Mathew Nirenberg
Metropolis at Dadeland
Structural
Schneider
October 31, 2005
Technical Report 2

Executive Summary
Pro-Con Structural Study of Alternate Floor Systems

This report contains an analysis of a variety of alternative floor systems that are possibilities to be implemented into my thesis building. My building is the Metropolis at Dadeland, which is a 313' tall tower that is primarily residential space with some commercial and parking space included. The existing floor system is a post-tensioned concrete slab that usually ranges from 8" to 9.5".

The first step in redesigning floor systems was to come up with the apparent bay sizes within the existing structure. With minimal adjustment column lines were assumed to be running parallel to the longest face of the building. The spans ranged from 10' to 27'. Because of the wide variety of spans I chose to design for the critical sections since everything else would be safely over designed at worst. The types of systems that I analyzed were concrete planks, concrete joists, concrete skip-joists, steel framing, and composite steel framing.

The floor systems range from 10" to 23.5" deep and have a variety of constructability and technical challenges that are inherent to the application of each system. After reviewing the characteristics of the floor systems I analyzed I feel that the ones most viable for further investigation are pre-cast concrete planking, concrete skip-joists, and non-composite steel framing.

Technical Report 2

Pro-Con Structural Study of Alternate Floor Systems

The bay sizes that I have estimated for the redesign of my structure range from 10' to 27'. Very few columns were removed since there is a pattern resembling column lines running across the diagonal of the building. While the spacing is not close to uniform I am going to just design for the critical cases since the entire floor depth should be uniform. This will result in excessive strength in many areas in order to ease construction and have a uniform structure to install other systems into. Some parts of some shear walls I have assumed to be able to be designed as columns, or possible locations of embedded columns, as well in order to mitigate space between columns in both directions. Floor layouts can be found in appendix A. This was looked at just to find critical bay sizes. The columns were not attempted to be rearranged to make a completely unified system since the focus of this report is on the floor systems.

The loading I am using is based on ASCE 7-98. The live load in the living spaces is taken as 40 psf, on the balconies as 60 psf, in public space as 100 psf, and in the garage 50 psf. The assumed superimposed dead load in the structure is 20 psf and the line load from CMU's is 65 psf. The loads on the eighth floor are substantially higher due to its use as a fitness club for the residents.

The factored loads before excluding floor self weight are:

Living Space:	90psf
Balconies:	125psf
Parking:	110psf
Public Space:	190psf
8^{th} Floor Interior:	265psf
8^{th} Floor Exterior:	530psf

My existing floor system is a post-tensioned concrete slab that is almost entirely 8" thick in the parking deck and 9-1/2" thick in the residential spaces. While this is primarily a one-way system, with secondary post-tensioning for serviceability running the other direction, the definition of one- versus two-way because hard to discern in some locations due to the unique shape of the building.

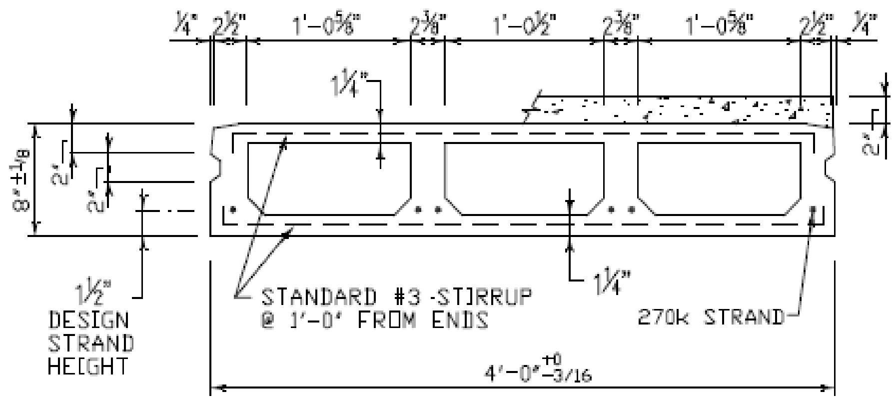
The floors I am investigating as possible replacements for the existing structure are pre-cast concrete plank on concrete beams and columns, a concrete skip-joist system, non-composite steel framing, and composite steel framing.

