FastFloor

Phase 1 Closeout

report for 2024 06 01

compiled on 2024 07 30

FastFloor: Behavior of Modular Steel Plate Floor Assemblies

Team

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FastFloor: Behavior of Modular Steel Plate Floor Assemblies

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FastFloor: Behavior of Modular Steel Plate Floor Assemblies

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Overview of Phase 1 Closeout

Phase 1 was under a no cost extension until 2023 06 30.

Phase 2 initiated 2023 07 01 and continues until 2024 12 31.

This slide report provides closeout materials for Phase 1.

Summary of Phase 1 activities, Excerpt from Phase 2 contract

Phase 1: January 2022 – June 2023: Work Completed and Ongoing (a request has been submitted to amend the contact to end Phase 1 on June 30, 2024)

1. Formed and met with Industry Advisory Panel (IAP) to iterate on design of prototype system. Several meetings were held with the IAP and subsets of the IAP.
2. Conducted a state-of-the-art review (ongoing)
   a. Modular floor systems
   b. Buckling behavior of structures built with steel plates
   c. Connection and fastening methods for modular floor systems
3. Finalized initial development of the modular floor system; assessed issues of construction sequence, connection detailing, local buckling, and other relevant behavior
4. Finalized initial prototype structures and specimen designs for the vibration tests and acoustic tests.
5. Conducted analyses of prototype structures to document behavior.
6. Initiated the design, analysis, and execution of subassemblage tests of modular floor system for serviceability and acoustics (ongoing).
7. Initiated design and analysis of panel-to-panel connections.
8. Initiated design and analysis on experiments of modular floor system for gravity strength and ductility.
9. (Forthcoming) Produce final report summarizing Phase 1 with recommendations for Phase 2.

A request has submitted for an amendment to the contract to change the end date of Phase 1 to June 30, 2024 so as to complete the acoustic and vibration tests that were part of Phase 1, and to advance the design and analysis of experiments to assess gravity strength and ductility of the modular floor system.

NCE was approved, and this slide deck provides the closeout of those activities.

-Phase 1 acoustic tests were completed and reported out, additional tests are now planned in Phase 2

-Work on gravity strength continues in Phase 2, with Phase 1 efforts complete, as provided in quarterly reports.

-Phase 1 vibration work is complete, with a full summary report provided in this closeout slide deck, and work moving to Phase 2 full bay specimen

FastFloor Vibration Update

2024 07 10

Sahab Rifai, Rajshri Kumar, Onur Avci, Ben Schafer

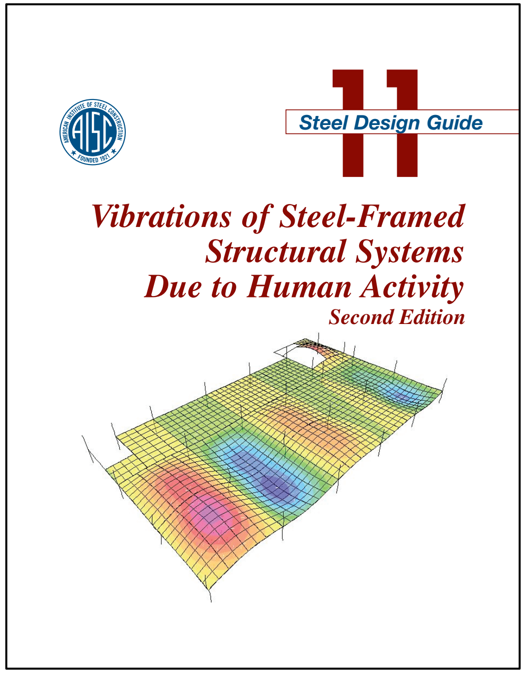
Note, boxes in yellow that appear throughout the presentation are comments collected during the 2024 07 10 meeting from RK: Ron Klemencic (MKA/Pankow), JM: Josh Mouras (MKA), DH: Devin Huber (AISC)

Objectives of Vibration Update Meeting

1. Discuss expectations (standards of care) for vibration performance, we have some freedom here, but also need to take care
2. Discuss influence of parameters in the design space under our control, challenges we can see, remediations and bounds
3. Get RonK et al. up to speed with current vibration test results and current modeling and DG11 work, technical state of play
4. Tentative agreement on the path/paths being pursued with respect to the single module performance
5. Implications of current work on finalizing full bay vibration specimen details and importance of timelines

Expectations (standards of care) for vibration performance

DG11



DG11 - Fundamental

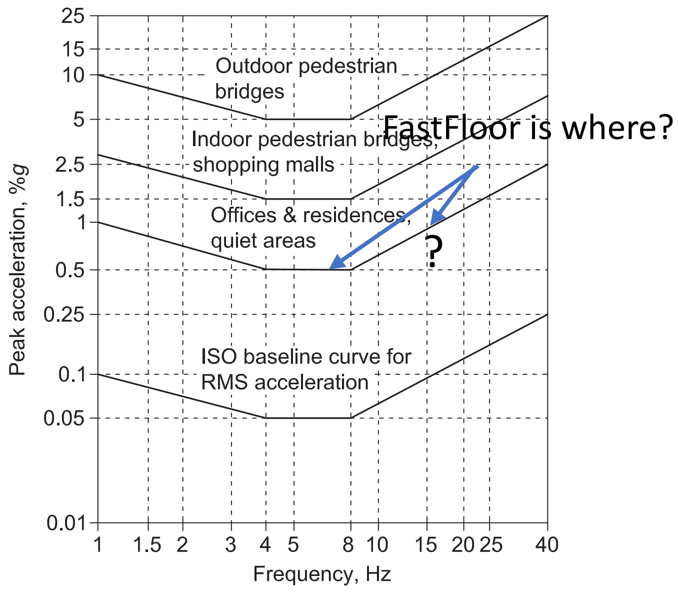
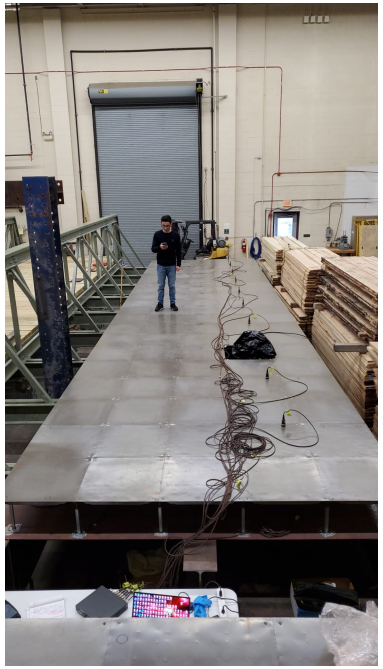


Fig. 2-1. Recommended tolerance limits for human comfort.

Lab



In Building

image from Omer Tigli, LinkedIn, floor vibration testing in situ

- DG11 uses past performance and provides procedures attempting to ensure no occupant complaints
- **DG11 procedures covers the "outlier" predictions for accelerations, and that is its intent**
- DG11 provides both low and high frequency methods, and acceptability is frequency dependent. Our modules are more likely to be under high frequency procedures.

- Lab provides ground truth for modeling
- Lab also allows participants to develop their own independent qualitative assessment
- Measured accelerations are (very) dependent on the person in terms of gait, etc. but are more likely to be average accelerations as opposed to DG11 (extrema)
- In situ measurements provide most realistic response and we know that response is highly sensitive to final details

Expectations (standards of care) fo

Discussion

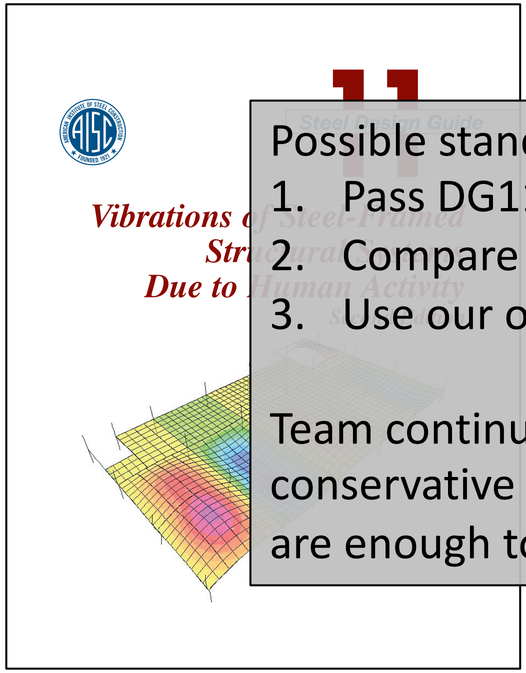
a. RK Path 1 maybe most defendable?

b. JM Or is Path 2 + DG11 targets the best we do? .. Modified DG11 for this system…

>RK sympathetic to (b) DG11 improved

DH.. Update DG11 is going to make sense…

DG11



DG11 - Fundamental

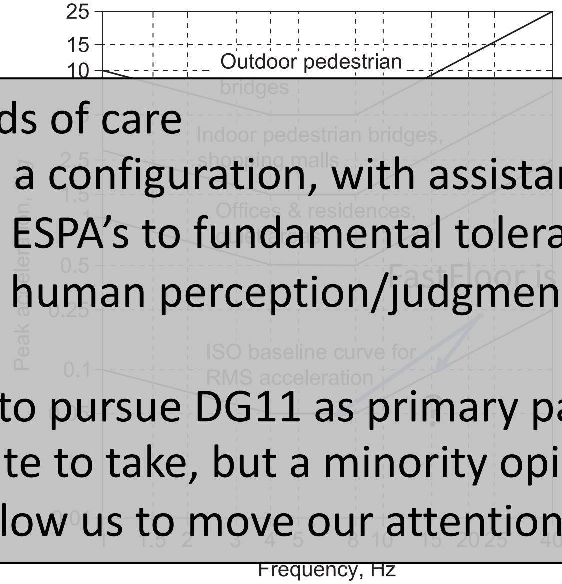


Fig. 2-1. Recommended tolerance limits for human comfort.

