Special Floor Loading Considerations in Typical Residential Construction

Design Guide

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SBCA

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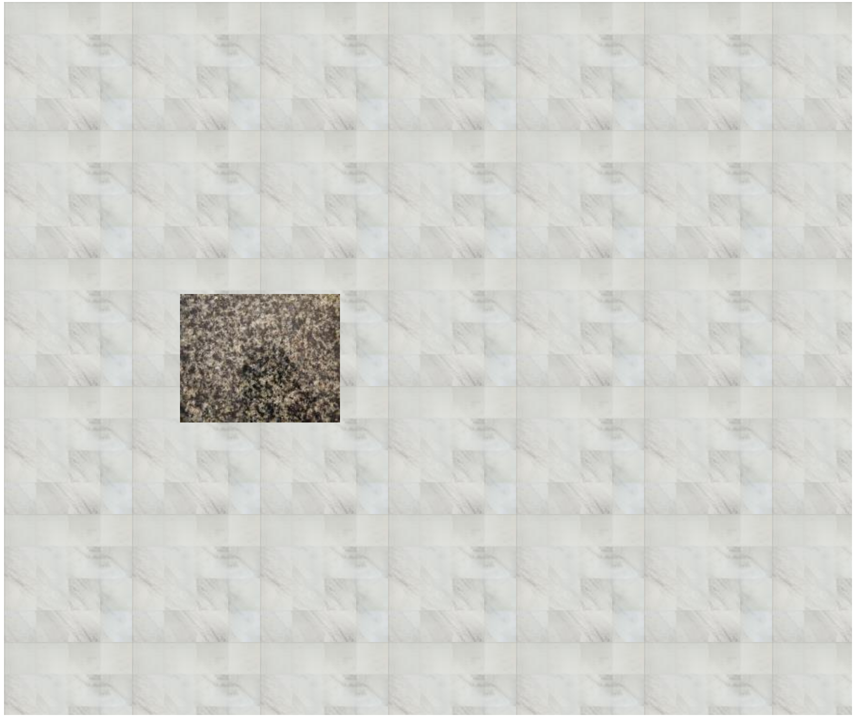
Introduction

- Special floor loading can require special attention by the designer to avoid serviceability issues within the floor system.
- This design guide will show how to address serviceability issues not addressed by the building codes.

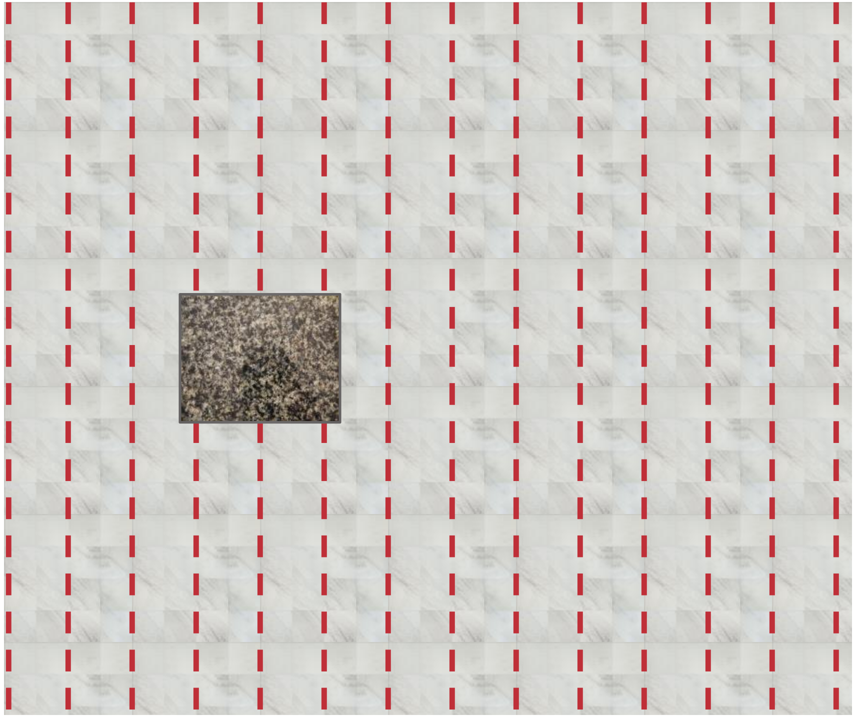
Step 1: Verify Truss Span and Spacing

- Consider a kitchen area in which stone floor tiles will be used.
- In addition, a 4' wide island with a granite countertop will be installed in the center of the floor span.