Floor System 1:

Pre-Case Concrete Planks

(Plank Span Tables found in Appendix B)

8"x4' Span Deck w/ 2" topping should work for most spaces. The two places that this will not carry the load for are the ground floor, which can remain as a slab on grade, and the eighth floor. A 12" thick Span Deck system would work for the interior space since the spans are smaller than the maximum 27', but the 530psf load on the exterior floors, which also has the largest span in the structure, is hard to support. Using the shallowest available double-T's will easily support the loads.



(Nitterhouse)

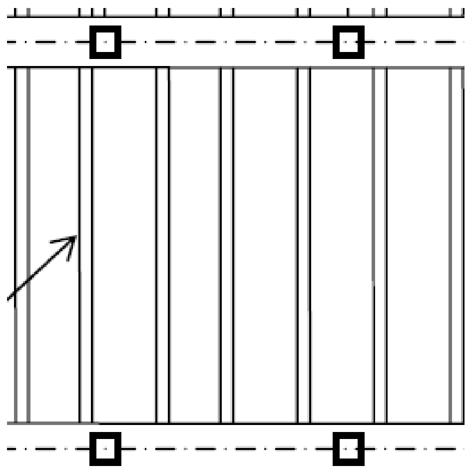
Support for the planks is provided by inverted WT sections. The selection of this section is based on minimum weight section that has a depth less than that of the planking. Due to this a design on using WT7x185 results.

Floor System 2:

Concrete Joists

(CRSI tables found in Appendix C)

There is the possibility here of either going with a joist of 36” modular widths or skip joists of 75” widths. The difference between the two will be a trade off between the number of pans used versus the depth of the system. The 36” system will consume a depth of 16.5” where as the skip-joists will be 18.5” inches deep. When it comes to analyzing the cost of the systems the added amount of steel required for the skip joist system should also be taken into account, both for material costs and labor of installing the bars prior to placing the concrete.



The 36” joist system consists of a 4.5” deep slab with 12” deep ribs that are spaced at 36” c.-c. The reinforcing required are #5 @ 9” on top and 1#6 and 1#7 bars in the bottom in exterior spans. Interior spans only require 1#5 and 1#6 bars in the bottom.

The 75” joist system consists of a 4.5” deep slab with 14” deep ribs that are spaced at 75” c.-c. The reinforcing required are #4 @ 8” on top and 2#5 and 2#6 bars in the bottom in exterior spans. In Interior spans only require 2#4 and 2#5 bars in the bottom.

Floor System 3:

Non-Composite Steel Frame

(Calculations can be found in Appendix D)

Deck: 1.5" LOK floor with 5.5" total concrete depth w/ #3@8"
Beams: W10x49
Girders: W14x120

This system leads to a total depth of 20" of the structural system. A dropped ceiling can be hung at any depth below in order to accommodate other building systems. Larger members can easily be used on the 8th floor to accommodate those loads.

Floor System 4:

Composite Steel Frame

(Calculations can be found in Appendix E)

Deck: 1.5" LOK floor with 5.5" total concrete depth w/ #3@8"
Beams: W10x12 w/ 14 shear studs
Girders: W18x46 w/ 48 shear studs

The shallower members listed in table 5-14 are not capable of carrying the required load.

Comparisons

System	Depth	Constructability (1=easiest)	Pro's	Con's	Further Review Encouraged
Post-Tensioned (Existing)	9.5"	6	thin, contractor familiarity	very technical in both design and installation equipment	----------------
Pre-Cast Concrete Planks	10"	1	thin, easy to work with, no fireproofing needed, greatest uniform thickness lessens sound and vibration transmission	long lead time, various bay sizes a production challenge	yes
Concrete Joists	16.5"	4	minimal lead time, no fireproofing needed	labor intensive, long construction	no
Concrete Skip-Joists	18.5"	5	minimal lead time, no fireproofing needed, lots of extra plenum space within structural depth	labor intensive, long construction	yes
Steel Framing	19.5"	2	quick erection, lighter than concrete system	long lead time, deep members, additional fire-proofing needed	yes
Composite Steel Framing	23.5"	3	moderate erection time, full advantage of materials involved	shear studs are a complication, deep members, additional fire-proofing needed	no

Conclusions:

After reviewing a variety of possible alternative floor systems it is clear that some of the systems are worth considering and some of them are impractical. For instance the difference between the concrete joist and skip-joist that I chose to review is only 2" in depth versus approximately half of the concrete used. That should handily make up for the additional rebar used within each of those joists. Similarly, making a possible steel frame into a composite structure is of little-to-no benefit. There is much more labor and detailing involved in creating a composite system and while some weight is saved some depth is lost. Pre-Cast planks seem to be a viable option because they are relatively shallow, easy to install, and since they are prepared in a controlled environment a high degree of quality and uniformity can be expected.

