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Vibration Analysis of Steel Metal Deck Floor

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Abstract—*In present scenario engineers are moving towards light and economical steel construction. Due to this, arising problem in any structure is of vibrations. In this paper, vibration analysis of steel metal deck flooring is done with different configurations of live loading and depth of the steel metal deck. In static analysis of the structure maximum live load is calculated for the stability unlike in vibration analysis, in which minimum load is required for the stability. Also different geometric configurations are considered with different profile decks in the analysis. This will help engineers to find the optimum design of the steel metal deck flooring. Response of the floor depends upon its functionality like partitions, semi partitions and no partitions, which is analyzed in order to study the vibration behavior of the metal deck floor.*

1. INTRODUCTION

Excessive floor vibrations are common in many types of building structures. Problems of this nature have been reported in office buildings, shopping malls, airport concourses, and restaurants, to name a few. Although floor vibrations can result from many sources (e.g., reciprocating machinery, explosions, and heavy truck traffic) the most common and problematic are caused by the occupants themselves. Occupants generate floor motion from activities such as walking, dancing, jumping, etc. Such forces are particularly problematic because they cannot be easily isolated from the structure and they occur frequently. The assessment of "excessive" is, in general, determined by the occupancy requirements. These requirements range from limitations of sensitive equipment to the "comfort" of the occupants.

Comfort of the occupants is a function of human perception. This perception is affected by factors including the task or activity of the perceiver, the remoteness of the source, and the movement of other objects in the surroundings. A person is distracted by acceleration levels as small as *0.5%g* in an office or residential environment. People involved in an activity such as aerobics may be comfortable with acceleration levels up to *5%g* (Allen and Murray 1993). Perception is also affected by the characteristics of the vibration response including frequency, amplitude and duration. In a steady-state episode, similar displacement amplitudes are more objectionable at higher frequencies (Reiher and Meister 1931). With respect to duration, Lenzen (1966) noted that a transient vibration episode dissipating quickly (in less than 5 cycles) is much less disturbing than one persisting beyond 12 cycles of oscillation. The factors affecting the perception of floor vibration must be carefully considered when repairing a problem floor. Traditional methods for improving floor vibration characteristics vary widely in cost of implementation, obtrusiveness, and effectiveness.

2. PROPOSED ALGORITHM

A time dependent harmonic force component which matches the fundamental frequency of the floor:

$$F_1 = P\alpha_i \cos\left(2\pi i f_{step} t\right)$$

The peak acceleration due to walking can be estimated from the below equation:

$$\frac{a_p}{g} = \frac{P_o \exp\left(-0.35 f_n\right)}{\beta W} < \frac{a_o}{g}$$

The peak acceleration is then compared with the appropriate limit as given in the figure. Fundamental natural frequency for simply supported beams can be estimated by:

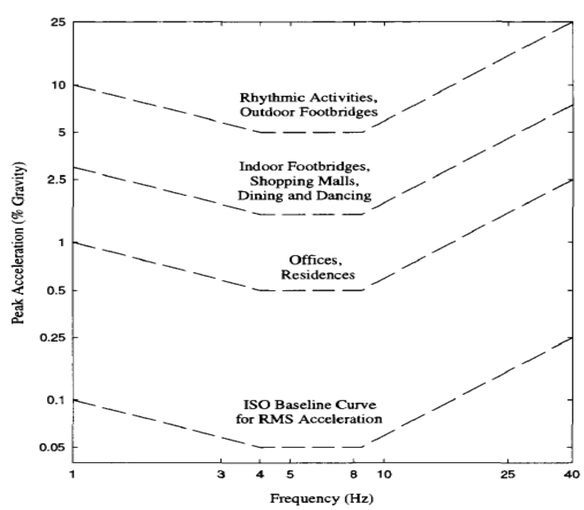


Fig. 1: Recommended peak acceleration for the human comfort for vibration due to human activity