Possible standards of care

1. Pass DG11 in a configuration, with assistance of a model, then move on
2. Compare lab ESPA's to fundamental tolerances, if typically pass, move on
3. Use our own human perception/judgment based on walking on lab floors

Team continues to pursue DG11 as primary path, team largely believes this is most conservative route to take, but a minority opinion in the team wonders if 2 and 3 are enough to allow us to move our attention to other issues.

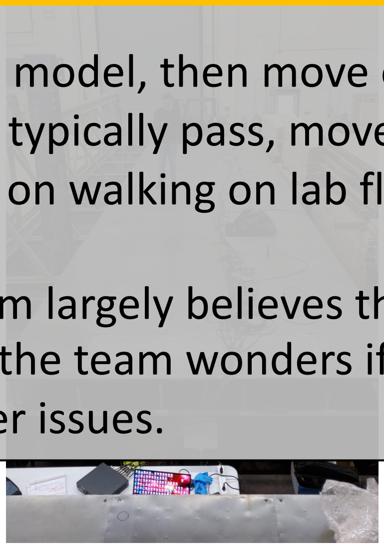


image from Omer Tigli, LinkedIn, floor vibration testing in situ

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- **DG11 procedures covers the "outlier" predictions for accelerations, and that is its intent**
- DG11 provides both low and high frequency methods, and acceptability is frequency dependent. Our modules are more likely to be under high frequency procedures.

- Lab provides ground truth for modeling
- Lab also allows participants to develop their own independent qualitative assessment
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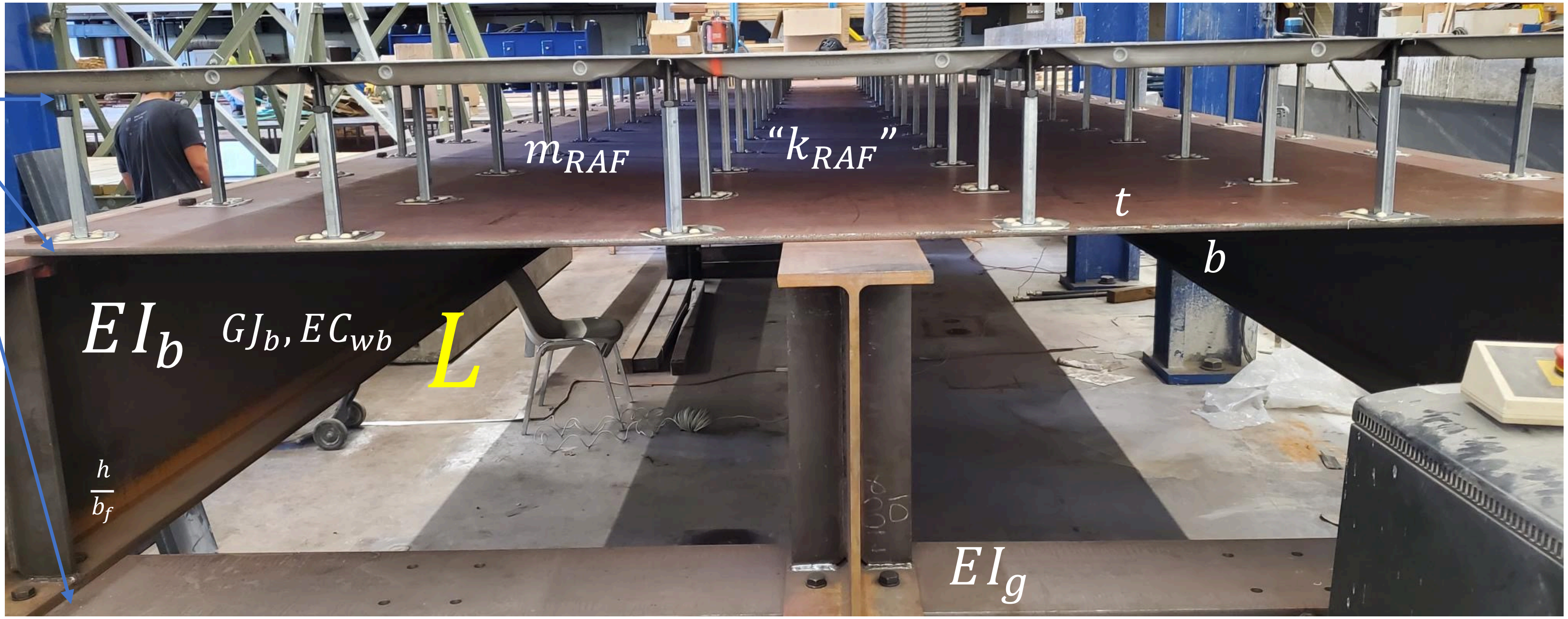
Vibration “design space”…

k, m, β



Why bring this up?

- Let’s make sure we understand the implications of our decisions on the vibration predictions.
- For instance L 40’ vs. e.g. L 36’, quantities are sensitive to L^3 so these choices are not secondary/trivial!
- Other basic issues like beam depth and as a result EI is driving us in important ways
- We can see what plate thickness is doing as well. (following slides)

We have many optimizations underway (architectural, erection, more) but we can make choices that improve vibration.

Upperbound Analysis for ”passing” DG11…

Assume the plate is stiffened above 20 Hz and no longer an issue
Assume the beam and girder are torsionally stiffened, so only flexural modes are left
Assume that the low frequency DG11 method is all we need, and L=40’

For 1/2" Plate

Girder	Girder \ Beam	W36X395	W36X302	W36X210	W36X160	W36X150	W36X135	W33X263	W33X221	W33X152	W33X130	W33X118	W30X108	W30X99	W30X90	W27X102	W27X94	W27X84	W24X104	W24X94	W24X84	W24X76	W24X68	W24X62	W24X55	W21X73	W21X68	W21X62	W21X55
	W36X395	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4
	W36X302	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4
	W36X210	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	5
	W36X160	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	5	4	5	5	5
	W36X150	2	2	2	2	2	3	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5
	W36X135	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5	5	5
	W33X263	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4
	W33X221	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	5
	W33X152	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5	5
	W33X130	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6
	W33X118	3	3	3	3	4	4	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6
	W30X108	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7
	W30X99	4	5	5	5	5	5	5	5	5	5	5	5	5															7
	W30X90	5	5	5	5	5	5	5	5	5	5	6	6	6															8
Girder	W27X102	5	5	5	5	5	5	5	5	5	5	5	6	6															8
	W27X94	5	5	5	6	6	6	5	6	6	6	6	6	6															8
	W27X84	6	6	6	6	6	6	6	6	6	6	7	7	7															9
	W24X104	5	5	6	6	6	6	6	6	6	6	6	6	6															8
	W24X94	6	6	6	7	7	7	[illegible]	[illegible]	7	7	7	7	7															9
	W24X84	6	7	7	7	7	7	7	7	7	7	8	8	8															9
	W24X76	7	7	8	8	8	8	7	8	8	8	8	8	8															10
	W24X68	7	8	8	9	[illegible]	[illegible]	[illegible]	[illegible]	9	9	9	9	9															11
	W24X62	8	9	9	10	10	10	9	9	10	10	10	10	10															12
	W24X55	9	9	10	10	10	11	10	10	11	11	11	11	11															13
	W21X73	8	8	9	9	9	10	9	9	9	10	10	10	10															11
	W21X68	8	9	9	10	10	10	9	9	10	10	10	10	11															12
	W21X62	9	9	10	10	11	11	10	10	11	11	11	11	11	11	11	11	12	11	12	12	12	12	12	12	12	12	12	13
	W21X55	9	10	11	11	12	12	10	11	12	12	12	12	12	13	12	13	13	12	13	13	13	13	13	14	13	13	13	14

Beam

Number in the cell is the damping ratio in % required for that combination to satisfy a<0.5%g

Numbers in cells are the β needed to pass DG11

RK, we need at least 40’, if anything, need longer!
JM, we do this for composite floors today… (what is the right tool to let the engineer construct this) our goal > aid the engineer.. Table is great.

