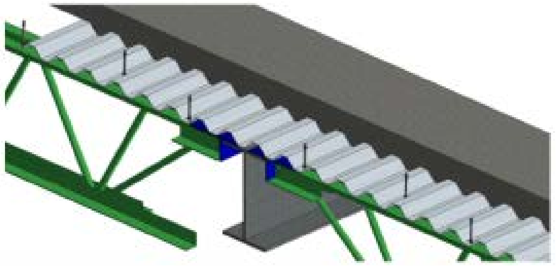
- Common UL listings

UL Fire Ratings	
UL Code	Application
***Design No. G561**	Direct Applied and/or Suspended Gypsum Board Ceiling
Design No. G213	Suspended Acoustical Ceiling
Design No. G227	Suspended Acoustical Ceiling
***Design No. G229**	Suspended Acoustical Ceiling
Design No. G236	Suspended Acoustical Ceiling
Design No. G243	Suspended Acoustical Ceiling
Design No. G222	Suspended Gypsum Board Ceiling
Design No. G547	Suspended Gypsum Board Ceiling
***Design No. G710**	Spray-on Fire Proofing
Design No. N789	Spray-on Fire Proofing
***Design No. D902**	Unprotected Comp. Deck in Corridor Areas
***Design No. D916**	Unprotected Comp. Deck in Corridor Areas
Design No. D918	Unprotected Comp. Deck in Corridor Areas
Design No. D919	Unprotected Comp. Deck in Corridor Areas

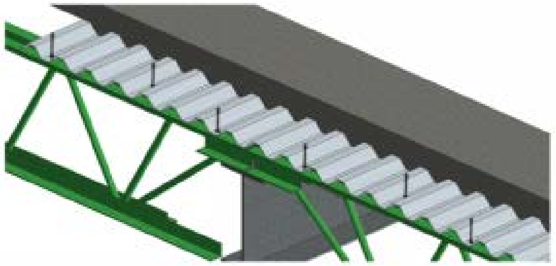
*Most commonly utilized UL Ratings

Table 4-1

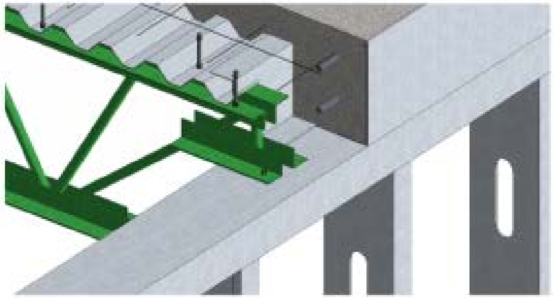
Ecospan Composite Joists:



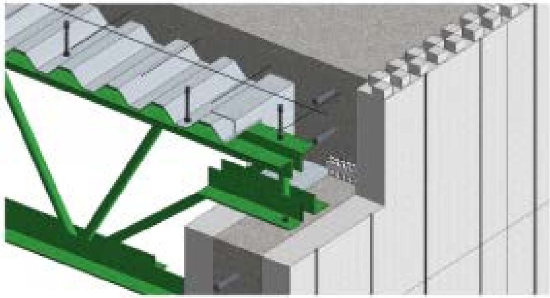
Flush Seat on Steel



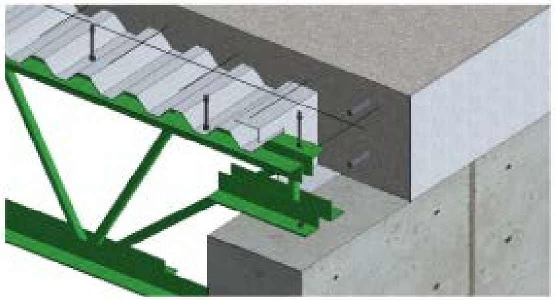
Standard Seat on Steel



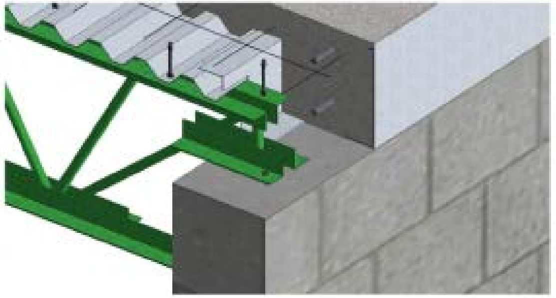
Cold Formed Steel



Insulated Concrete Forms



Concrete



Masonry

Ecospan Joist Seats:

E-Series Joist Bearing Seat Configurations:

2 ½” tall

Figure 3-2: Standard Bearing Seat

Figure 3-3: Extended Bearing Seat

2 ½” tall

4” tall

Figure 3-4: Gapped Bearing Seat

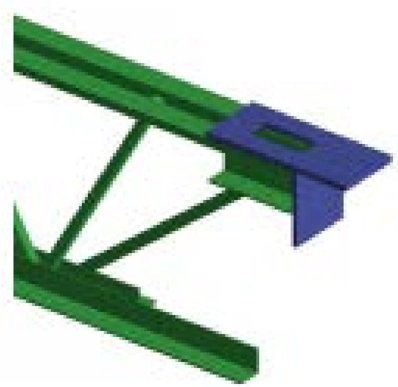
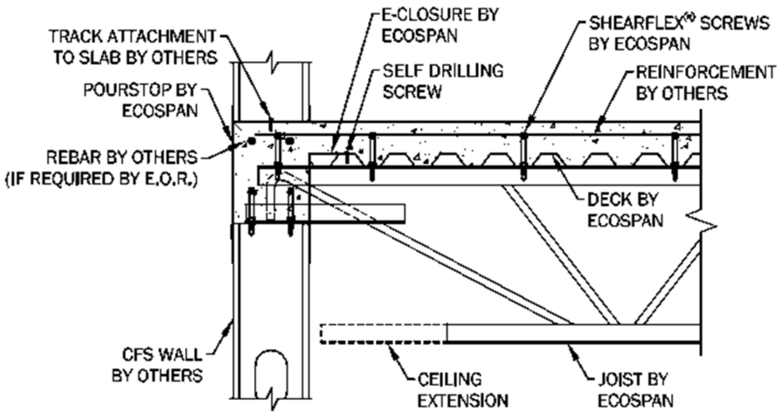


Figure 3-5: Flush Bearing Seat

10kip max end reaction

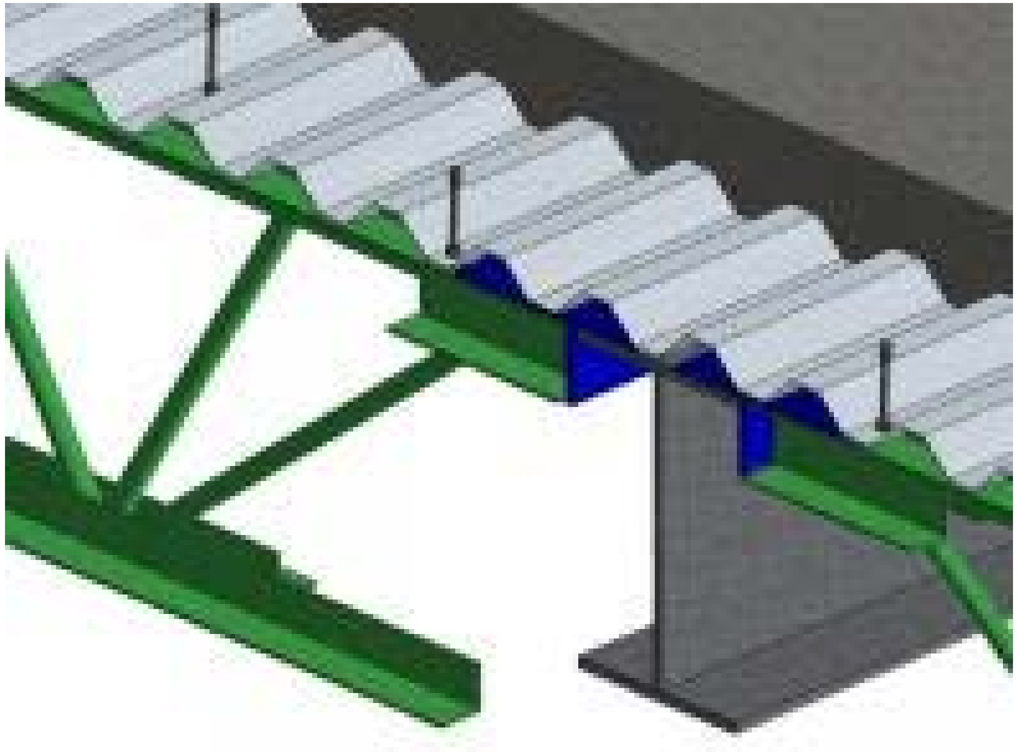
Ecospan Joist Seats:



3.2 DEEP JOIST SEAT ON CFS

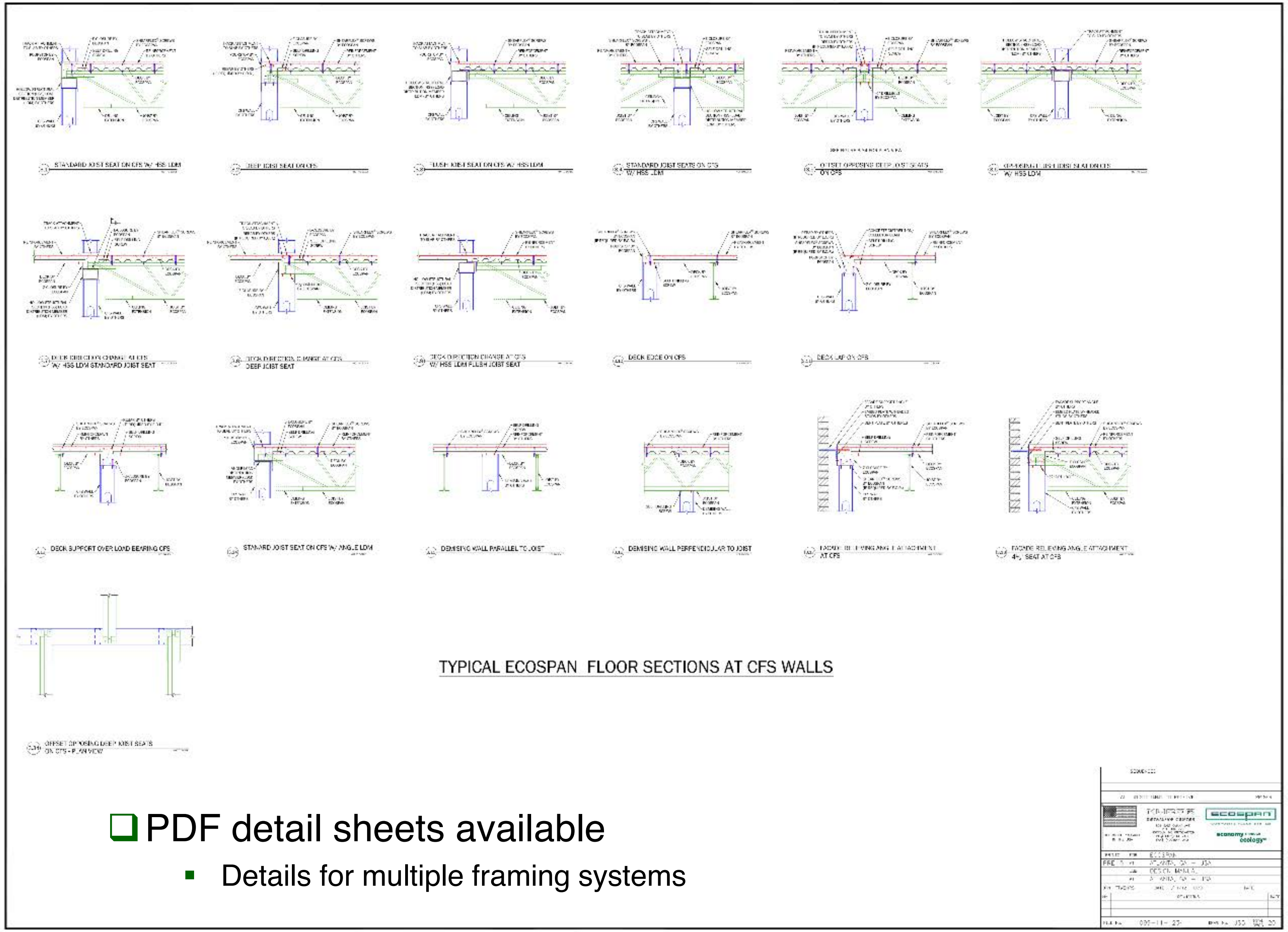
NOT TO SCALE

Ecospan Joist Seats:



❑Ecospan Flush Joist Seat

Ecospan System Details:



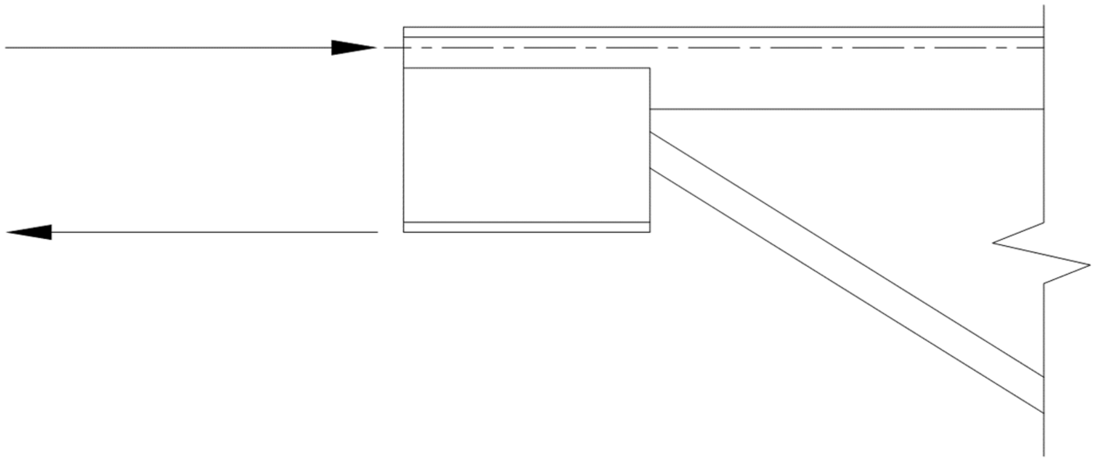
- ❑ PDF detail sheets available
  - Details for multiple framing systems

Joist End Connection:

- At Concrete / Masonry wall
  - Standard seat probably best
  - Can connect to ledger or pocket
  - Standard seat can take axial load
- Standard seat at Joist Girder

Axial Load Thru Seat:

- Joists:
  - 2 ½” deep seat: 26k ASD (E = 36.4k)
  - 5” deep seat: 20k ASD (E = 28.0k)
- As the joist seat gets deeper, capacity decreases.



