Northbrook Corporate Center is a four story building located in Philadelphia, PA. All four stories will be occupied by office space, while the basement will be used for parking. Floor systems of all the stories are almost identical. Because the basement does not take up the whole building's floor area, the first floor system is not uniform through out. First floor design incorporates four inch concrete slab on grade system in areas where the ground is not excavated. Second, third and fourth floor systems are very similar in design. In this study a typical 30'x30' bay is analyzed (see fig-1). Majority of the rest of the floor area is composed of 4 inch concrete slab on metal decking held in place by 26K7 steel joists. Joists are spaced 3 feet apart center to center, and are held from both sides by W24X68 steel girders. Concrete is poured on 9/16" – 26 GA. UFS form deck, and is reinforced with 6x6 – W2.9xW2.9 WWF; thus, the total slab thickness is 4 inches.

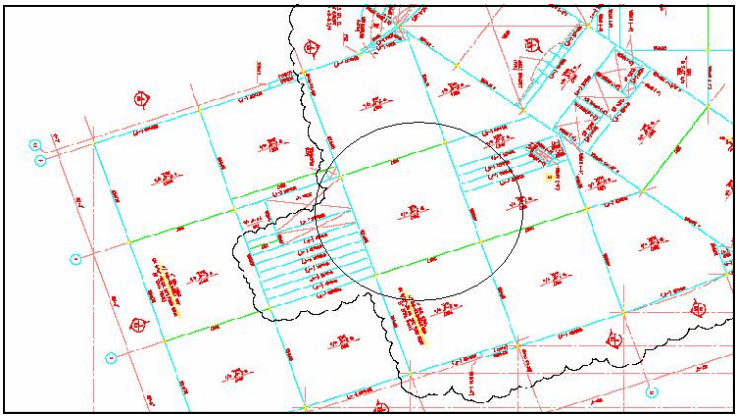

Figure 1

In this design live load of 60 psf (+20 psf partition) is used for office occupancy. Superimposed and self-weight loads were calculated in accordance with the IBC 2003. The 26K7 steel joists prove to be sufficient to withhold all necessary loads including office live loads, superimposed dead loads, concrete slab, and self weight loads.

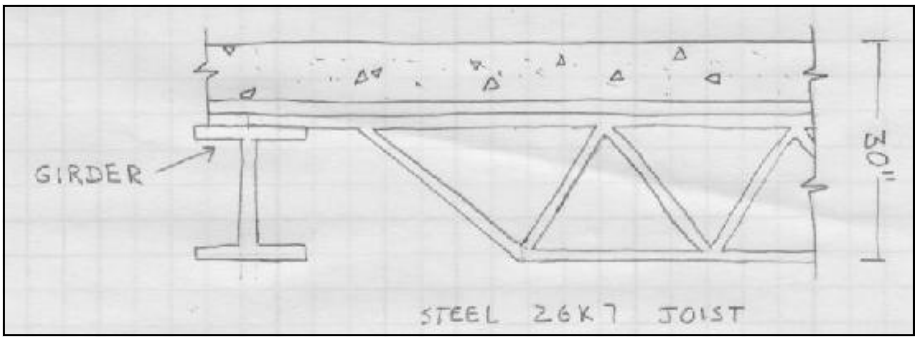

Figure 2

The major disadvantage of the original floor system its overall depth. The steel joists chosen to sufficiently hold the required load are 26 inches deep, and the overall depth of the floor system is 30 inches (see fig-2). However, a 14 feet height of an individual story compensates for the unfortunate depth of the floor system. Steel joists (10 lbs/ft, total weight of the bay is 36.6 kips) do not weigh as much as equivalent steel or concrete beams. Consequently, the columns sizes and seismic load calculations are positively affected. Assembly of steel joist system is fast and cost efficient. As shown in the comparison chart, the total cost of the system is $16.20 per square foot.

All in depth calculations and tables of this design are provided in the appendix.

MODIFIED FLOOR SYSTEM

Replace steel joist by steel beams

The modified floor system includes 4 inch concrete slab on metal decking held in place by W12x22 steel beams. The beams, spaced at 10' o.c., are designed to carry all required live and dead gravity loads. The beams are placed in the same direction as joists in the original design. The overall depth of this system is 17.5 inches (see fig-3), which is much less than the depth the original system (30 in). Change in depth of the floor system will allow the overall building height to be smaller. However, that is about the only advantage this system has over the original. The spacing of beams is 10' o.c., consequently, the slab thickness is larger than one in the original design. As a result, the weight of the system is larger. The total weight of the bay (total weight per column) is 44.3 kips, that is 7.7 kips more than in the existing design. The total cost of the system is around $20 per square foot. The cost estimation of this system is taken from RS Means assemblies Cost Data, 2005. All the tables used to in cost calculations are included in the appendix of this report.