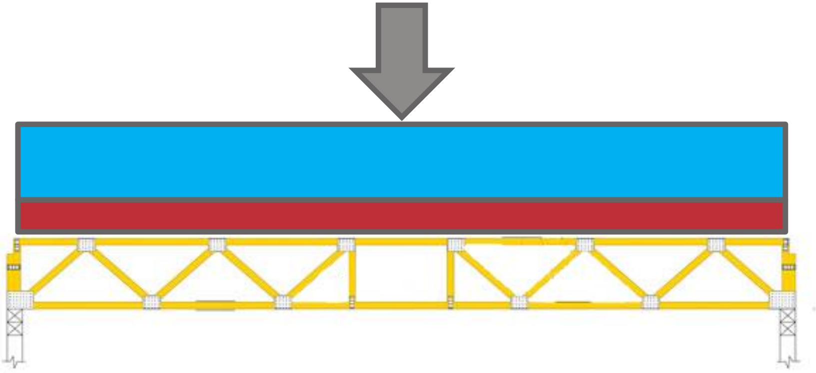
Step 1: Verify Truss Span and Spacing

- Floor trusses are 18" deep with SPF No. 2 2x4 top and bottom chords spaced at 24" on center.
- Floor truss span is 22‘.



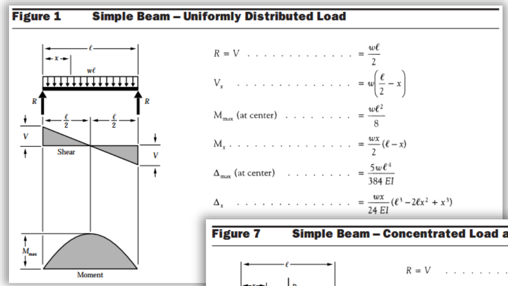
Step 2: Verify Loading

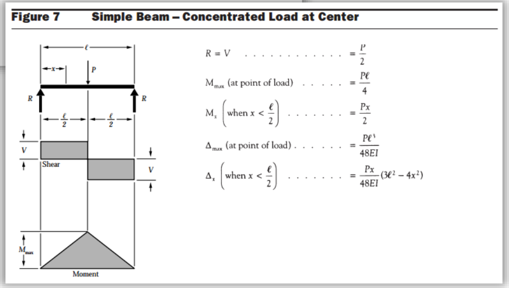
- Dead load from stone tile floor (including subfloor) is 20 psf.
- Floor live load is 40 psf (per *IBC* and *IRC* codes).
- Granite topped island acts as a 200 lb. concentrated load (per truss) at the center of the span.



Step 3: Verify Engineering Assumptions

- Floor trusses are analyzed as being simply supported beams.
- Critical load combination = 1.0D + 1.0L.





1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W \text{ or } 0.7E)$

6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$

6b. $D + 0.75L + 0.75(0.7E) + 0.75S$

7. $0.6D + 0.6W$
8. $0.6D + 0.7E$

Step 4: Calculate Deflection

- The first term equals the deflection from the uniform dead and live loads.
- The second term equals the deflection from the concentrated midspan load from the island.

$$\frac{5(120\,{}^{lbf}/_{ft})(\frac{1ft}{12in})(264in)^4}{384\left(1{,}400{,}000\,{}^{lbf}/_{in^2}\right)(716.6in^4)} + \frac{200lbf(264in)^3}{48\left(1{,}400{,}000\,{}^{lbf}/_{in^2}\right)(716.6in^4)} = \boldsymbol{0.707in}$$

Note: Deflections shown are calculated using an equivalent beam equation for example. Actual truss design software calculated deflections should be used for actual designs.

Step 4: Calculate Deflection

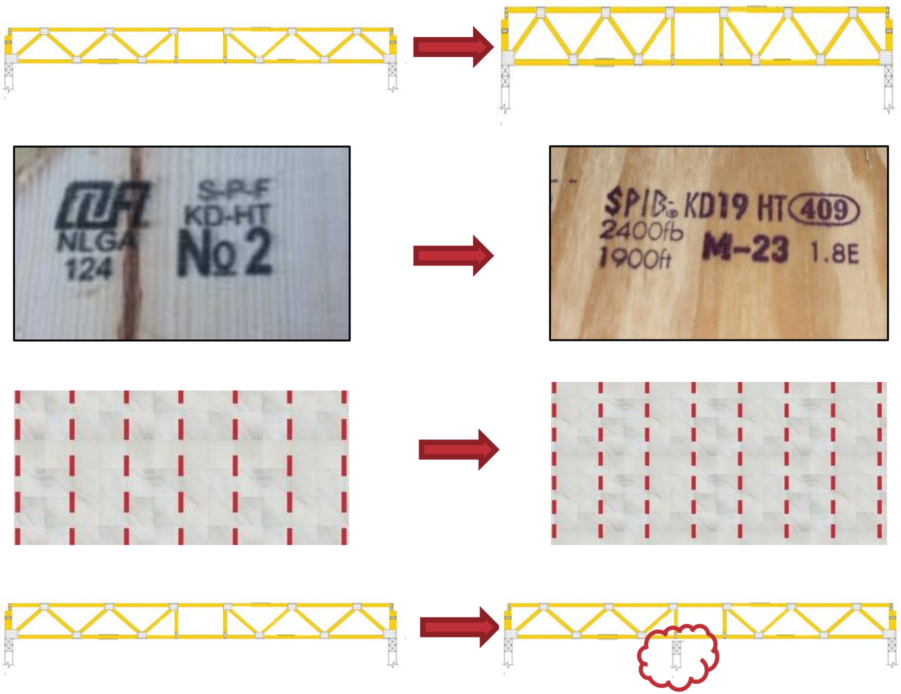
- The standard deflection limit (L/360) is satisfied:
  - 0.707"< 0.733" (264/360)
- However, the deflection limit for floors supporting stone flooring tiles (L/720) is substantially exceeded:
  - 0.707" > 0.367" (264/720)

Step 5: Decrease Deflection

- Excess deflection could lead to cracking in the tiles.
- The floor system should therefore be made stiffer to reduce the deflection.