Axial Loads:

- More common on Non-composite projects
- State axial loads in code terms
  - E, E_m, W, 0.7E, $0.7E_m$, or 0.6W
  - Do not simply say "axial load"
- Specify E_m & $0.7E_m$ loads
  - do not specify E or 0.7E load and say to multiply by Ω_o
- Max Axial Capacities:

Joist Type	Bearing Depth	Top Chord Seismic Axial Loads (ASD)*
K	2.5" & 3"	55 kips
LH	3"	100 kips
LH	5"	450 kips **

*Max axial capacity will vary slightly depending on the vertical loads on the joist

**The connection between the joists may control when there are large axial loads.

Joist End Connection:

- Wide Flange Girders: LH & CJ Series
  - Bolted Flushed Framed End connection is great option

Bolted Flushed Framed End Connection:

- Benefits:
  - Deeper Girder
  - Composite Girders
  - Installation similar to Steel Beams
  - Blocking not required between joists
  - Significant improvement in Vibrational performance

- Draw Back:
  - No axial load thru bolted plate
  - Not enough weld from plate to top chord for eccentricity

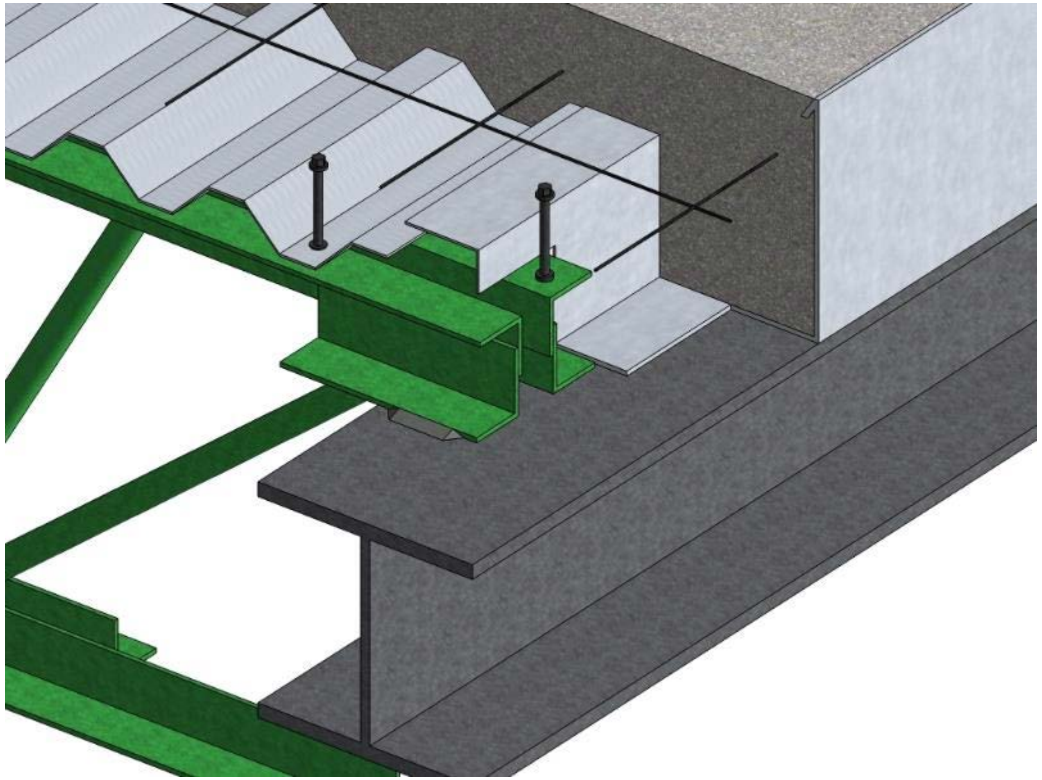
Bolted Flushed Framed End Connection:

- Bolts:
  - High Strength Bolts (A325 or A490)
  - 1” Diameter min recommended
  - Fully Tensioned Bearing Connection
  - Spacing & Edge distances by project Engineer

- Slip Critical Bolts issues:
  - Add’l cost for req’d surface prep of plate
  - Add’l cost to protect plate when priming joist

Joist End Connection

- Wide Flange Girders: Ecospan
  - Standard Joist Seat with E-Closure
  - Flushed Joist Seat



Software Solutions

❑Vulcraft Design Tools

- CJ Series: Composite Joist Floor System Aid
- Ecospan: Ecospan Floor System Estimating Aid

❑RAM Steel

- Expanded Non-composite joist tables
- Includes camber in deflection calculations
- Currently does not have composite joists

❑RISA

- Composite joists in program
- Expanded load tables & deflection with camber in upcoming version 16 release

Software Solutions

Vibration:

- Neither RAM or RISA have Bolted Flush Framed Connections in their Vibration analysis
  - Standard joists seat will yield higher accelerations than Bolted Flushed Frame End Connections.
  - The difference between Standard seat & Bolted Flush Framed End Connection can be the difference of the floor satisfying the criteria or not.
- Vulcraft Vibration Analysis - Walking
  - Includes Bolted Flushed Frame End Connections.
  - Includes Ecospan Flush Joist Seat.
  - Free Online Design tool

Vibration Analysis – Walking Tool

Vibration Walking | Calculation & Output | Design Aid Info | Design Aid Diagrams | Technical Revision

Keep up with Vulcraft by following us at https://www.linkedin.com/company/vulcraft--division-of-nucor-steel/

Vibration Analysis Tool - Walking

SJI Technical Digest 5: Vibration of Steel Joist - Concrete Slab Floors 2015

AISC Steel Design Guide 11: Vibrations of Steel-Framed Structural Systems Dues to Human Activity 2nd Edition 2016

Note to User:

1) Joists and Girders are both treated as simple span (not continuous) in this tool.
2) If you have a more complex floor system, like continuous joists or girders, or if you need to analyze a floor for vibration from something other tha
it is recommended to use Floorvibe for the analysis. https://www.floorvibe.com/wp/
3) Prompts for input information in this Tool are dynamic and will change based on the selections made. Some of the drop down menus are dynamic
The latest options will appear in the drop down when it is selected. It may take a second or two for the latest options to appear.
4) Pop-up Comments have been provided to help aid the user on what information needs to be provided or appropriate values.

Project Information:

Project : Vibration Analysis — Job No. 20-
Engineer :

Floor Information:

Bay Info: Line
Vibration Occupancy: Office - Electronic — Tolerance Acceleration Limit: $a_0/g =$ 0.50% to 0.55

Modal Damping Work-up Aid
The Final Modal Damping Ratio is the sum of the Damping from Components
Structural System β_1 = 0.010
Ceiling & Duct Work: Yes
Ceiling β_2 = 0.005
Duct β_3 = 0.005
Electronic Office: Fit-Out β_4 = 0.005
Full Height Drywall Partitions in Bay: No

Modal Damping R
1) Damping Ratio β
Acceleration. Small
much larger impact
loads on the membe
the members.
2) See Design Aid Ir
for Damping Ratio.

❑ https://vulcraft.com/DesignTools

Vibration Analysis – Walking Tool

Floor Information:

Bay Info: Line

Vibration Occupancy: Office - Electronic

Tolerance Acceleration Limit: $a_0 / g =$ 0.50% to 0.55%

Modal Damping Work-up Aid

The Final Modal Damping Ratio is the sum of the Damping from Components

Structural System $\beta_1 = 0.010$

Ceiling & Duct Work: Yes

Ceiling $\beta_2 =$ 0.005

Duct $\beta_3 =$ 0.005

Electronic Office: Fit-Out $\beta_4 =$ 0.005

Full Height Drywall Partitions in Bay: No

Additional Damping $\beta_7 =$ 0.000

Work-up Total Modal Damping Ratio $\beta = \Sigma\beta_i = 0.025$

USE: Modal Damping Ratio $\beta =$ 0.025

Modal Damping Ratio Design Note:

1) Damping Ratio β has a major impact on the Final Bay Acceleration. Small changes to the Damping Ratio will have much larger impact to final acceleration than changing the loads on the members or changing the moments of inertia of the members.