The #’s are the β we need To pass DG11 in these configurations….

Right now we estimate 2.25% damping in installed condition

What do we learn??

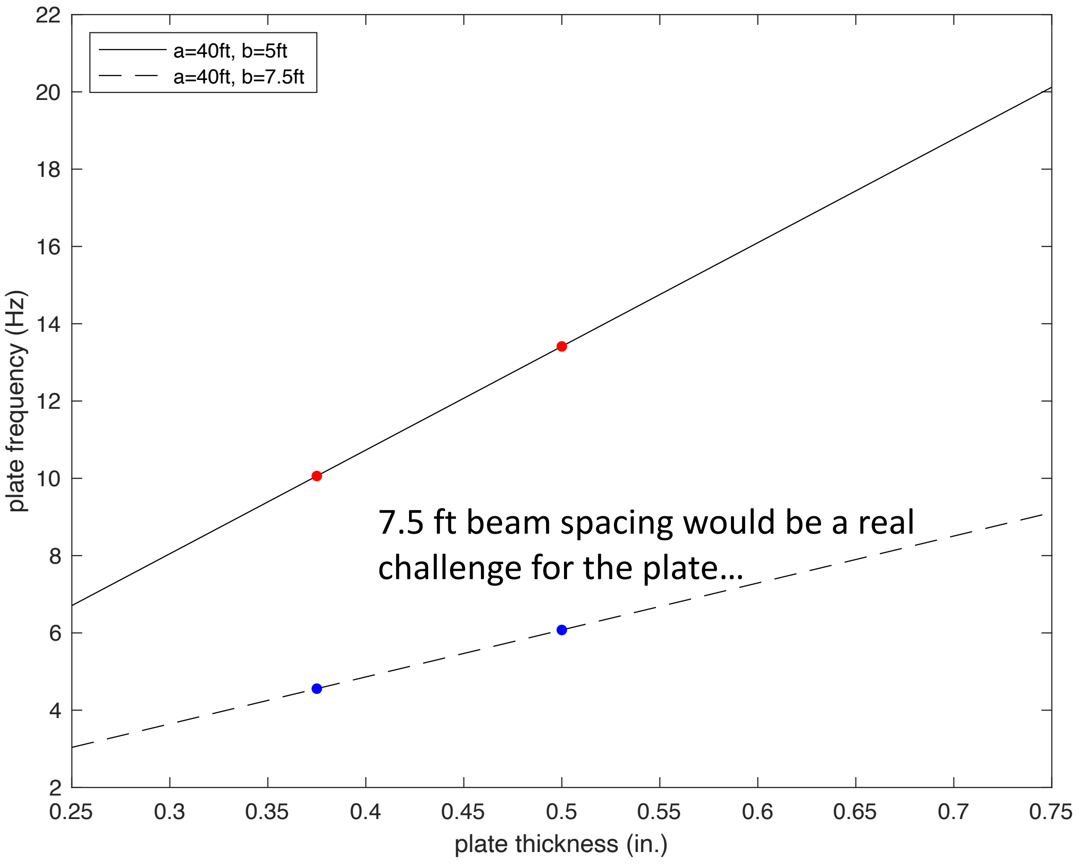
-Even if we make plate modes and beam torsion go away, passing DG11 is not easy. (must we pass?)
-The role of the girder (and related beam end conditions) is really important
-If EI (or L) or β are knobs we can turn, we can find a path, if not may need to think about standard of care choice, fancier ideas…

Plate stiffening “design space” and upperbound ideas

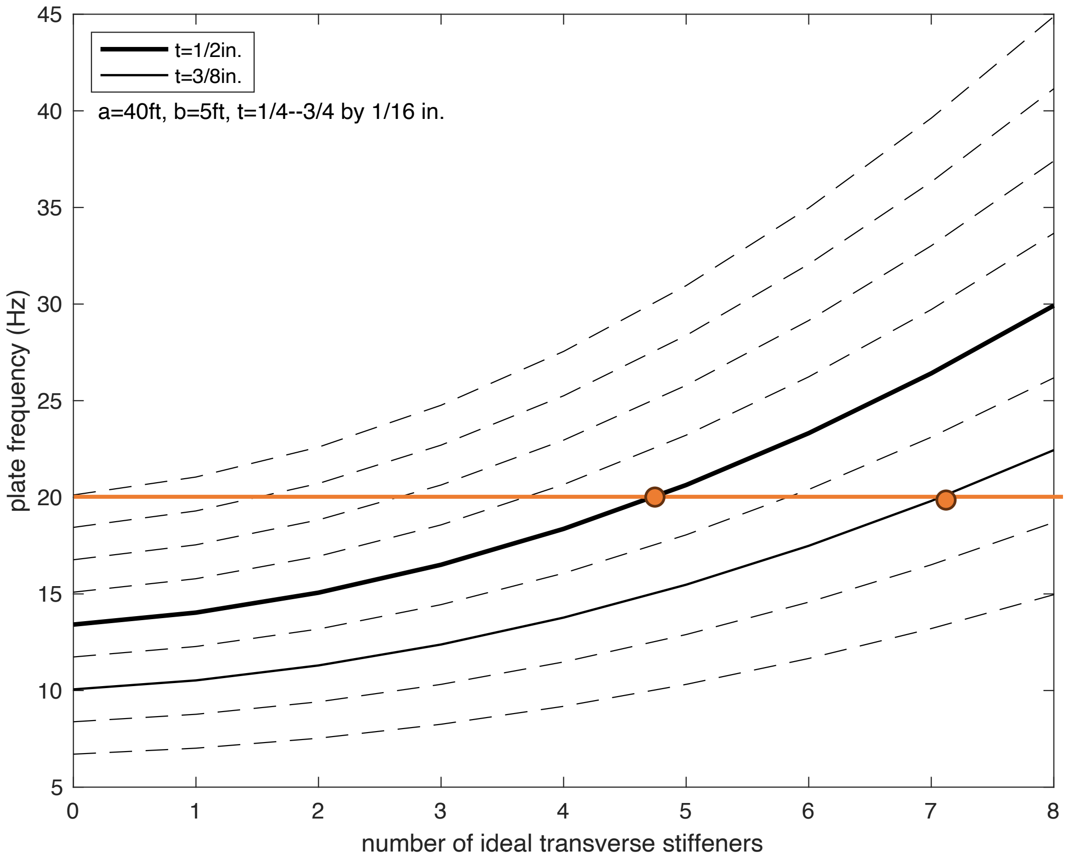
If you can get plate frequencies above 20Hz then they are not influencing perceived accelerations