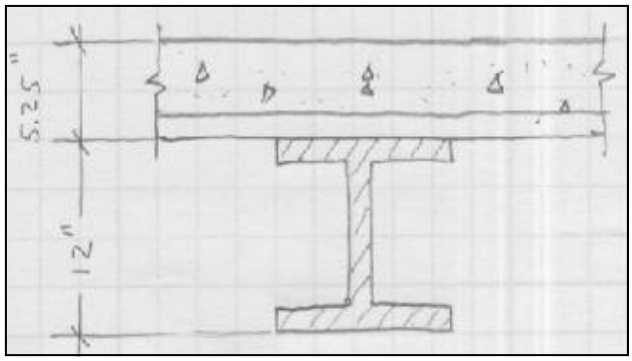

Figure 3

TWO-WAY CONCRETE SLAB

Concrete poured in place

Two way concrete slab floor thickness is usually used in smaller bays. However, to satisfy the purpose of this report this system was analyzed as one of the alternative systems. Because of the larger bay size, the thickness of the slab is calculated to be 11 inches. The slab transports load directly into the columns. Steel reinforcement area of each strip is provided in the table bellow.

STRIP	MOM / FT FT·K / FT	A_s, prov. (in²)	d (in)	a (in)	ϕM_n FT·K/FT
COLUMN STRIP (TOP)	30.7	0.90	8.94	1.32	33.5
MIDDLE STRIP (TOP)	10.2	0.31	9.31	0.46	12.7
COLUMN STRIP (BOTTOM)	13.2	0.34	9.5	0.50	14.1
MIDDLE STRIP (BOTTOM)	8.8	0.31	9.31	0.46	12.7

Table 1

Reinforcement:
CS top: #7@8
CS bttm: #4@7
MS top: #5@12
MS bttm: #5@12

In this specific case, two-way concrete slab system has major disadvantages. Since there are no drop panels used in this

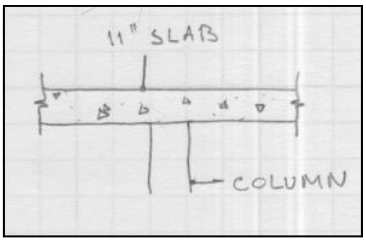

Figure 4

analysis, the minimum column side dimension must be larger than 30 inches (RS Means). The self weight of the slab is extremely large. Total weight per column is 119.6 kips, that is 83 kips more than the existing floor system.

Two-way concrete slab system eliminates all possible obstruction such as beams and girders, making it easy to install all electrical conduits and/or mechanical duct work. The total floor thickness is only 11 inches; that is 19 inches thinner than the original system. Because the system does not have any beams, joists, or girders, building the form for the concrete is very fast and cost efficient. The overall cost of two-way concrete slab is around $15 per square foot. The RS Means table used for this estimate is provided in the appendix.

ONE-WAY VOIDED SLAB

Voided concrete slab poured in place

CRSI 2002 Concrete Design Handbook was used to size this floor system.

One-way voided slab is supported by girders on both ends. This system is similar to two-way slab system; however, the system reduces its self weight by creating the tubular voids (7 inch diameter) inside the slab. Due to the use of girders the puncture shear factor is no longer a concern, and the columns can remain their original size. The overall weight per column is 91.1 kips; that is 28.5 kips less than two-way slab system, and yet, 54.5 kips more than the steel joist system.

Reinforcement:

- Bottom: #6@8
- Shrinkage and temperature top and bottom: #4@18

CRSI 7-17

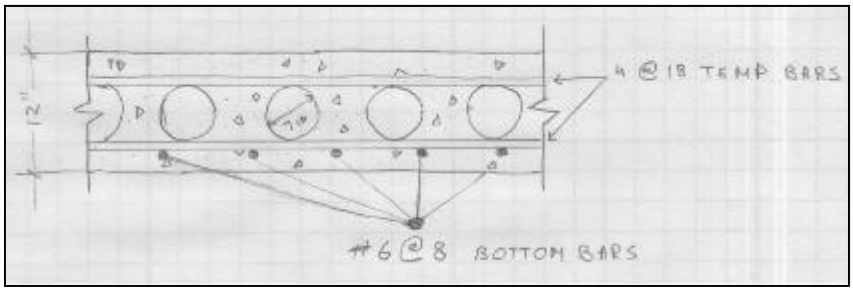

Figure 5

The depth of the system is 12 inches, as shown in figure 5. The cost is more than $15 per square foot. The set up of the form work is rather complicated and time consuming. The voids are created using thin plastic tubes or using foam based material. The concrete is poured in place.