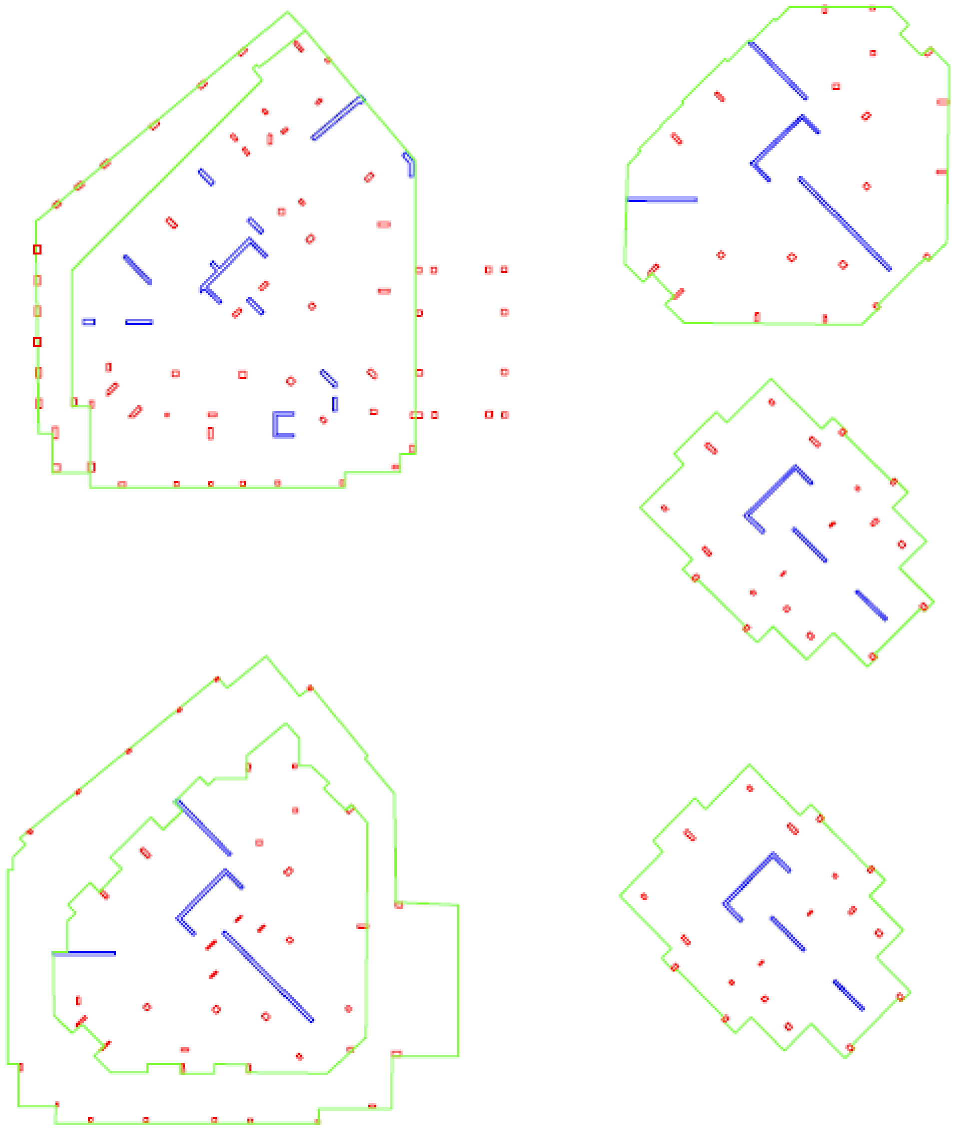
As for the existing system, aside from the savings in slab depth, and therefore structure height, is that in Miami it is such a common system that contractors are familiar with the system and there are enough capable installers in the area to be able to get the job done.

After reviewing the characteristics of the floor systems I analyzed I feel that the ones most viable for further investigation are pre-cast concrete planking, concrete skip-joists, and non-composite steel framing.