First vibration mode results

Use a thicker plate…



Add “ideal*” transverse stiffeners



*ideal in this analysis = infinitely rigid and massless stiffener

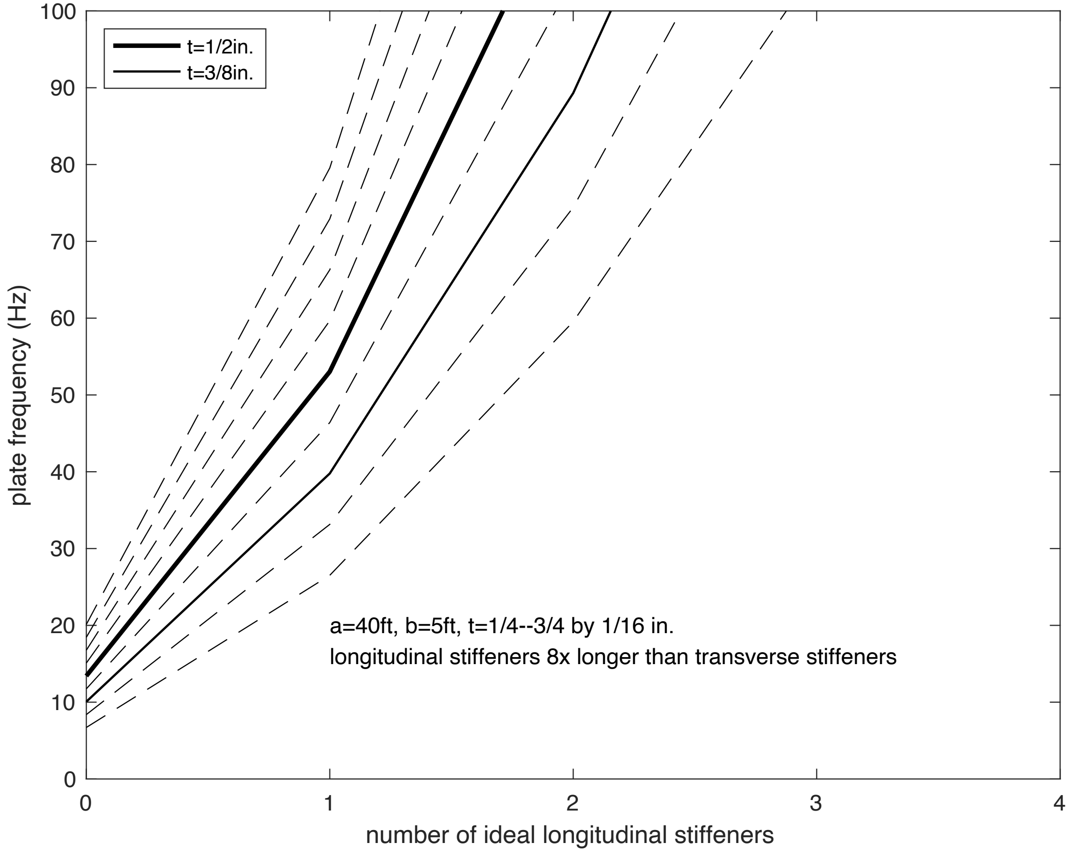
Conclusion? In an ideal scenario we can use stiffeners Or thickness to get the plate modes out of the picture.

Plate stiffening “design space” and upperbound ideas

If you can get plate frequencies above 20Hz then they are not influencing perceived accelerations

First vibration mode results

Add “ideal” longitudinal stiffeners



Great in ideal case, but preliminary analysis says too good to be true. Can’t get a practical longitudinal stiffener which is 40’ long! To be stiff enough – basically equivalent to another beam…

But we are imagining that K trusses or other braces can provide this same type of support, perhaps at transverse brace locations to break up the vibration mode and improve the frequency.. This is being investigated numerically.

*ideal in this analysis = infinitely rigid and massless stiffener

Conclusion? Even in practical scenario we prelim. predict stiffeners and braces can get plate modes out of the picture.

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3. Get RonK et al. up to speed with current vibration test results and current modeling and DG11 work, technical state of play
4. Tentative agreement on the path/paths being pursued with respect to the single module performance
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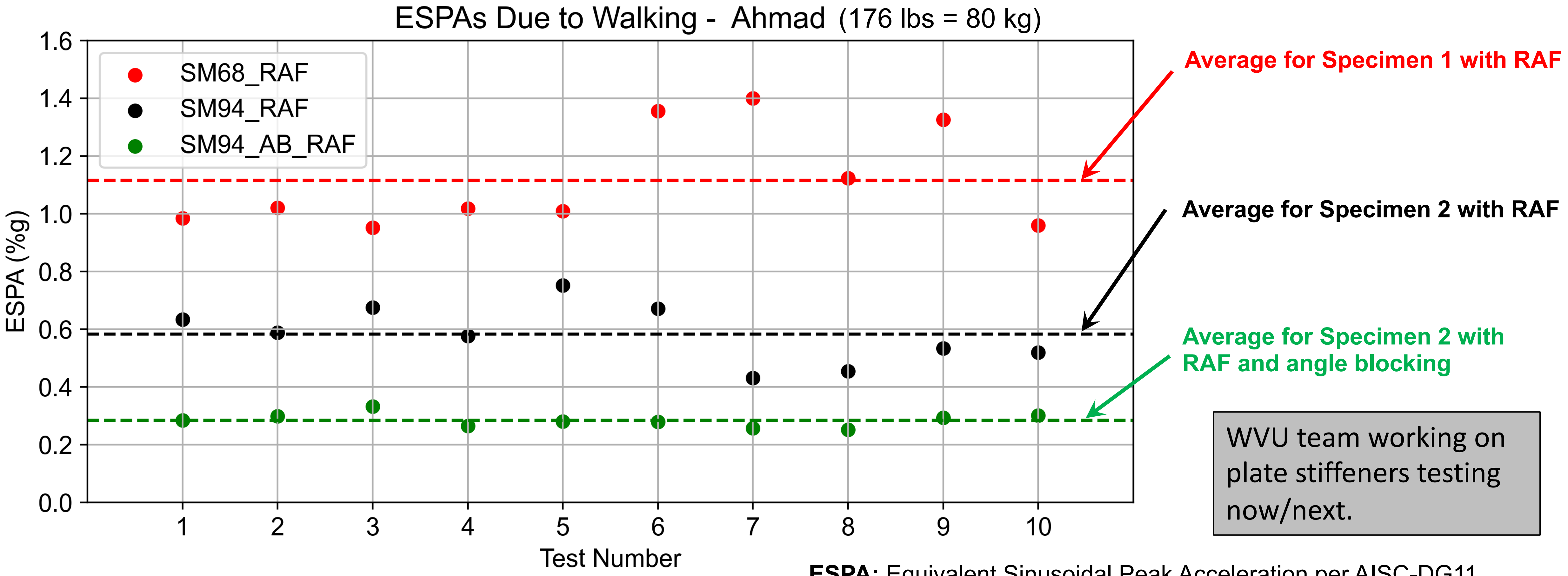
Peak Accelerations (ESPA) from Random Walking Tests **for One Person**



WVU team working on plate stiffeners testing now/next.

ESPA: Equivalent Sinusoidal Peak Acceleration per AISC-DG11
RAF: Raised Access Floor

Takeaways:

1. Angle blocking resulted in significant reduction in accelerations.
2. While not a judge of acceptability, it is good sign that accelerations less than 0.5%g in this case
3. This is an example for one person walking. Tests conducted with other people show same trend.
4. Final floor vibrations acceptability will be judged using model results on full bay.

Experimental results from walking

Specimen	Experimental Results from Vibration Testing		
	Modal Damping Ratios (β)[1,2,3]	Min-Max ESPA (% g)[4,6]	Mean ESPA (% g)[4,6]
SM68_Bare	0.1% - 0.4%	0.2 - 3.9	1.2
SM68_RAF_Bare	0.3% - 0.9%	0.1 - 2.2	0.9
SM68_RAF_AB_L_3	completed	completed	completed
SM68_RAF_AB_PS_L_3	-	-	-
SM68_RAF_K_L_3	-	-	-
SM94_Bare	0.2% - 0.4%	0.1 - 3.1	0.8
SM94_RAF_Bare	0.6% - 0.9%	0.3 - 1.8	0.6
SM94_RAF_AB_L_3	completed	completed	~0.4?
SM94_RAF_AB_PS_L_3	in progress	in progress	in progress
SM94_RAF_K_L_3	-	-	-

Looking at impact of
RAF: raised access floor
AB: angle blocking to beam bottom flange
PS: plate stiffeners transverse to plate
K: K braces from bot. flange to mid-width plate

Experimental results to date exhibit clear trends in the desired direction.

Mean ESPA from experiments is not the same as predicted ESPA from DG11

1. Obtained using a low-amplitude mass shaker excitation.
2. Modal Damping ratios are amplitude-dependent. Each mode has a different damping ratio. Damping ratios were determined per frequency response functions (FRF).
3. Low-amplitude mass shaker tests were considered which correspond to walking excitation amplitudes (rather than high-amplitude shaker tests).
4. ESPA: Equivalent Sinusoidal Peak Acceleration. Determined based on walking with subharmonics of modal frequencies guided with metronome.
6. Walking tests include random and metronome-guided walking. Max. ESPA results generally correspond to metronome-guided walking.

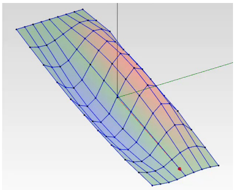
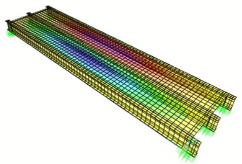
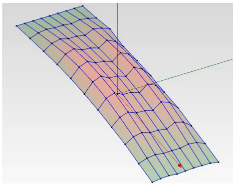
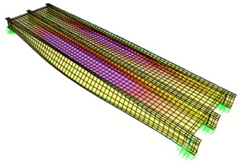
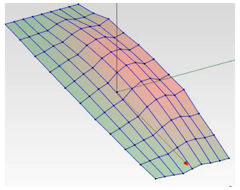
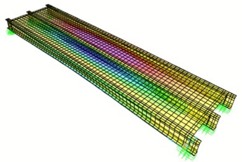
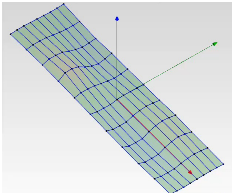
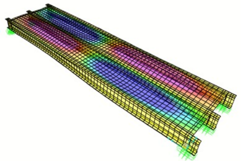
RK: Agree the trends and calibrating the models are our goal here.