$$f_n = 0.18\sqrt{\frac{g}{\Delta}}$$

Effective Panel Weight, W

W = wBL

For the beam or joist panel mode, the effective width

$B_j = C_j(D_s/D_j)^{1/4}L_j$

For the girder panel mode, the effective width is

$B_g = C_g(D_j/D_g)^{1/4}L_g$

3. ANALYTIC STUDY

Typical interior bay of an office building with hot rolled framing system having dimensions **10.5**m x **9**m is taken with different live load configuration is analyzed and there dynamic response are calculated using **32**, **50** and **100** mm deep metal deck profile. Also floor with similar dimensions but with different boundary conditions i.e. one restrained and another having mezzanine floor boundaries, their responses are compared. Following are the responses compared graphically. Table 1 represents floor response considering the functionality of the floor i.e. with partitions and without partitions, this will have direct impact on their damping and hence the response.

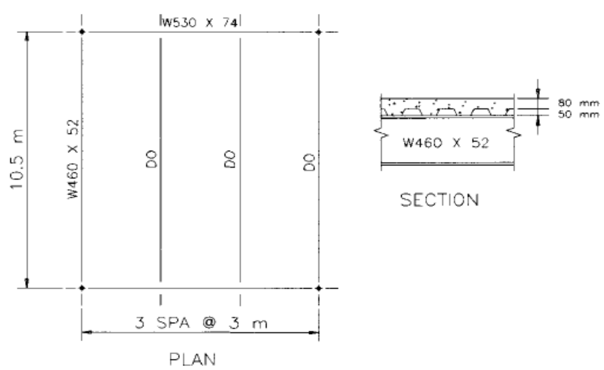


Fig. 2: Interior bay of an office building.

Table 1: Floor response considering floor functionality

Damping	**0.05**		**0.03**		**0.02**	
live load (kg/m2)	floor fundamental frequency(Hz)	peak acceleration (% of gravity)	floor fundamental frequency(Hz)	peak acceleration (% of gravity)	floor fundamental frequency(Hz)	peak acceleration (% of gravity)
100	4.671	0.3045	4.671	0.5074	4.671	0.7612
110	4.660	0.3042	4.660	0.5071	4.660	0.7606
120	4.650	0.3040	4.650	0.5067	4.650	0.7600
130	4.640	0.3038	4.640	0.5063	4.640	0.7594
140	4.630	0.3035	4.630	0.5058	4.630	0.7588
150	4.620	0.3033	4.620	0.5054	4.620	0.7582
160	4.610	0.3030	4.610	0.5050	4.610	0.7576
170	4.601	0.3028	4.601	0.5046	4.601	0.7569
180	4.591	0.3025	4.591	0.5042	4.591	0.7563
190	4.580	0.3023	4.580	0.5038	4.580	0.7557
200	4.572	0.3020	4.572	0.5034	4.572	0.7551

Graph 1 Represents the relationship of the response of the floor according to their functionality. Graph 2 represents the response of the floor according to the different configuration of the joists and beams, there were different constant values given according to the configuration and are as follows:

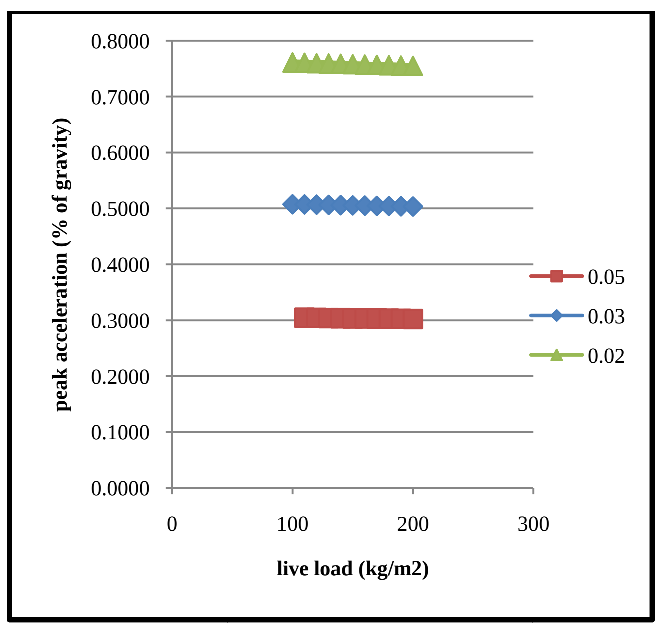
C_j = 2.0 for beams or joists in most areas