Appendix A

(red=column; blue=shear wall; green=footprint)

Floor Plans



Appendix B

8" SPANDECK W/2" TOPPING										ALLOWABLE SUPERIMPOSED LOAD (PSF)												
STRAND PATTERN	SPAN (FEET)																					
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure 4 – 1/2"ø	795	718	650	590	500	426	366	317	275	240	210	184	162	142	125	110	96	84	73	60	49	39	
Shear 4 – 1/2"ø	571	509	458	415	378	347	320	296	275	257	240	222	199	178	160	145	133	126	115	103	93	84	
Flexure 6 – 1/2"ø	1155	1040	945	859	732	629	544	474	416	366	324	287	256	228	204	183	164	147	32	118	103	90	77
Shear 6 – 1/2"ø	589	525	472	428	391	360	331	308	286	266	249	235	220	207	195	184	175	160	45	132	120	110	100

12" SPANDECK W/2" TOPPING										ALLOWABLE SUPERIMPOSED LOAD (PSF)									
STRAND PATTERN	SPAN (FEET)																		
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Flexure 4 – 1/2"ø	446	392	345	305	271	240	214	190	170	151	134	120	106	94	83	73	64	
Shear 4 – 1/2"ø	436	408	379	357	335	309	281	257	234	214	195	181	172	162	149	136	125	
Flexure 6 – 1/2"ø	671	593	527	470	421	378	340	307	277	251	227	206	187	170	154	140	127	115
Shear 6 – 1/2"ø	453	423	397	373	351	331	313	297	282	268	255	237	218	201	186	171	158	146

Double T

Section	$\varnothing M_n$ (in. Kips)
32–4.6 P	6,075
32–6.6 P	8,806
32–8.6 P	11,280

Inverted WT section in order to support planks:

140psf ➔ Mu = $140*27^2/8$ = 130 ft-k

fy=50ksi

S_{req}=M / fy = 130(12)/50 = 31.2in^3

WT7x185 (S=33.9) lightest section with depth<10"

Appendix C

Design to the critical load of 190psf factor superimposed load on the joists.

STANDARD ONE-WAY JOISTS (1) MULTIPLE SPANS	30" Forms + 6" Rib @ 36" c.-c. (2) FACTORED USABLE SUPERIMPOSED LOAD (PSF)											f'_c = 4,000 psi f_y = 60,000 psi
	12" Deep Rib + 4.5" Top Slab = 16.5" Total Depth											
TOP BARS Size @	# 4 12	# 4 9.5	# 4 8	# 5 10.5	# 5 8.5	End Span Defl. Coeff. (3)	# 4 11	# 4 9	# 5 11	# 5 9	# 6 10.5	Int. Span Defl. Coeff. (3)
BOTTOM BARS # #	# 4 # 5	# 5 # 5	# 5 # 6	# 6 # 6	# 6 # 7		# 4 # 4	# 4 # 5	# 5 # 5	# 5 # 6	# 6 # 6	
Steel (psf)	.69	.86	1.04	1.24	1.46		.75	.93	1.18	1.42	1.73	
CLEAR SPAN	END SPAN						INTERIOR SPAN					
21'-0"	168	229	300	319*	332*	2.342	210	299	364	372*	379*	1.441
	0	0	0	371	449*		0	0	388	490	541*	
22'-0"	142	198	263	283*	305*	2.820	181	261	337	345*	351*	1.736
	0	0	0	328	405		0	0	343	436	490*	
23'-0"	120	171	230	270*	281*	3.369	155	229	303	320*	325*	2.073
	0	0	0	290	361		0	0	0	389	446*	
24'-0"	101	148	202	250*	259*	3.995	133	201	269	298*	302*	2.458
	0	0	0	256	322		0	0	0	347	408*	
25'-0"	83	127	176	227	240*	4.703	113	175	238	278*	282*	2.894
	0	0	0	0	287		0	0	0	311	376*	
26'-0"	68	108	154	201	222*	5.502	96	153	211	258*	263*	3.386
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
27'-0"	54	91	134	177	206*	6.398	80	133	187	243*	246*	3.938
	0	0	0	0	229		0	0	0	249	312	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0	0	0	0	205		0	0	0	0	282	
29'-0"		63	100	138	179*	8.516	53	100	147	200	216*	5.240
		0	0	0	183		0	0	0	0	255	
30'-0"		51	86	121	163	9.752	42	85	120	179	203*	6.001
		0	0	0	0		0	0	0	0	230	