Latest models "working" frequency matching OK

Specimen	Mode	Frequency (Hz)	
		Experiment[1]	SAP2000
SM68_Bare	1	7.2	7.61
	2	8.3	8.3
	3	10.6	9.76
	4	12.0	13.8
SM68_RAF[2]_Bare	1	7.8	8.2
	2	8.4	8.7
	3	11.3	10.3
	4	12.4	14.7
SM68_RAF[2]_AB_L_3	1	10.0	10.8
	2	10.4	13.7
	3	13.3	13.9
	4	14.7	15.9
SM94_Bare	1	9.1	9.4
	2	10.8	10.7
	3	12.9	12.2
	4	15.5	17.0
SM94_RAF[2]_Bare	1	9.2	10.0
	2	10.3	11.0
	3	13.7	12.4
	4	15.3	17.3
SM94_RAF[2]_AB_L_3	1	9.5	12.8
	2	12.7	16.2
	3	17.4	16.3
	4	19.3	20.2

1. Obtained using a low-amplitude mass shaker excitation.
2. Explicit modelling of the RAF with frames (pedestals) and shells (panels).

EXAMPLE RESULTS

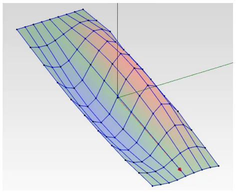
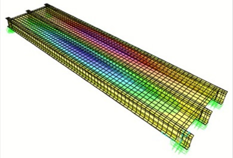
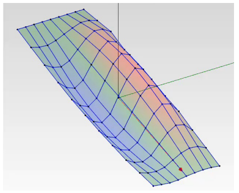
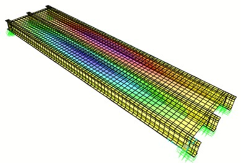
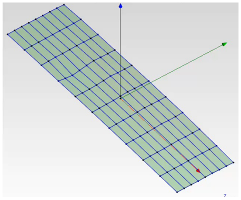
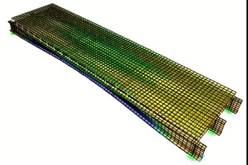
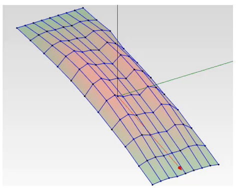
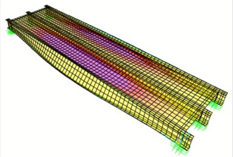
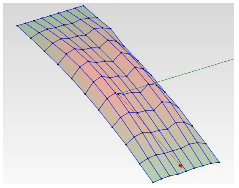
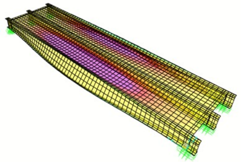
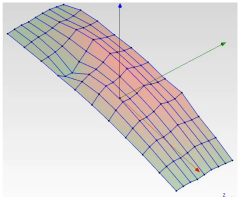
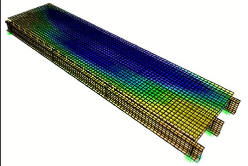
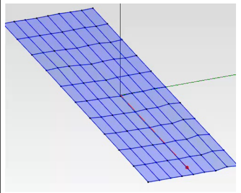
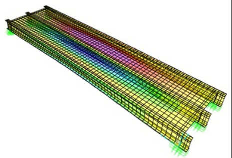
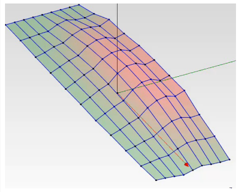
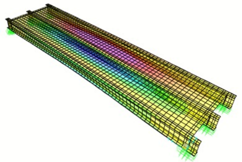
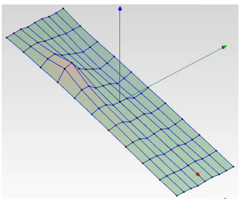
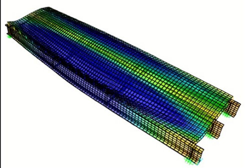
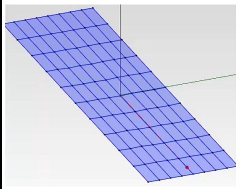
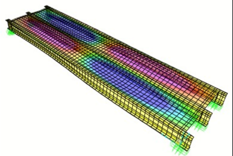
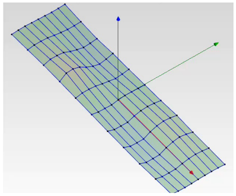
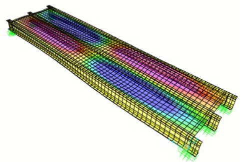
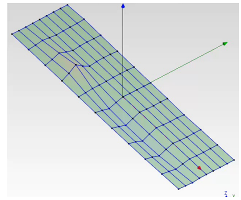
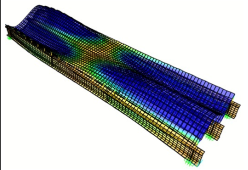
SM68_RAF_Bare			
Modal Testing (Low Amplitude Shaker)		**SAP2000**	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
7.75		8.18	
8.40		8.72	
11.31		10.28	
12.39		14.72	

Model results provided for SAP2000 plate FE models, similar results observed to date with ABAQUS shell FE models. Minimal calibration conducted, but true to details (intermittent flange to plate connections, etc.)

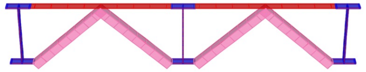
Additional model results

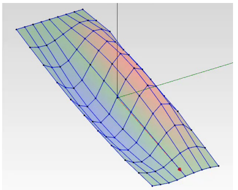
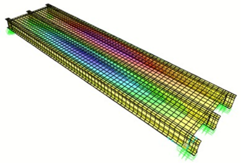
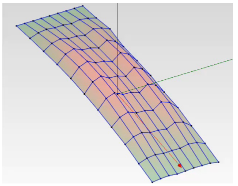
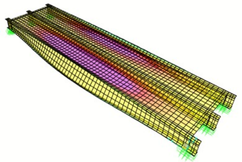
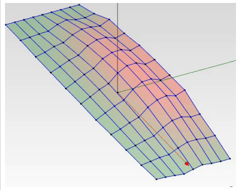
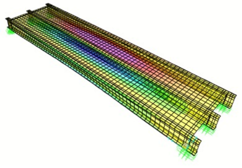
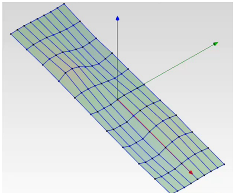
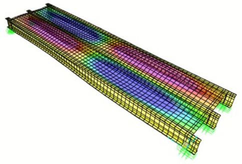
Full suite of experimental to SAP model results for frequency matching, not discussed in the meeting but provided for completeness. Companion ABAQUS models also underway.

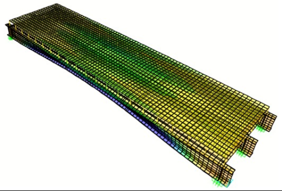
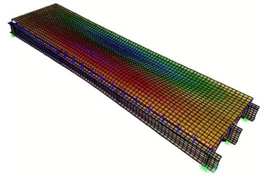
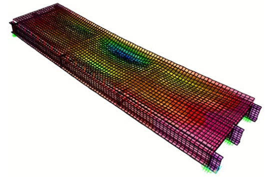
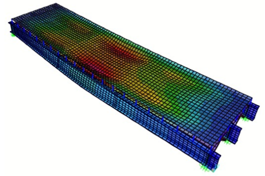
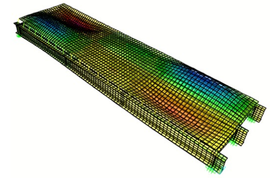
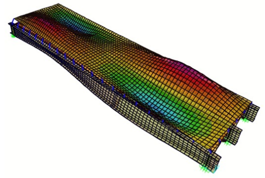
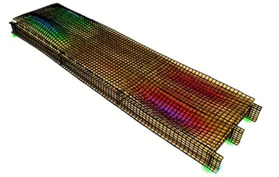
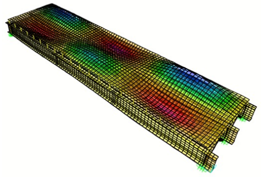
Mode Shapes and Natural Frequencies – SM68 (Specimen 1)