2) See Design Aid Info tab for additional reference information for Damping Ratio.

Constant Force $P_o = 65$ lb

Bay Dimensions:

Floor Width = 150.00 ft

Floor Length = 105.00 ft

Superimposed Loading for Vibration Analysis:

Dead Load = 4.0 psf

Live Load = 8.0 psf

Collateral Load = 0.0 psf

Deck & Concrete:

Total Slab Depth (including deck) d = 5.00 in

Deck Height = 1.50 in

Deck Self-weight = 2.3 psf

Conc. Strength f'c = 3.00 ksi

Conc. Unit Weight = 145 pcf

Conc. Slab Weight = 48.7 psf

Vibration Analysis – Walking Tool

VULCRAFT

VIBRATION ANA

Vibration Walking | Calculation Output | Design Aid Info | Design Aid Diagrams | Technical Revision

Vibration Analysis Tool - Walking

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Print Recommendations

Reference Information:

The tables below are provided as reference for the user, in order to aid in the design process:

Recommended Live Loads & Tolerance Acceleration Limits for Walking Vibration Analysis:

Table 2 (from SJI TD5 Table 1.2 & 3.1 - for walking)

Vibration Occupancy	Recommended Live Load for Vibration Analysis	Tolerance Acceleration Limit ao/g x 100%
Office - Paper	11.0 psf	0.5 to 0.55
Office - Electronic	6.0 psf to 8 psf	0.5 to 0.55
Assembly Area	0.0 psf	0.5 to 0.55
School	0.0 psf	0.5 to 0.55
Church	0.0 psf	0.5 to 0.55
Shopping Mall	0.0 psf	1.5
Residence	6.0 psf	0.5 to 0.55

Ecospan E-Series Joist Maximum Moment of Inertia:

Table 4

Joist Depth (in)	Max I_{chords} (in^4)
10	55
12	85
14	115
16	260
18	335
20	575
22	695
24	835
26	985
28	1145
30	1320

Note: Due to installation considerations for the Shearflex screws, which are part of the Ecospan system, Ecospan E series joists have a maximum top chord angle thickness of 5/16". The above maximum moments of inertia for E-series joists reflect this limitation.

CJ-series Composite Joist Moment of Inertia:

CJ-series joists use headed weld studs for

Office Fit-Outs & Recommended Damping Ratios:

Recommendations from:
"Office Fit-Out and Floor Vibrations" by Christopher M. Hewitt and Thomas M. Murray, P.E., Ph.D. ; April 2004 Modern Steel Construction

https://www.floorvibe.com/wp/articles/

Table 3.1

Traditional Office. Full-Height Partitions running parallel to joist span	
WITH suspended ceiling and ductwork attached below the slab: Estimated Dead Load: 4 psf Estimated Live Load: 11 psf Estimated partition Load: 4 psf	Estimated Damping Ratio β = 0.050
WITHOUT suspended ceiling or ductwork attached below the slab: Estimated Dead Load: 4 psf Estimated Live Load: 11 psf Estimated partition Load: 4 psf	Estimated Damping Ratio β = 0.050

Table 3.2

Electronic Office. Nearly no paperwork. Limited number of file cabinets. No full height partitions	
WITH suspended ceiling and ductwork attached below the slab: Estimated Dead Load: 4 psf Estimated Live Load: 8 psf	Estimated Damping Ratio β = 0.020 to 0.025
WITHOUT suspended ceiling or ductwork attached below the slab: Estimated Dead Load: 1-2 psf Estimated Live Load: 8 psf	Estimated Damping Ratio β = 0.020

Table 3.3

Open Office. Cubicles and no full height partitions.	
WITH suspended ceiling and ductwork attached below the slab: Estimated Dead Load: 4 psf Estimated Live Load: 8 psf	Estimated Damping Ratio β = 0.025 to 0.030
WITHOUT suspended ceiling or ductwork attached below the slab: Estimated Dead Load: 2 psf Estimated Live Load: 8 psf	Estimated Damping Ratio β = 0.020 to 0.025

Table 3.4

Office Library. Full-height bookcases in heavily loaded room.	
WITH suspended ceiling and	Estimated Damping Ratio

- Tolerance Acceleration Limits Table

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Vibration Analysis – Walking Tool

Floor Information:

Bay Info: Line

Vibration Occupancy: Office - Electronic

Tolerance Acceleration Limit: $a_0/g =$ 0.50% to 0.55%

Modal Damping Work-up Aid

The Final Modal Damping Ratio is the sum of the Damping from Components

Structural System β_1 = 0.010

Ceiling & Duct Work: Yes

Ceiling β_2 = 0.005

Duct β_3 = 0.005

Electronic Office: Fit-Out β_4 = 0.005

Full Height Drywall Partitions in Bay: Yes

Partitions in Bay β_5 = 0.020

Additional Damping β_7 = 0.000

Work-up Total Modal Damping Ratio $\beta = \Sigma\beta_i$ = 0.045

USE: Modal Damping Ratio β = 0.045

Modal Damping Ratio Design Note:

1) Damping Ratio β has a major impact on the Final Bay Acceleration. Small changes to the Damping Ratio will have much larger impact to final acceleration than changing the loads on the members or changing the moments of inertia of the members.

2) See Design Aid Info tab for additional reference information for Damping Ratio.

Constant Force P_o = 65 lb

Bay Dimensions:

Floor Width = 150.00 ft

Floor Length = 105.00 ft

Superimposed Loading for Vibration Analysis:

Dead Load = 4.0 psf

Live Load = 8.0 psf

Collateral Load = 4.0 psf

Deck & Concrete:

Total Slab Depth (including deck) d = 5.00 in

Deck Height = 1.50 in

Deck Self-weight = 2.3 psf

Conc. Strength f'c = 3.00 ksi

Conc. Unit Weight = 145 pcf

Conc. Slab Weight = 48.7 psf

- Actual loads on floor (daily basis):
  - Not code level loads

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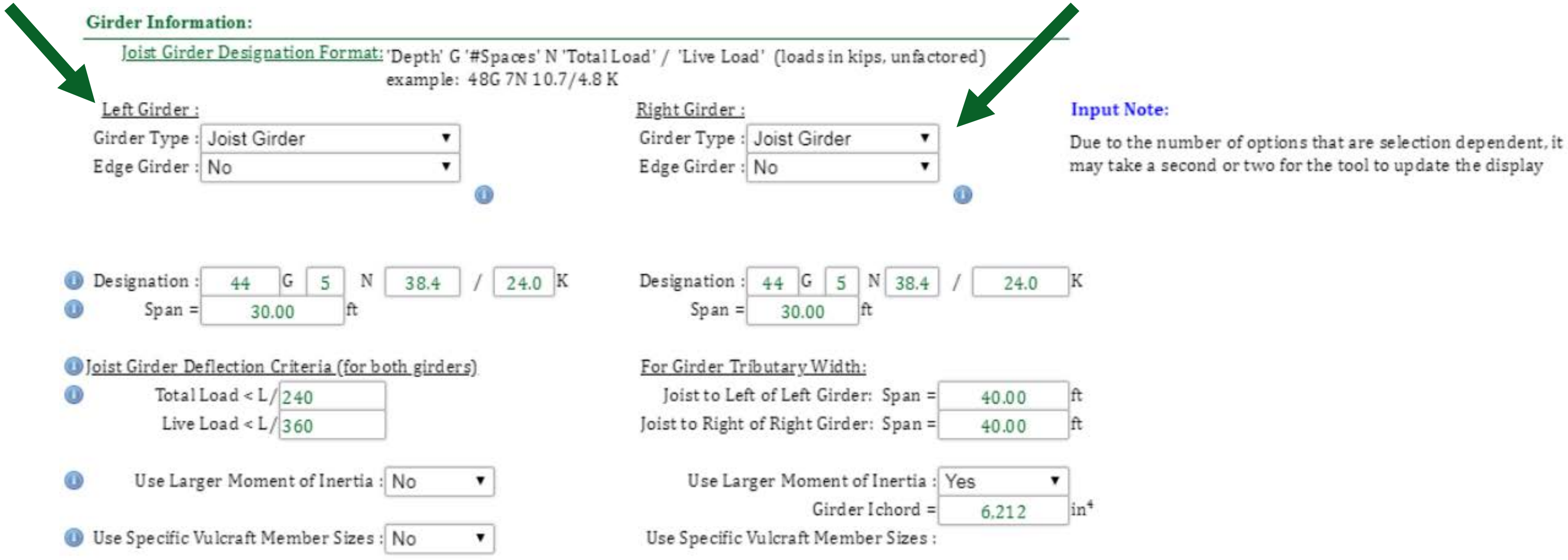
Vibration Analysis – Walking Tool

Bay Dimensions:

- Floor Width:
  - Distance Perpendicular to Joist span
  - Framing is identical or nearly identical
  - Size, spacing, length, etc

- Floor Length:
  - Distance Perpendicular to Girder span
  - Framing is identical or nearly identical
  - Size, spacing, length, etc

Vibration Analysis – Walking Tool



Girder Information:

Joist Girder Designation Format: 'Depth' G '#Spaces' N 'Total Load' / 'Live Load' (loads in kips, unfactored)
example: 48G 7N 10.7/4.8 K

Left Girder :
Girder Type : Joist Girder
Edge Girder : No

Designation : 44 G 5 N 38.4 / 24.0 K
Span = 30.00 ft

Joist Girder Deflection Criteria (for both girders)
Total Load < L/ 240
Live Load < L/ 360

Use Larger Moment of Inertia : No

Use Specific Vulcraft Member Sizes : No

Right Girder :
Girder Type : Joist Girder
Edge Girder : No

Designation : 44 G 5 N 38.4 / 24.0 K
Span = 30.00 ft

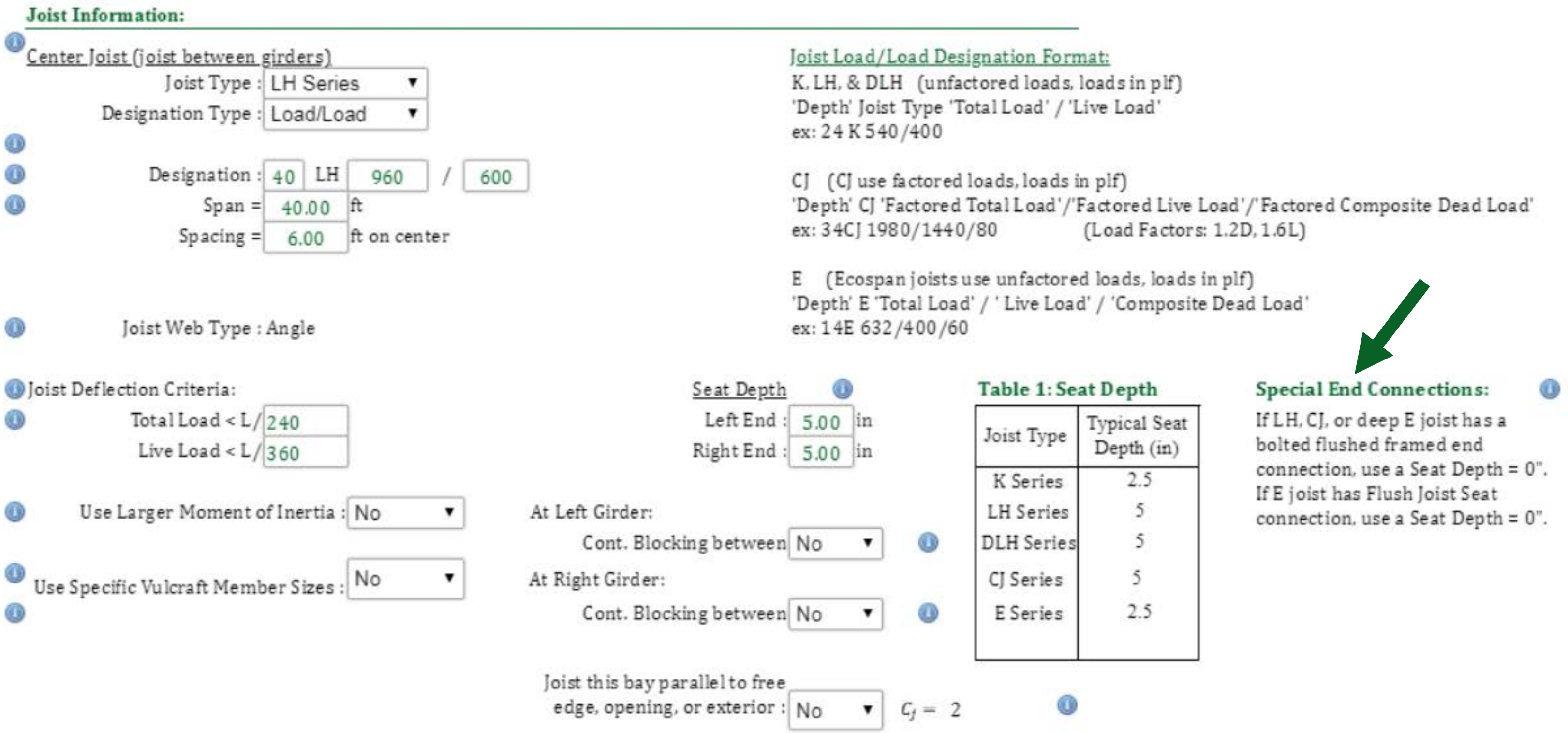
For Girder Tributary Width:
Joist to Left of Left Girder: Span = 40.00 ft
Joist to Right of Right Girder: Span = 40.00 ft

Use Larger Moment of Inertia : Yes
Girder Ichord = 6.212 in^4
Use Specific Vulcraft Member Sizes :

Input Note:
Due to the number of options that are selection dependent, it may take a second or two for the tool to update the display

- ❑ Left & Right Girders can be different

Vibration Analysis – Walking Tool



- ❑ Handles Special End Connections:
  - Bolted Flushed Framed End connection
  - Ecospan Flush Seat connection

Vibration Analysis – Walking Tool

Results: Calculate Default Values

	Joists:	
I_{chords} (in^4) :	1,634	
Dynamic Eff. I_j (in^4) :	2,356	
Natural Frequency f_j (Hz) :	6.108	
Self-Weight (plf) :	20	
	Left Girder	**Right Girder**
I_{chords} or I_x (in^4) :	6,212	7,800
Dynamic Eff. I_g (in^4) :	4,896	12,294
Natural Frequency f_g (Hz) :	5.987	9.371
Bay Frequency f_n (Hz) :	4.275	5.117
Self-Weight (plf) :	67	135