This design is based on f'c = 4000 psi concrete and f_y = 60,000 psi steel; $\rho = 0.005$

Details of this design are documented in the appendix.

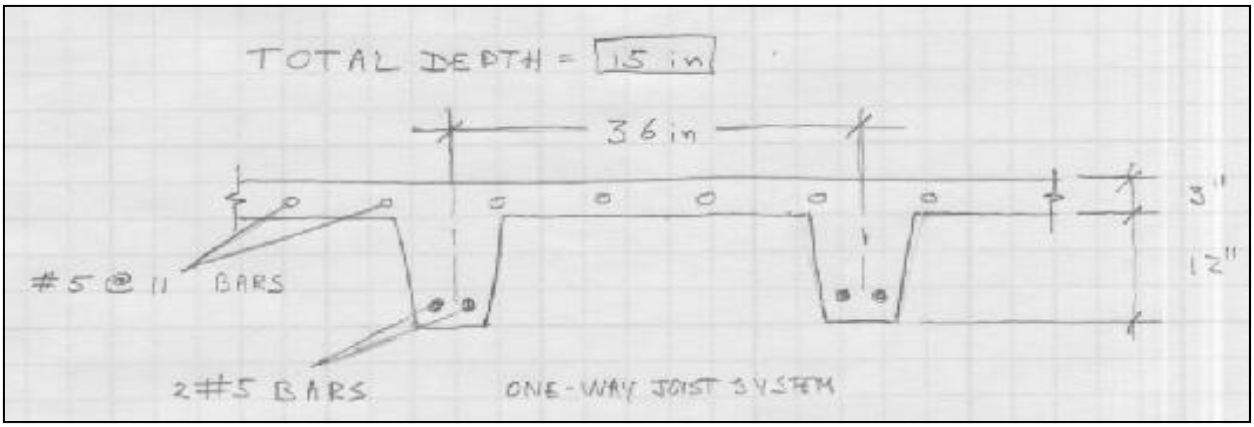

Figure 6

CRSI 2002 Concrete Design Handbook was used to size this floor system.

This design is based on f'c = 4000 psi concrete and f_y = 60,000 psi steel.

Using the table CRSI 8-19 (see appendix) one-way concrete joist system with 12 inch deep ribs and 3 inch concrete slab was chosen for this design (see fig-6). The standard square end joists are 6 inch wide and spaced 3 feet o.c. There are 2#5 reinforcement bars used at the bottom of each joist, and #5@11 bars used in the 3 inch slab.

The overall depth of the system is 15 inches, as shown in the figure above. The weight per column is 63.4 kips, that is 26.8 kips more than the original system, and 27.7 less than the void slab system. The form work of this system is little more complex than the two-way slab system, yet, the system is cost efficient. The total cost of the concrete joist floor system is $14.50 per square foot.

Because of the cost and depth advantages, the system has a potential to compete with the original system. If concrete joist system is used, the height of each story can be reduced by 15 inches. However, the added weight will affect the column size, especially the columns on the lower floors.

COMPARISON CHART

System	Tot. Depth	Col. Weight	Constructability	Total Cost
	(in)	(kips)	1-5; 5=best	($ psf)
Steel Joist	30	36.6	4	16.20
Steel Beams	17.5	44.3	4	20.00
Two-Way Concrete Slab	11	119.6	4	15.00
One-Way Voided Slab	12	91.1	2	15.00
One-Way Con. Joists	15	63.4	2	14.50

CONCLUSION

The purpose of this report is to determine what alternate floor system is the most reasonable system to consider for further design and analysis of the Northbrook Corporate Center. Including the original design, this report analyzes a total of five different floor systems. Two-way concrete slab, and one-way voided slab systems have the smallest overall depth, but the disadvantage of massive self weight outweighs the depth advantage. The modified design has a small overall depth, acceptable self weight, and high constructability ranking, but it is the most expansive system of them all. One-way concrete joists slab is exactly one half the thickness of the original design, however, its self weight almost doubles the existing system. This report concludes that the existing steel joist system is the most feasible system for the four story height Northbrook Corporate Center. The report also recommends a further study of one-way concrete joist slab system as a potentially practical alternative solution.