SM68_Bare				SM68_RAF_Bare				SM68_RAF_AB_L_3 Recently Acquired			
Modal Testing (Low Amplitude Shaker)		SAP2000		Modal Testing (Low Amplitude Shaker)		SAP2000		Modal Testing (Low Amplitude Shaker)		SAP2000	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
7.19		7.49		7.75		8.18		9.97		10.80	
8.31		8.25		8.40		8.72		10.40		13.73	
10.63		9.76		11.31		10.28		13.30		13.93	
11.97		13.8		12.39		14.72		14.70		15.89	

Mode Shapes and Natural Frequencies – SM68 (Specimen 1)

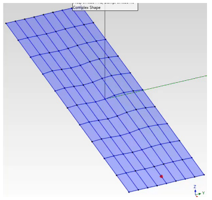
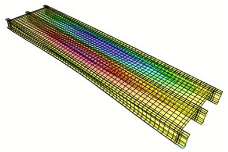
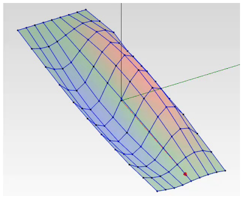
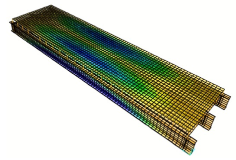
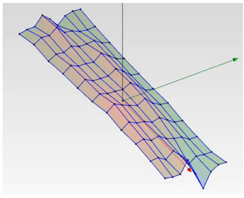
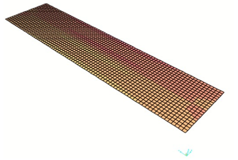
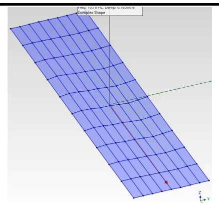
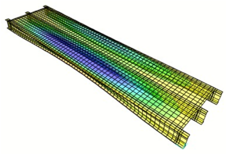
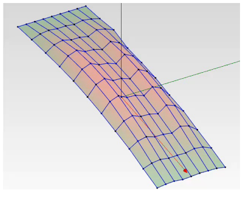
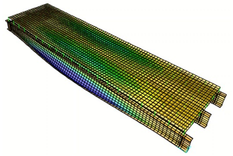
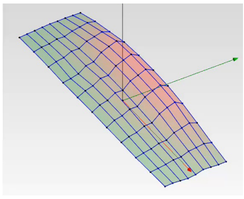
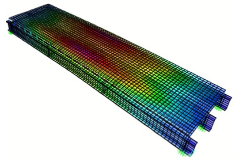
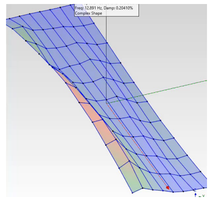
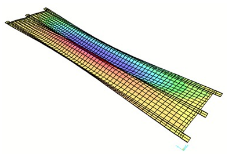
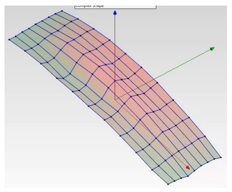
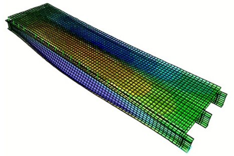
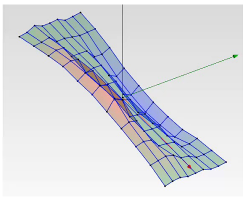
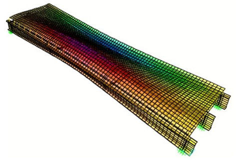
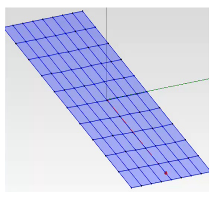
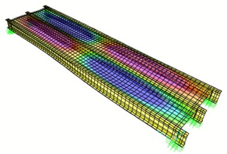
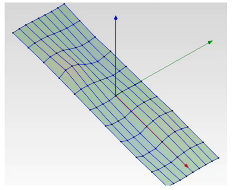
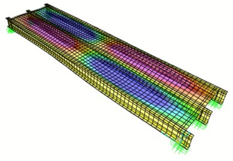
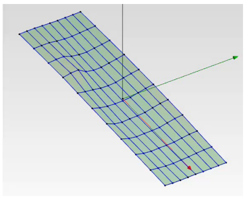
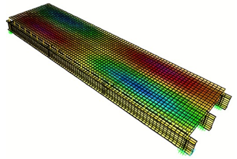


SM68_RAF_Bare			
Modal Testing (Low Amplitude Shaker)		SAP2000	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
7.75		8.18	
8.40		8.72	
11.31		10.28	
12.39		14.72	

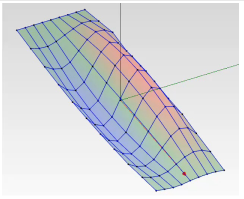
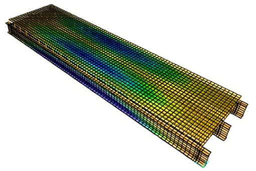
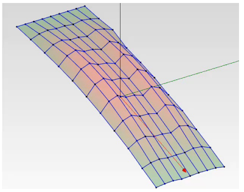
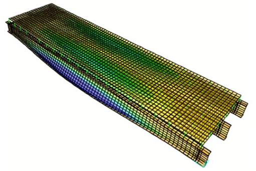
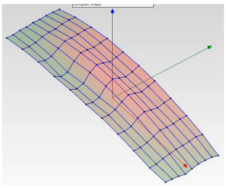
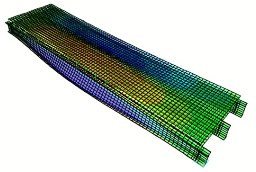
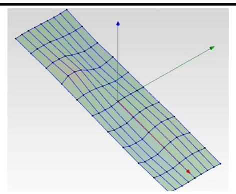
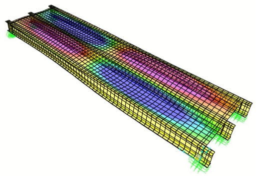
SM68_RAF_AB_PS_L_3 (SAP2000)		SM68_RAF_K_L_3 (SAP2000)	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
10.88		12.88	
14.32		13.95	
16.79		16.06	
18.42		17.61	

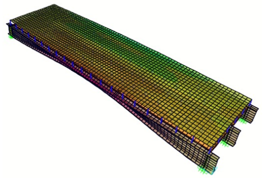
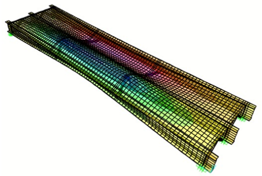
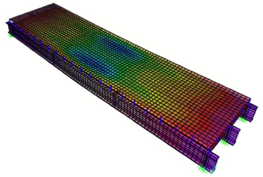
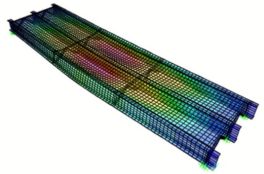
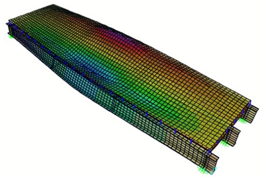
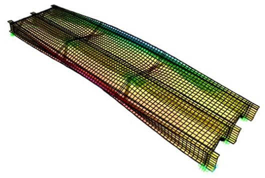
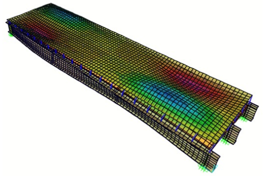
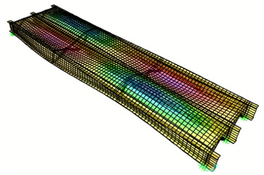
* K Braces are welded with each other at the top.