Calculations based on v1.0, Released 3/2019

Left Girder & Joist: Controls

$a_p/g = 0.538\% > 0.5\%$

$< 0.55\%$ - Engineering Judgement Required if this is Acceptable

Right Girder & Joist:

$a_p/g = 0.471\% < 0.5\%$ - OK

Floor Bay - Engineering Judgement required to determine if Acceptable

- Acceleration Tolerance Limits:
  - AISC DG 11 has lower limit
  - SJI TD5 has slightly higher limit for floor with Joist
  - Engineer to decide if acceptable when between 2 limits

Vibration Analysis – Walking Tool

Recommendations:

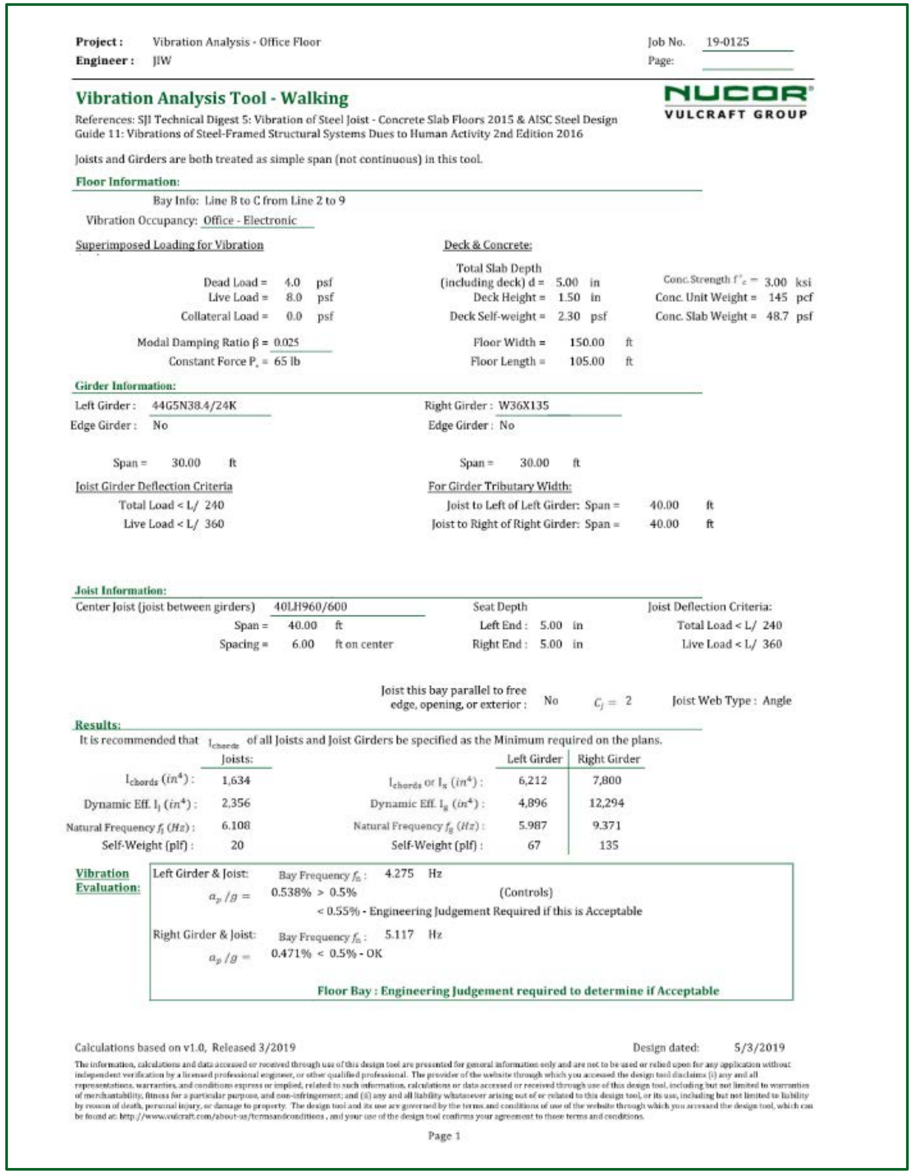
Vibration Analysis is an Iterative process. It may take a few revisions to an initial design to find a floor system that meets the acceleration tolerance criteria. This is typical for all floor systems.

The following are recommendations for modifications that can be made to an initial design when the analysis comes back with the acceleration being higher than the Acceleration Tolerance Limit. See "Design Aid Info" tab and "Design Aid Diagrams" tab for additional information and discussions into the items below.

1) Increase the Damping Ratio, if appropriate. Small changes to the Damping Ratio have a major impact on lowering acceleration.
2) Hotels, Multi-family, Dorms, Assisted Living, & Similar, if there are partitions in the bay, including partition in Damping Ratio can have a major impact.
3) Increase the Concrete Strength. This will increase the composite moment of inertia, increase the natural frequency and lower the acceleration.
4) Increase Dead Load, Live Load, or Collateral Load to be used for vibration analysis, if appropriate. Increases resisting weight & lowers acceleration.
5) Use Bolted Flushed Framed End Connection on LH, DLH, CJ, & deep E series joists. Set seat depth to 0". Increases WF or Joist Girder eff. moment of inertia.
6) Use Ecospan Flush Joist Seat on E Series joist, if end reaction is less than 10kips. Increases Girder effective moment of inertia.
7) For standard joist seats, consider providing Continuous Blocking between joists. Increases Girder effective moment of inertia.
8) For Ecospan E joist with seat, consider using Cont. Blocking or E-Closures between joists. Increases Girder effective moment of inertia.

- Order of Recommendations is intentional:
  - Earlier recommendations will have biggest impact for least cost
  - Listed in descending order of bang for the buck
- More detailed description on Design Aid Info tab

Vibration Analysis – Walking Tool



Project : Vibration Analysis - Office Floor
Engineer : JIW

Job No. 19-0125
Page:

Vibration Analysis Tool - Walking

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References: SJI Technical Digest 5: Vibration of Steel Joist - Concrete Slab Floors 2015 & AISC Steel Design Guide 11: Vibrations of Steel-Framed Structural Systems Dues to Human Activity 2nd Edition 2016

Joists and Girders are both treated as simple span (not continuous) in this tool.

Floor Information:

Bay Info: Line B to C from Line 2 to 9
Vibration Occupancy: Office - Electronic

Superimposed Loading for Vibration

Dead Load = 4.0 psf
Live Load = 8.0 psf
Collateral Load = 0.0 psf

Modal Damping Ratio β = 0.025
Constant Force P_o = 65 lb

Deck & Concrete:

Total Slab Depth (including deck) d = 5.00 in
Deck Height = 1.50 in
Deck Self-weight = 2.30 psf

Conc. Strength f'_c = 3.00 ksi
Conc. Unit Weight = 145 pcf
Conc. Slab Weight = 48.7 psf

Floor Width = 150.00 ft
Floor Length = 105.00 ft

Girder Information:

Left Girder : 44G5N38.4/24K
Edge Girder : No
Span = 30.00 ft

Right Girder : W36X135
Edge Girder : No
Span = 30.00 ft

Joist Girder Deflection Criteria
Total Load < L/ 240
Live Load < L/ 360

For Girder Tributary Width:
Joist to Left of Left Girder: Span = 40.00 ft
Joist to Right of Right Girder: Span = 40.00 ft

Joist Information:

Center Joist (joist between girders) 40LH960/600
Span = 40.00 ft
Spacing = 6.00 ft on center

Seat Depth
Left End : 5.00 in
Right End : 5.00 in

Joist Deflection Criteria:
Total Load < L/ 240
Live Load < L/ 360

Joist this bay parallel to free edge, opening, or exterior : No C_j = 2 Joist Web Type : Angle

Results:

It is recommended that I_{chords} of all Joists and Joist Girders be specified as the Minimum required on the plans.