= 1.0 for joists or beams parallel to an interior edge.

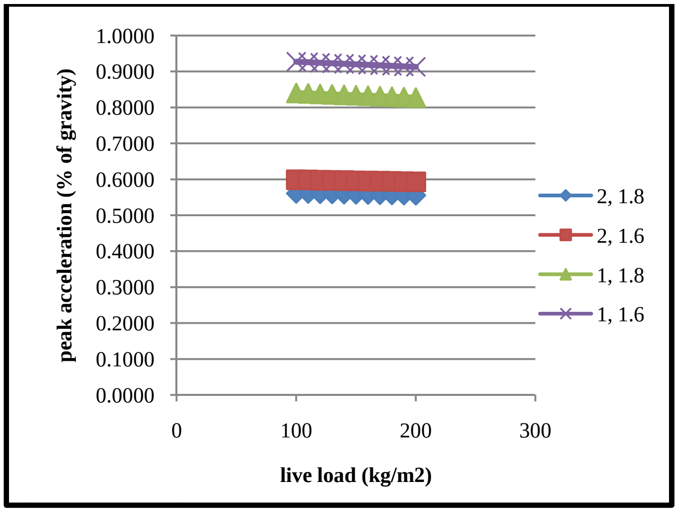
C_g = 1.6 for girders supporting joists connected to girder flange.

= 1.8 for girders supporting beams connected to girder web.

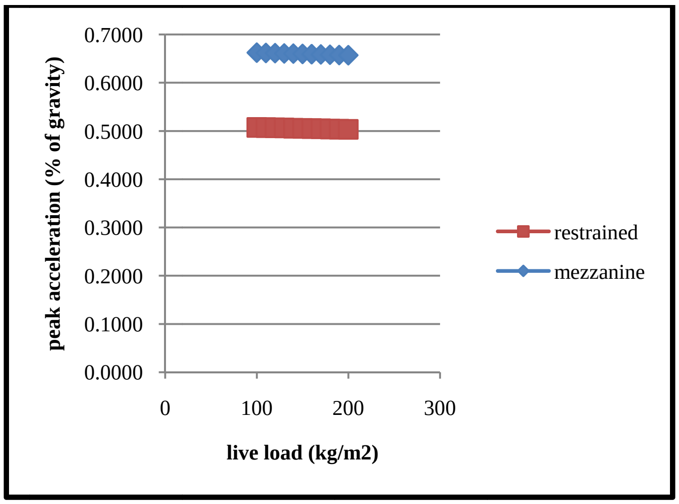
Hence using different combinations analysis was done and hence the response in the Graph 2. Graph 3 represents the response of mezzanine and restrained floor in which there is the change in the boundary conditions, which will change the response and hence the comparison can be done between restrained and mezzanine flooring. Also response is checked for different depth of the steel profiles which can be seen in graph 4. Table 2 represents the minimum thickness of the concrete at different live load conditions for no vibration condition according to design guide series issued by AISC.