Mode Shapes and Natural Frequencies – SM94 (Specimen 2)

SM94_Bare				**SM94_RAF_Bare**				**SM94_RAF_AB_L_3** Recently Acquired			
Modal Testing (Low Amplitude Shaker)		**SAP2000**		**Modal Testing (Low Amplitude Shaker)**		**SAP2000**		**Modal Testing (Low Amplitude Shaker)**		**SAP2000**	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
9.10		9.35		9.15		9.99		9.48		12.78	
10.76		10.70		10.33		10.97		12.68		16.23	
12.89		12.23		13.73		12.39		17.34		16.31	
15.51		16.98		15.34		17.27		19.25		20.17	

Mode Shapes and Natural Frequencies – SM94 (Specimen 2)

Modal Testing (Low Amplitude Shaker)		**SM94_RAF_Bare (SAP2000)**	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
9.15		9.99	
10.33		10.97	
13.73		12.39	
15.34		17.27	

SM94_RAF_AB_PS_L_3 (SAP2000)		**SM94_RAF_K_L_3 (SAP2000)**	
f_n (Hz)	Mode Shape	f_n (Hz)	Mode Shape
12.90		13.87	
16.55		15.92	
17.00		16.84	
21.11		18.81	

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Objectives of Vibration Update Meeting

1. Discuss expectations (standards of care) for vibration performance, we have some freedom here, but also need to be careful
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Comparison of Peak Accelerations from Walking and DG-11 Using Fundamental Frequencies from SAP2000

Specimen	Experimental Results from Vibration Testing			Predicted ESPA per AISC DG-11 (% g)[5]					
	Modal Damping Ratios (β)[1,2,3]	Min-Max ESPA (% g)[4,6]	Mean ESPA (% g)[4,6]	HFF Procedure[5] in Ch. 7		Eq. 2-10[7]		Smoothed Eq. 2-10[8]	
				β = 0.75%	β = 2.25%	β = 0.75%	β = 2.25%	β = 0.75%	β = 2.25%
SM68_Bare	0.1% - 0.4%	0.2 - 3.9	1.2	6.0	3.8	2.4	2.1	2.7	2.4
SM68_RAF_Bare	0.3% - 0.9%	0.1 - 2.2	0.9	3.9	2.6	2.2	1.9	2.2	1.9
SM68_RAF_AB_L_3	-	-	completed	2.5	1.6	2.2	1.8	1.9	1.6
SM68_RAF_AB_PS_L_3	-	-	in progress	3.7	2.3	2.2	1.8	1.9	1.5
SM68_RAF_K_L_3	-	-	-	4.1	2.6	2.1	1.6	1.8	1.4
SM94_Bare	0.2% - 0.4%	0.1 - 3.1	0.8	1.4	1.1	1.7	1.4	1.8	1.5
SM94_RAF_Bare	0.6% - 0.9%	0.3 - 1.8	0.6	1.1	0.8	1.4	1.2	1.6	1.3
SM94_RAF_AB_L_3	-	-	~0.4?	0.3	0.2	1.6	1.3	1.4	1.1
SM94_RAF_AB_PS_L_3	-	-	in progress	1.2	0.7	1.6	1.3	1.4	1.1
SM94_RAF_K_L_3	-	-	-	1.8	1.3	1.4	1.0	1.3	1.0

1. Obtained using a low-amplitude mass shaker excitation.
2. Modal Damping ratios are amplitude-dependent. Each mode has a different damping ratio. Damping ratios were determined per frequency response functions (FRF).
3. Low-amplitude mass shaker tests were considered which correspond to walking excitation amplitudes (rather than high-amplitude shaker tests).
4. ESPA: Equivalent Sinusoidal Peak Acceleration. Determined based on walking with subharmonics of modal frequencies guided with metronome.
5. Per AISC DG-11, Chapter 7 procedures. The method provides estimations for peak walking accelerations to be compared with recommended limits. SAP2000 and ABAQUS results were utilized.
6. Walking tests include random and metronome-guided walking. Max. ESPA results generally correspond to metronome-guided walking.
7. Unsmoothed Equation 2-10 from DG-11
8. Smoothed Equation 2-10 proposed by **Brad Davis** (**Unpublished Work**)

Both DG-11's Eq. 2-10 and smoother Eq. 2-10 proposed by B. Davis output close acceleration results.

Comparison of Peak Acc[…] fro[…] and DG-1[…] Using Fundament[…]ie[…] 2000

“compare” to test

“best” in-service pred.

ignore low freq. pred. for now, hist. interesting, but not appropriate for these floors

Specimen	Experimental Results from Vibration Testing			Predicted ESPA per AISC DG-11 (% g)[5]					
	Modal Damping Ratios (β)[1,2,3]	Min-Max ESPA (% g)[4,6]	Mean ESPA (% g)[4,6]	HFF Procedure[5] in Ch. 7		Eq. 2-10[7]		Smoothed Eq. 2-10[8]	
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SM68_RAF_K_L_3	-	-	-	4.1	2.6	[illegible]	[illegible]	[illegible]	1.4
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angle blocking helps as expected

pl. stiffener not helping, needs work?

K brace ineffective on its own

1. Obtai[…]
2. Moda[…] a different dam[…]ponse function[…]
3. Low-a[…]d to walking exci[…]
4. ESPA[…]on walking with s[…]
5. Per A[…]stimations for p[…]limits. SAP200[…]
6. Walki[…] ESPA results ge[…]
7. Unsm[…]
8. Smoo[…]ork)
Both DG[…]utput close accel[…]

RK – what’s the source of the 0.75% to 2.25% assumption? Ben - DG11 chart has been used for us to justify beta increase in installed condition. RK.. Prefers the measured damping at the lower level… Or we need to look at real fitout to get higher beta.. Onur – carpet, desk, table, etc. and a full floor 30x40, can perhaps help us here

- DG11 predictions more conservative than experimental mean ESPA, closer to max observed ESPA in testing
- Specimen 2 (SM94) has much better behavior and consistency in tests and in models…

Comparison of Peak Acc … fro … and DG-1
Using Fundament … ie … 2000

“compare” to test

“best” in-service pred.

If we don’t ignore the classical method this is the results…

Specimen	Experimental Results from Vibration Testing			Predicted ESPA per AISC DG-11 (% g)[5]					
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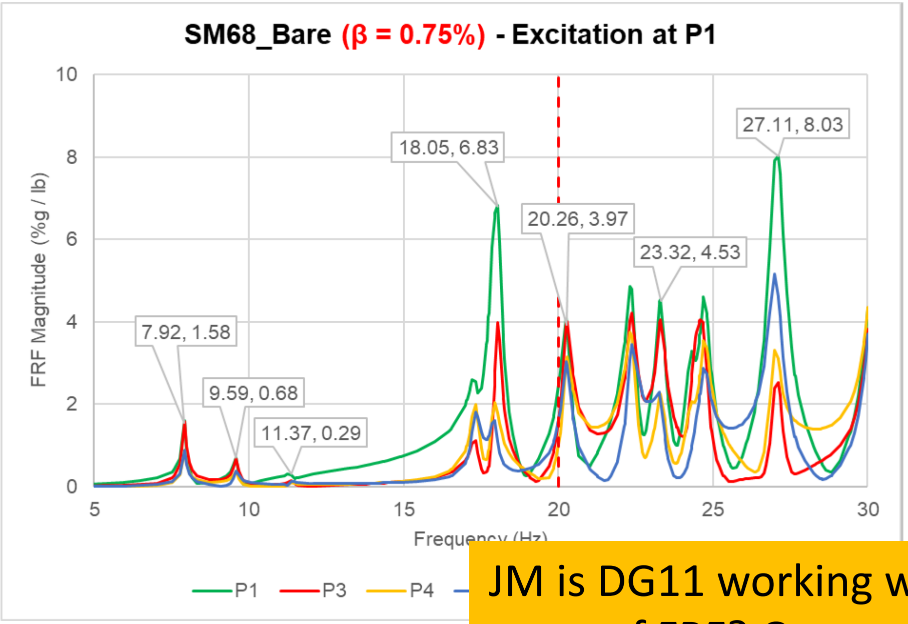
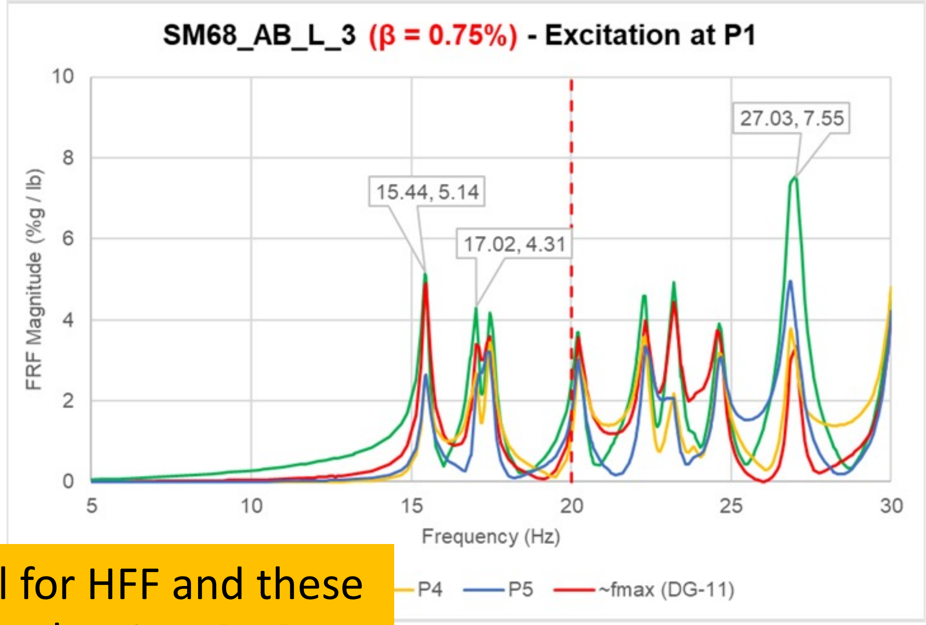
Details – FRF from SAP200 that drives the DG11 solution: Effect of Braces on Frequencies and FRF Peaks