	Joists:		Left Girder	Right Girder
I_{chords} (in^4) :	1,634	I_{chords} or I_x (in^4) :	6,212	7,800
Dynamic Eff. I_j (in^4) :	2,356	Dynamic Eff. I_g (in^4) :	4,896	12,294
Natural Frequency f_j (Hz) :	6.108	Natural Frequency f_g (Hz) :	5.987	9.371
Self-Weight (plf) :	20	Self-Weight (plf) :	67	135

Vibration Evaluation:

Left Girder & Joist: Bay Frequency f_n : 4.275 Hz
a_p/g = 0.538% > 0.5% (Controls)
< 0.55% - Engineering Judgement Required if this is Acceptable

Right Girder & Joist: Bay Frequency f_n : 5.117 Hz
a_p/g = 0.471% < 0.5% - OK

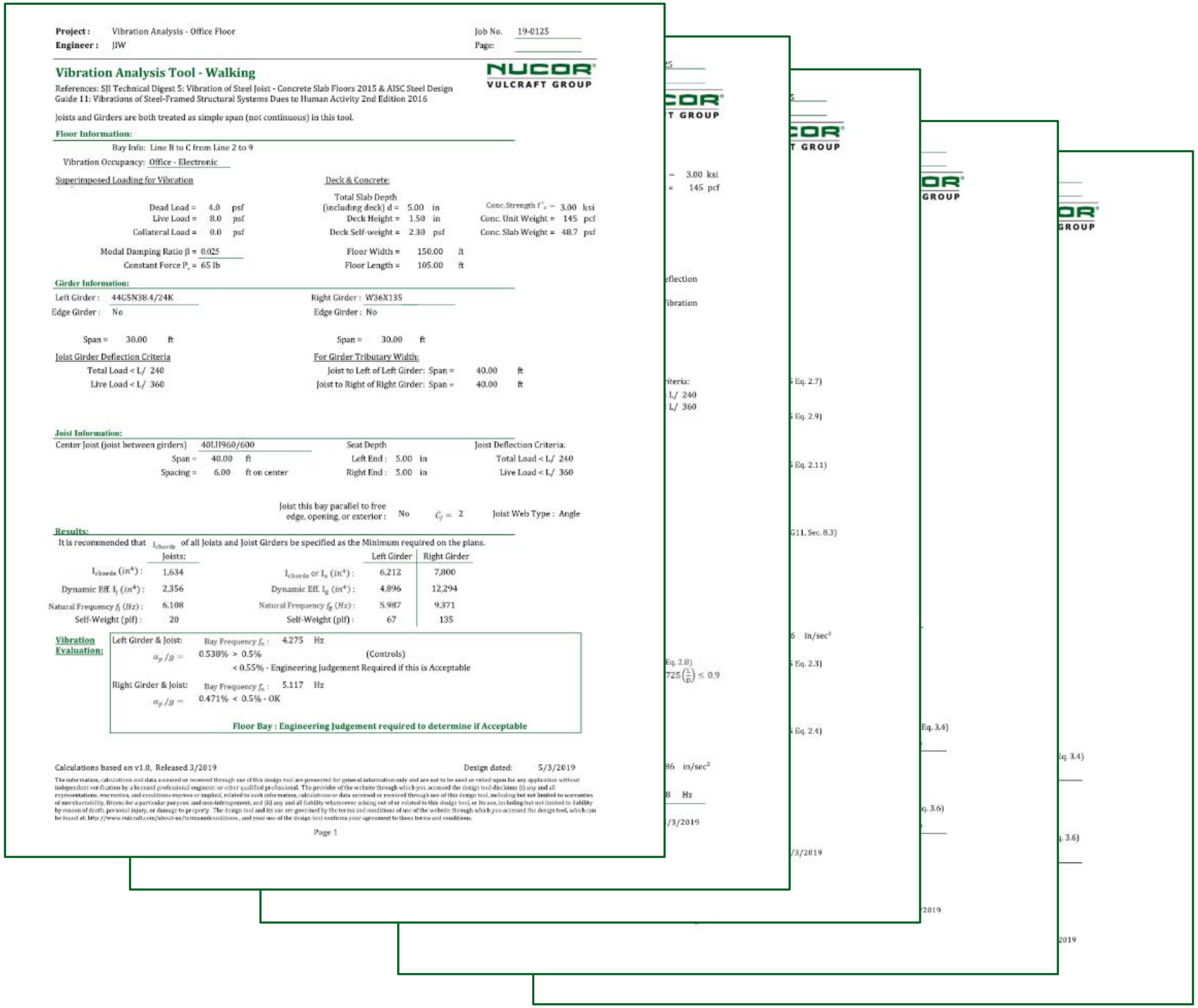
Floor Bay : Engineering Judgement required to determine if Acceptable

Calculations based on v1.0, Released 3/2019 Design dated: 5/3/2019

Page 1

- Summary Output:
  - 1 page document
  - has Inputs & Results
  - set-up to go in Engineer's Calculation package
  - also part of "Summary & Calc" output

Vibration Analysis – Walking Tool



Project : Vibration Analysis - Office Floor
Engineer : JJW

Job No. 19-0125
Page:

Vibration Analysis Tool - Walking

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Joists and Girders are both treated as simple span (not continuous) in this tool.

Floor Information:

Bay Info: Line B to C from Line 2 to 9

Vibration Occupancy: Office - Electronic

Superimposed Loading for Vibration

Dead Load = 4.0 psf
Live Load = 8.0 psf
Collateral Load = 0.0 psf

Modal Damping Ratio β = 0.025
Constant Force P_o = 65 lb

Deck & Concrete:

Total Slab Depth (including deck) d = 5.00 in
Deck Height = 1.50 in
Deck Self-weight = 2.30 psf

Conc. Strength f'_c = 3.00 ksi
Conc. Unit Weight = 145 pcf
Conc. Slab Weight = 48.7 psf

Floor Width = 150.00 ft
Floor Length = 105.00 ft

Girder Information:

Left Girder : 44G5N38.4/24K
Edge Girder : No
Span = 30.00 ft

Right Girder : W36X135
Edge Girder : No
Span = 30.00 ft

Joist Girder Deflection Criteria
Total Load < L/ 240
Live Load < L/ 360

For Girder Tributary Width:
Joist to Left of Left Girder: Span = 40.00 ft
Joist to Right of Right Girder: Span = 40.00 ft

Joist Information:

Center Joist (joist between girders) 40LH960/600
Span = 40.00 ft
Spacing = 6.00 ft on center

Seat Depth
Left End : 5.00 in
Right End : 5.00 in

Joist Deflection Criteria:
Total Load < L/ 240
Live Load < L/ 360

Joist this bay parallel to free edge, opening, or exterior : No C_j = 2 Joist Web Type : Angle

Results:

It is recommended that I_{chords} of all Joists and Joist Girders be specified as the Minimum required on the plans.