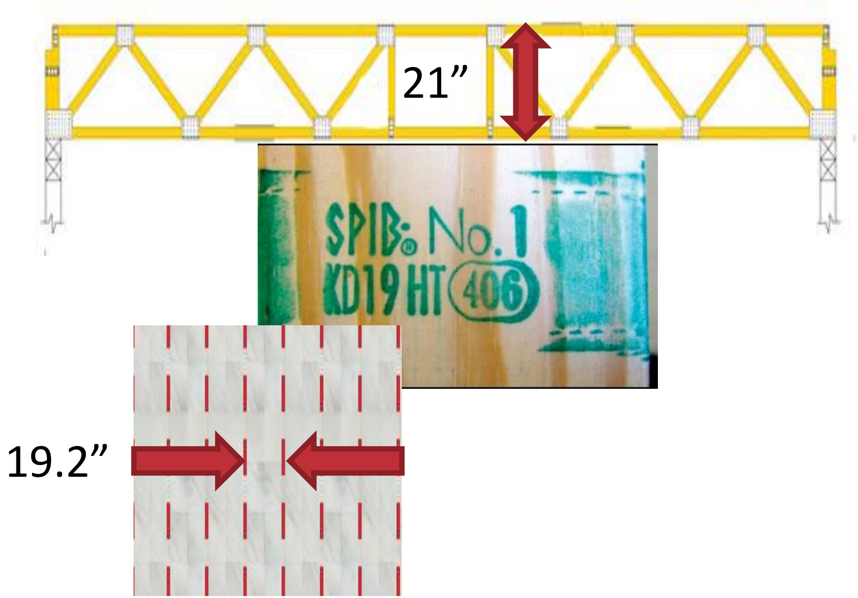
Step 5: Decrease Deflection

- Some common options to stiffen a floor system include:
  - Increasing the depth of the floor truss
  - Selecting a wood grade (specifically for the truss chords) with a higher modulus of elasticity (E)
  - Reducing the truss spacing
  - Reducing span (typically not an option)



Step 5: Decrease Deflection

- One solution could be to do the following:
  - Increase the truss depth to 21"
  - Use SP No. 1 2x4 chords, which have a greater modulus of elasticity,
  - Reduce the joist spacing to 19.2" on-center



Step 6: Re-calculate Deflection

- Doing so yields the following deflection:

$$\frac{5(96\,{}^{lbf}/_{ft})(\frac{1ft}{12in})(264in)^4}{384\left(1{,}700{,}000\,{}^{lbf}/_{in^2}\right)(1000.1in^4)} + \frac{200lbf\,\frac{19.2}{24}\,(264in)^3}{48\left(1{,}700{,}000\,{}^{lbf}/_{in^2}\right)(1000.1in^4)} = \mathbf{0.334\ in}$$

- The deflection now meets the stricter requirements for tile flooring. (0.334" < 0.367")
- The modified design is further beneficial because the narrower truss spacing will result in the sheathing deflecting less between the trusses and will allow loads to be distributed to adjacent trusses more efficiently.

Step 7: Evaluate Vibration

- To determine if vibration may be an issue, we can use a rule of thumb from "Serviceability of Floor Systems in Existing Residential Timber Frame Structures" by Castle and Pomerleau.
- The equations for calculating the natural frequency and deflection of a beam are combined to determine a deflection value below which vibration should not be an issue.

Substituting the midspan deflection of a uniformly loaded joist,

$$\Delta_{DL} = \frac{5WL^3}{384EI} \text{ or } \frac{EI}{WL^3} = \frac{5}{384\Delta_{DL}}$$

into the frequency equation produces a relation between the frequency and the dead load deflection after some rearrangement as shown below.

$$f = (1.57)^2 \left[\frac{5g}{384\Delta_{DL}}\right]^{1/2}$$

$$\Delta_{DL} = \frac{315}{f^2} \text{ mm or } \Delta_{DL} = \frac{12.4}{f^2} \text{ in.}$$

Step 7: Evaluate Vibration

- According to this approach, a beam of any length having a dead load deflection below 0.055" will have a natural frequency that is greater than 15 Hz and places it outside of the range of human sensitivity.
- This criteria is more restrictive for longer spans than other criteria.

Step 7: Evaluate Vibration

- The dead load deflection for both scenarios is greater than 0.055".
- Therefore, the natural frequency of the truss is within the range of human sensitivity and the floor system could be susceptible to vibration issues.

Figure 1 - Frequency Controlled Oscillating Mass Used to Measure Frequency Response in Floors