No Braces

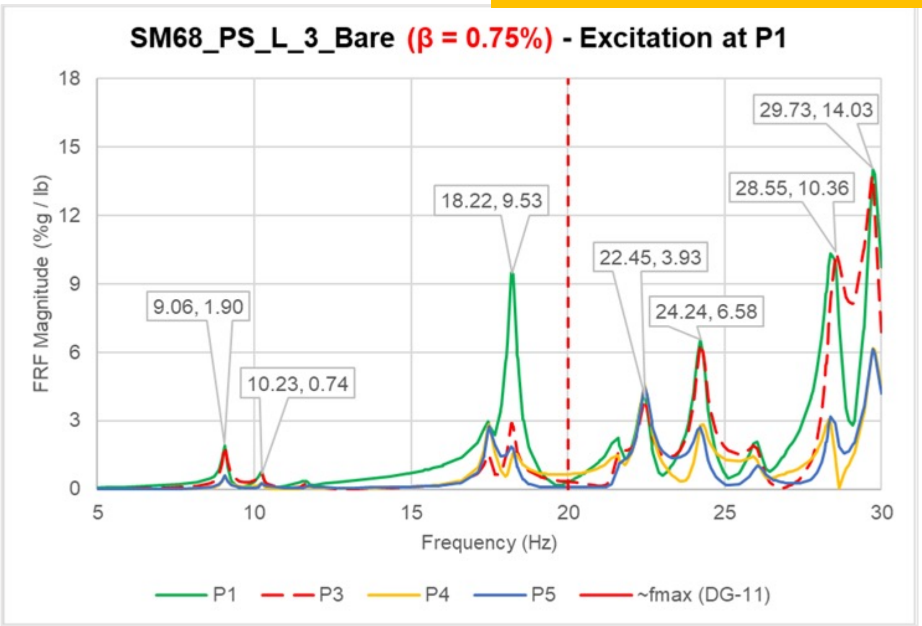


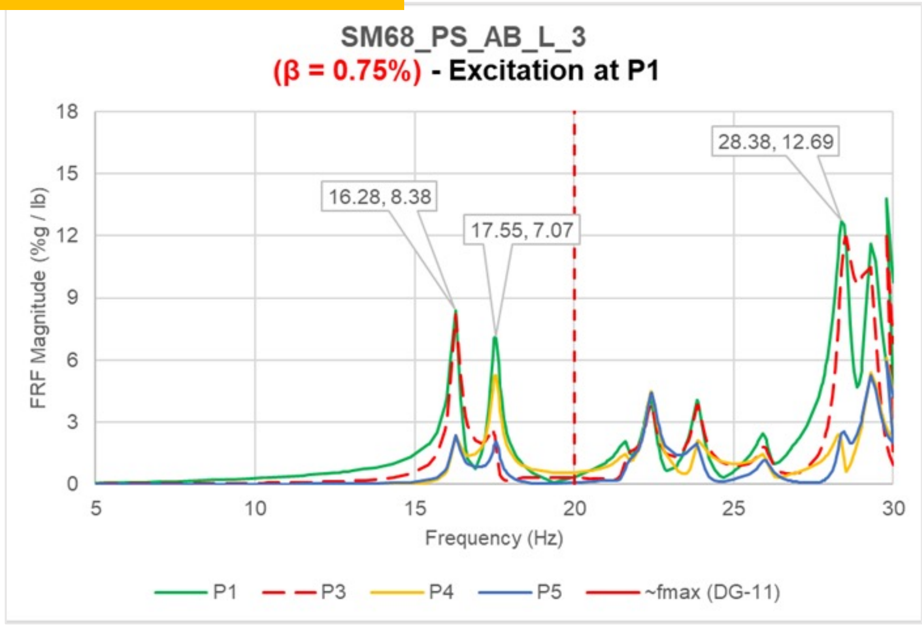
Angle Blocking (AB)



JM is DG11 working well for HFF and these types of FRF? Onur – k pushes L to R.. Past 20Hz is a good thing.

Plate Stiffeners (PS)





These FRF results are inputs into the DG11 analysis, primarily with respect to frequencies (and mode shapes, not shown)

Angle blocking is effective in shifting lower frequencies

Plate stiffeners primarily influencing frequencies above 20Hz, and seem to cause issues (cause not determined) at middle frequencies

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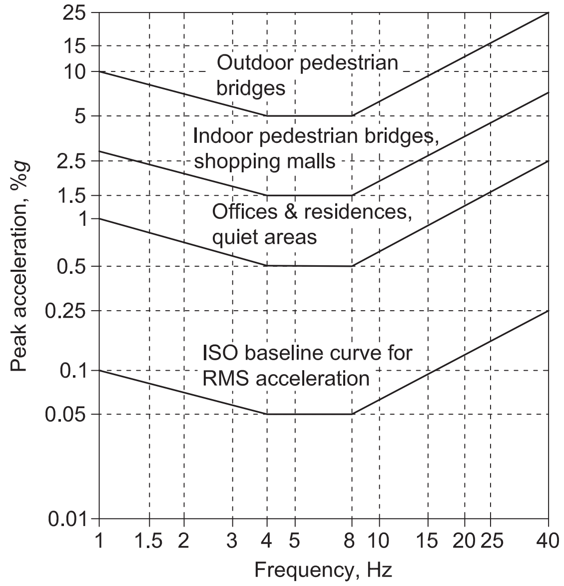
5. Implications of current work on finalizing full bay vibration specimen details and importance of timelines

Tentative agreement on the path/paths being pursued with respect to the single module performance

- We are pursuing experiments on angle blocking (complete) and transverse plate stiffeners (in progress)
- The models have close enough agreement with experiments that we can begin to “have some trust”; however, DG11 ESPA results and test-based ESPA results are not directly comparable
  - so we do not have model validation against accelerations, if we want to pursue that, adds a lot of complication, now we need to explicitly model walking/gait/step strikes etc.
- What is our standard of care/acceptability before moving on to the full bay testing?
  - Do we want a modeled system that passes DG11 high frequency method at 0.5%g – this has been promoted internally as a goal
  - Would we allow the relief of a higher %g at higher freq?
  - Is a tested system with a mean ESPA near or less than 0.5%g adequate our current 10x40 purposes?
  - What about our own user perception as a standard of care?
- Are we open to some of the bigger “knobs” in our design space vibrations?
  - Length, beam depth, plate thickness, supplemental damping – are compromises here worth seeing in some further form so we understand the impact of our decisions?



RK: something like bullet point 3 might be acceptable. Consider it at DG11 with some improvements. (Bullet 1 is a fallback. But does not have to be primary)
JM, DH agree… Let’s us move forward, don’t feel stuck..all good

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Full-bay vibration specimen discussion

- Tests will be at WVU, we can examine drawings again, but basic ideas are set.
  - What is not set is girder size, beam size, plate thickness, angle blocking, plate stiffeners – exact configuration to test…
- Upperbound DG11 analysis suggests girders will pull down frequency and this will potentially be bad for ESPA (i.e. %g) drives to different beam sizes, etc., do we care at this stage? (account for this?)
- Continuity across modules has been hypothesized as helpful (we know it is in concrete-filled steel deck floors) but here the vertical plate stiffness is low, should we expect a substantial benefit?
- If end effects matter, should we look at some of the beam end conditions that produce favorable conditions? What about the girder support conditions, do we want to see what happens when that modes are locked away? Do we want to see a test that clearly shows acceptable behavior (is a test enough?)
- We are developing models of the full bay specimen, do we want to see preliminary results of such models before we finalize full bay detailing? We think yes.
- The clock is ticking, full bay specimens perhaps need to be locked in by end of July can we make the leap with current standards of care and assumptions?

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  a test that clearly shows acceptable b
- We are developing models of the full
  preliminary results of such models be
  We think yes.
- The clock is ticking, full bay specimens
  July can we make the leap with curren

DH- end supports, benefit from any end stiffness, and end plate tieing to a core – that helps, what about the haunch bolted down? Stiffness there?

JM- locking out girder, just prop so it does not vibrate, let's have that in the setup. On one side.

RK-In real buildings will have both conditions, won't have locked off in all conditions… in some only have "unlocked"

RK – sidebar - **transverse walking** not tested much to date, because of the specimens.. On 40' span can you get up to pace, but in transverse in real building – then you can get up to pace, so maybe transverse dir. really important. Larger specimen revelatory on the real world case.

JM – full bay hopes and dreams, ok to be aggressive and good with predictions rather than solution that guarantees it works, but not innovative enough.. RK concurs.