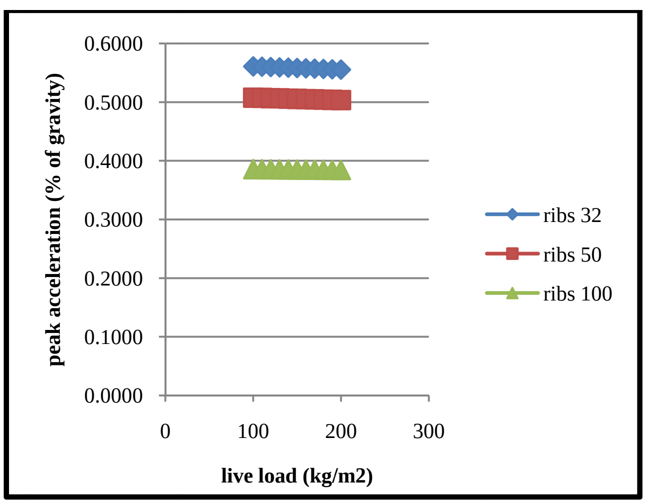
Graph 1: Response of the floor according to floor functionality (damping 0.02, 0.03, 0.05)



Graph 2: Response of the floor according to the different configuration of joists and girders



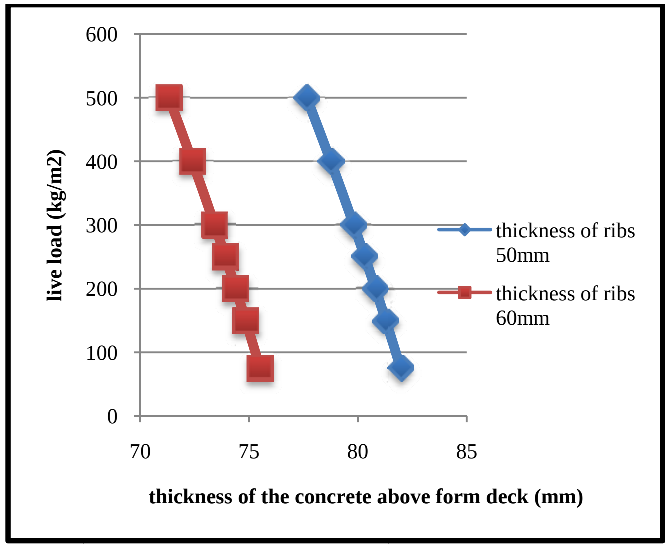
Graph 3. Response of restrained and mezzanine flooring.



Graph 4: Response of the floor taking different depth of the ribs (32mm, 50mm, 100mm)

Table 2: Minimum thickness of the concrete above the form deck for no vibration criteria at given live loads

LL (kg/m2)	50mm thick rib thickness of the concrete (mm) above form deck	60mm thick rib thickness of the concrete (mm) above form deck
75	81.96	75.50
150	81.28	74.85
200	80.81	74.39
250	80.32	73.91
300	79.81	73.42
400	78.76	72.40
500	77.65	71.32



Graph 5: Minimum thickness of the concrete above the form deck for no vibration criteria at given live loads.

4. CONCLUSIONS

As the thickness of the concrete above the form deck increases the minimum live load requirement for no vibration condition decreases. Hence, static stability of structure is checked for maximum load but for vibration stability, the structure should be checked for minimum load hence an optimum range of load (live load) for particular metal deck floor can be obtained for an economic design. Floors with full height partitions between floors are less prone to vibrations as compared to floors with small demountable partitions (modular office areas) and floors with few non structural components (ceilings, ducts, partitions, etc) as can occur in open work areas and churches. Floors with configuration having beam or joists not parallel to interior edge and girder supporting beams are connected to girder web with C_j **= 2.0** C_g **= 1.8** are less vibrating then the floors with beams or joists parallel to interior edge and girders supporting joists connected to the girder flange (e.g. joists seats).

Deeper steel metal deck floors are less prone to vibrations as compared to the shallower metal deck floors. Hence particular metal deck should be chosen according to the availability, design and economy. From the above graphs, taking same dimensions of the floors, mezzanine floor was more vibrating than the restrained interior bay of an office building.

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