Table values go by plf. (190psf)*(75")/(12"/') = 1188plf

WIDE MODULE (1) ONE-WAY JOISTS MULTIPLE SPANS	66" Forms + 9" Ribs @ 75" c.-c. 14" Deep Rib + 4.5" Top Slab = 18.5" Total Depth FACTORED USABLE SUPERIMPOSED LOAD (PLF)											f'_c = 4,000 psi f_y = 60,000 psi
TOP BARS NO AT	#4 12.0	#4 12.0	#4 10.5	#4 9.5	#4 8.0	End Span Defl. Coeff. (2)	#4 12.0	#4 9.0	#5 11.5	#5 10.5	#5 9.0	Int. Span Defl. Coeff. (2)
BOTTOM BARS NO / BARS NO	2#4 1#4	2#4 2#5	1#5 2#6	2#6 1#6	2#5 2#6		2#4 1#4	2#4 2#5	1#5 2#6	2#6 1#6	2#5 2#6	
STEEL (PSF)	.47	.66	.76	[illegible]	.98		.18	.18	.18	.18	.18	
CLEAR SPAN	END SPAN						INTERIOR SPAN					
24'-0" (3)	160	754	987	[illegible]	1423	1.265	55	1415	1764	2017	2389	.779
STIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
25'-0"	92	640	856	[illegible]	1257	1.490	45	1240	1562	1804	2147	.917
STIR	#3- 32	#3- 90	#3-101	[illegible]	#3-104		[illegible]	#3- 93	#3- 89	#3-108	#3-113	
26'-0"	33	539	738	[illegible]	1109	1.743	36	1102	1391	1615	1932	1.073
STIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
27'-0"		449	633	776	978	2.027	288	971	1239	1447	1740	1.247
STIR		#3- 90	#3-103	#3-111	#3-120		#3- 49	#3- 96	#3-104	#3-113	#3-119	
28'-0"		368	540	672	860	2.344	219	854	1103	1296	1560	1.443
STIR		#3- 89	#3-104	#3-112	#3-122		#3- 47	#3- 97	#3-107	#3-101	#3-122	
29'-0"		296	456	579	754	2.888	157	749	981	1161	1415	1.660
STIR		#3- 88	#3-104	#3-113	#3-124		#3- 44	#3- 98	#3-108	#3-109	#3-125	

Appendix D

Non-Composite Steel Frame

Deck: span 5'; 190psf critical load

Use 20 Gage 1.5" LOK floor (United Steel Deck nomenclature)

2 hour fire rating required

2-1/2" concrete required

Slab:

w = 190+(1.2*(5.5/12)*150) = 272.5psf

Mu = $wl^2/8$ = 851.6ft-lb = 0.85ft-k

Asfy = .85*f'c(d-a/2) (assume: d-(a/2) = 0.9d => 3.6")

As = .85*3*3.6 / 60 = .153$"^2$/ft

#3@8" (.165)

a=(As*fy)/(.85*f'c*b) = .3235"

d-(a/2) = 3.84" OK

Beams:

w = 272.5psf * 5' = 1.36klf

Mu = 124ft-k

W10x49 [LRFD p.5-99]

Girders:

w = 272.5psf * 27' = 7.36klf

Mu = 670ft-k

W21x101 or W14x120 [LRFD p. 5-89]

Appendix E

Composite Steel Frame

- Use same loads as in Appendix D for deck, slab, and members.

Beams:
w = 272.5psf * 5' = 1.36klf
Mu = 124ft-k
    W10x12 [LRFD p. 5-146]
        ∑Qn=135k
    21k/stud = 6.43 => 7studs ➔14 total shear studs
        (spaced at 23")

Girders:
w = 272.5psf * 27' = 7.36klf
Mu = 670ft-k
    W18x46 [LRFD p. 5-142]
        ∑Qn=492k
    21k/stud = 23.43=> 24 studs ➔ 48 total shear studs
        (spaced at 6.75")

Resources

AISC LRFD Steel Manual 2001
All steel design

CRSI Concrete Handbook 2002
Joist design and slab thickness suggestions

Nitterhouse Concrete Products
Concrete Planks

United Steel Deck design manual
Deck and slab design