	Joists:		Left Girder	Right Girder
I_{chords} (in^4) :	1,634	I_{chords} or I_x (in^4) :	6,212	7,800
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Right Girder & Joist: Bay Frequency f_n : 5.117 Hz
a_p/g = 0.471% < 0.5% - OK

Floor Bay : Engineering Judgement required to determine if Acceptable

Calculations based on v1.0, Released 3/2019

Design dated: 5/3/2019

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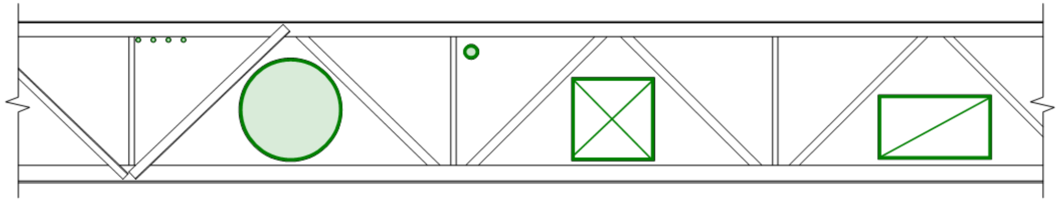
Page 1

- Summary & Calc Output:
  - 5 page document
  - has full calculations
  - set-up to go in Engineer's Calculation package

Mechanical, Electrical & Plumbing

- Ducts work best when located in middle 2/3 of span.



Mechanical, Electrical & Plumbing

- Page 36 of Joist Manual gives Approximate opening sizes
- Ducts with Insulation
  - Compare outside diameter with insulation to table

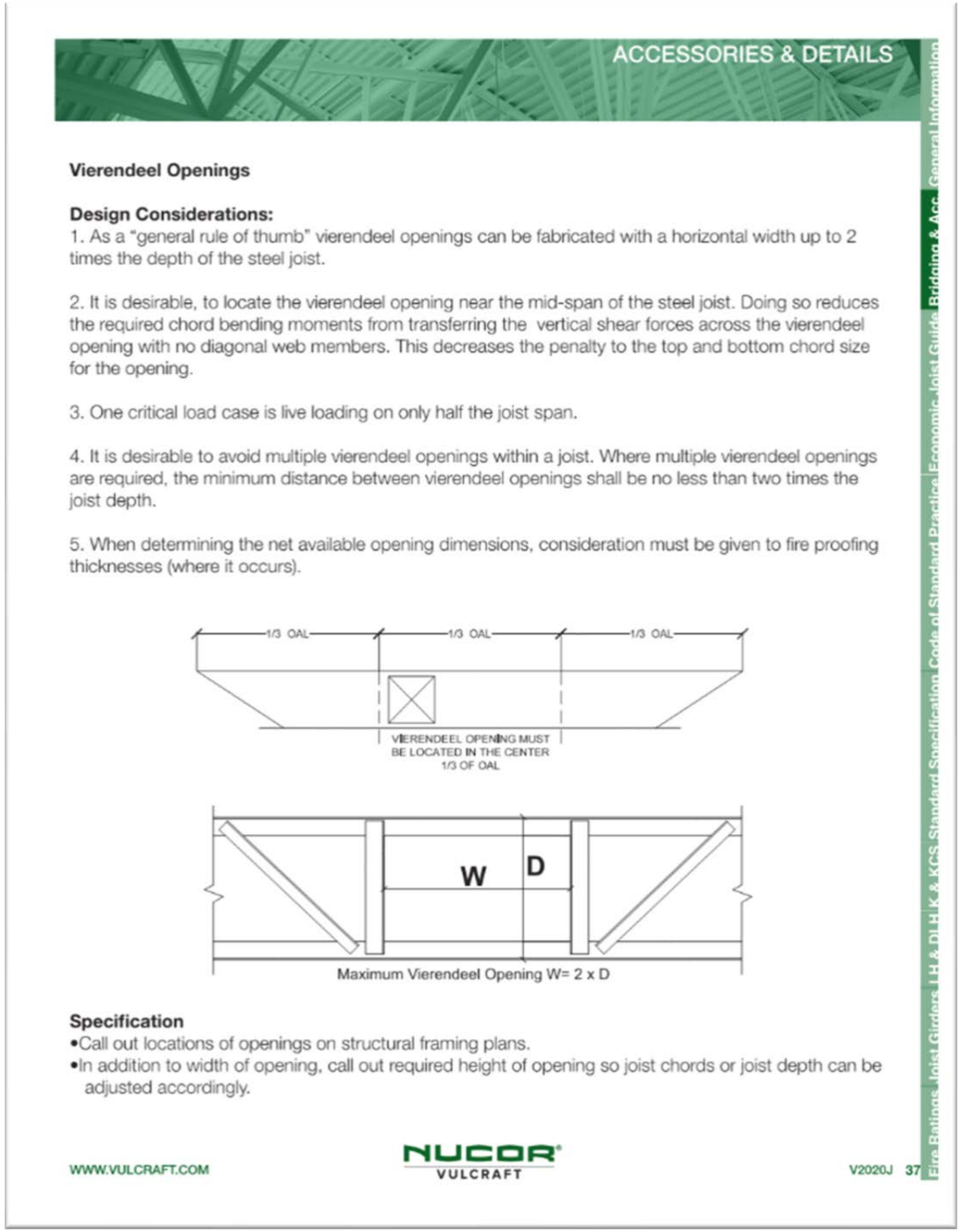
ALLOWABLE DUCTWORK

Joist Depth (in.)	Panel Length (in.)	Round (in.)	Square (in.)	Rectangular (in. x in).
10	19*	5	4	3x6
12	19*	6	5	4x7
14	19*	7	6	5x7
16	19*	8	6	6x7
18	24*	9	7	6x9
20	24*	10	8	7x9
22	24*	10	9	8x9
24	24*	11	9	9x9
18	48	10	8	6x18
20	48	10	8	7x18
22	48	10	9	8x18
24	48	12	10	8x19
26	48	15	12	9x19
28	48	16	13	10x18
30	48	17	14	11x19
32	64	20	16	11x25
34	68	22	18	12x28
36	72	24	18	13x29
38	76	25	20	13x30
40	80	26	22	14x32
42	84	27	22	16x34
44	88	28	23	17x36
46	92	30	24	18x36
48	96	32	26	19x40
50	100	33	27	20x42

* rod joist

Large Openings

- Vierendeel Openings can be done
  - LH, DLH, CJ
- Page 37 of Joist Manual
- Locate in mid-third of span
- Possible Cost premium for these
  - If chord angles have to be upsized, there are add'l costs


ACCESSORIES & DETAILS

Vierendeel Openings

Design Considerations:
1. As a "general rule of thumb" vierendeel openings can be fabricated with a horizontal width up to 2 times the depth of the steel joist.

2. It is desirable, to locate the vierendeel opening near the mid-span of the steel joist. Doing so reduces the required chord bending moments from transferring the vertical shear forces across the vierendeel opening with no diagonal web members. This decreases the penalty to the top and bottom chord size for the opening.

3. One critical load case is live loading on only half the joist span.

4. It is desirable to avoid multiple vierendeel openings within a joist. Where multiple vierendeel openings are required, the minimum distance between vierendeel openings shall be no less than two times the joist depth.

5. When determining the net available opening dimensions, consideration must be given to fire proofing thicknesses (where it occurs).

Maximum Vierendeel Opening W= 2 x D

Specification
•Call out locations of openings on structural framing plans.
•In addition to width of opening, call out required height of opening so joist chords or joist depth can be adjusted accordingly.

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Catalogs/Manuals

- Catalogs/Manuals can be downloaded
  - https://vulcraft.com/Literature

- Websites:
  - https://vulcraft.com/
  - https://vercodeck.com/

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SJI Technical Digests

www.SteelJoist.org

- TD No. 2 Bridging Design
- TD No. 3 Structural Design of Steel Joist Roofs to Resist Ponding Loads
- TD No. 5 Vibration of Steel Joist – Concrete Slab Floors
- TD No. 6 Structural Design of Steel Joist Roofs to Resist Uplift Loads
- TD No. 8 Welding of Open Web Steel Joists
- TD No. 9 Handling and Erection of Steel Joists and Joist Girders
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