Final Report

Medical Office Building

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Structural Option

April 5, 2005

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Acknowledgements

Kevin Matthews

For furnishing me plans to my building, allowing me to tour his facility, and answering all my questions along the way.

Jim Kerr

For helping me in the search for my building and introducing me to Kevin

The Architectural Engineering Faculty and Staff

Sharon Williams – For keeping track of everything and everyone, and always being someone to talk to.

Dr. Louis Geschwindner – For his excellent advising, and constant willingness to answer even the most inane questions I could imagine.

Dr. Jelena Srebric – For giving me the opportunity to grow in my studies through research.

Dr. Thomas Boothby – For carefully reading and evaluating my work on this project.

My Parents: Timothy A. Burley Ann E. Burley

For their tireless love, their constant support (both emotional and financial), and their confidence in the person I will become.

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Executive Summary

The Medical Office Building, in Malvern, PA is a six story concrete structure that is part of a larger corporate complex. As the third building in the growing complex, the Medical Office Building's design was largely influenced by its attached neighbors. In order to maintain the same exterior appearance as the two older buildings, the general design and construction methods were retained. In particular, the gravity system of concrete columns was continued, and the floor elevations were matched to make the transition between the buildings through the sky bridge unnoticeable. Despite the matching, some modifications were made to the non-visible systems.

The Medical Office Building introduces a raised floor on Filigree beams instead of a cast-in-place slab on beams system. In addition, open office spaces, and an auditorium were incorporated into the design. Although these systems all serve a purpose, some introduce unexpected complications, and others are not being used to their full potential. One example of a complication is that the Filigree beam system is proprietary, and thus cannot be designed for lateral loads by the engineer. This resulted in a complicated moment frame and system being overlaid to handle lateral loads.

In response to the complexity of this system, a shear wall alternative was suggested. The shear wall system was just as effective as the moment frames, and cost half as much, but it requires the addition of footings with underpinning, which may make the cost rise again. Another option to reduce the system complexity is to simply replace the Filigree beams.

A post-tensioned two-way slab was compared with the Filigree beam system to simplify the floor design. The proprietary nature of the Filigree system made it impossible to determine an actual cost and a comparison between the two-way slab and a banded beam system, which is similar to Filigree, was inconclusive. On the basis of simplicity, and reducing the overall floor depth, the two-way system is the better solution. The advantages of the two-way slab can also be carried to the mechanical system.

The mechanical system of the Medical Office Building is a conventional overhead system. Because the building already has a raised floor, implementing an underfloor air distribution (UFAD) system is a logical improvement. An effective UFAD system was designed for the open office area when the two-way slab had been implemented to increase the ceiling height by 2'-0" over the Filigree system. However, the system would not likely work correctly if the Filigree system were retained.

The last area considered by this project was the auditorium. As an alternative to traditional downlighting, a direct-indirect lighting system was designed. This system resulted in energy savings, which were used to add task lighting. At the same time, the system seems out of place in the auditorium because it is not the traditional design. In this case, the owner's opinion would have to guide the final decision.

Based on the results of the analyses, it is obvious that the current systems in the Medical Office Building are comparable to the new ones. Generally, optimizing the design requires that the whole building be investigated instead of its parts. For the Medical Office Building, both the existing and the proposed designs work just as effectively for the entire building.

Introduction

The Medical Office Building is part of an office complex spanning 111 acres of East Whiteland Township and 5 acres of Tredyffrin Township in Malvern, Pennsylvania. The complex was started in the 1970's with an office building and a data center. A second office building was added in the 1980's and a third office building and a parking garage were added in 1999. The complex has been designed to separate the data center from the office buildings, but the office buildings have been built in the same area and connected by sky bridges to form a single architectural monument (Figure I-1).

Figure I-1 Artist rendering of the sky bridge between The Medical Office Building (left) and its neighbor

The combined structure of the office buildings forms a helix around a sloping central park. The Medical Office Building holds the highest ground on the site and tries to bring the park into its bottom floor through a circular landing that is half occupied by the building's atrium (Figure I-2). This atrium, which resides on the curved southwestern façade, is the only disturbance to the otherwise alternating bands of pre-fabbed panels and windows. The aesthetic appeal of the consistency of these bands across all three office buildings also impacts the design of the interior spaces.

Figure I-2 The Medical Office Building atop of the sloping central park

In addition to matching the exterior components of the Medical Office Building with its neighbor, the designers matched the interior components as well. The most important of these matches was maintaining the same floor elevations so that stairs or ramps would not be need in the sky bridges. To further maintain consistency between the structures, the ceiling heights and visible structural systems were also mimicked. In particular, the large concrete columns (Figure I-3) not only serve as a gravity resistant system, but also as a visual continuation of the previous structures. Where visual continuity is not necessary, the Medical Office Building takes more liberties with its structural systems.

Figure I-3 Concrete columns that serve as the gravity system for The Medical Office Building and an architectural continuation from the existing office buildings

The structural systems of the Medical Office Building are composed of banded beams on columns to resist gravity loads and concrete moment frames to resist lateral loads. The banded beams chosen for this project are a proprietary system from Filigree that consists of 8' by 18" beams built integrally with 9" to 10" slabs (Figure I-4). The beams span 28' in the north-south direction while the slabs span 20' between the beam edges in the west-east direction. Cast-in-place columns, 26" in diameter and 11' high, spaced on a 28' by 28' grid, with additional points for the curved face, support the Filigree beams. Some of these columns also act as part of the moment frames in the building.

The lateral support system of the Medical Office Building is simple in theory, but complicated in practice. Lateral forces in the west-east direction are taken by two exterior and five interior moment frames spanning in that direction (Figure I-5). Interior beams running between torsional members in the west-east moment frame absorb lateral forces in the north-south direction. This system, which is inefficient compared to a direct frame, was necessary because the Filigree system is not intended to resist lateral loads. Although the Filigree system adversely affected the lateral system, it did provide other benefits because of the reduced slab and beam thickness.

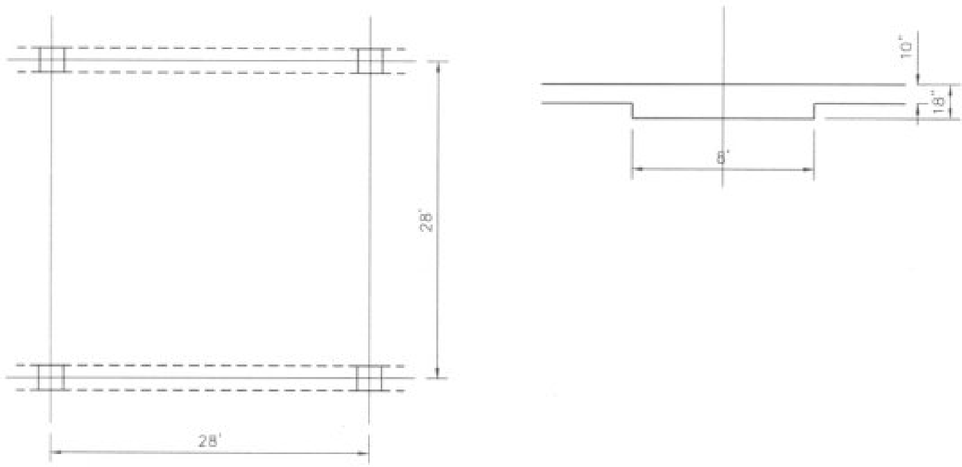


Figure I-4 Filigree beam system schematic

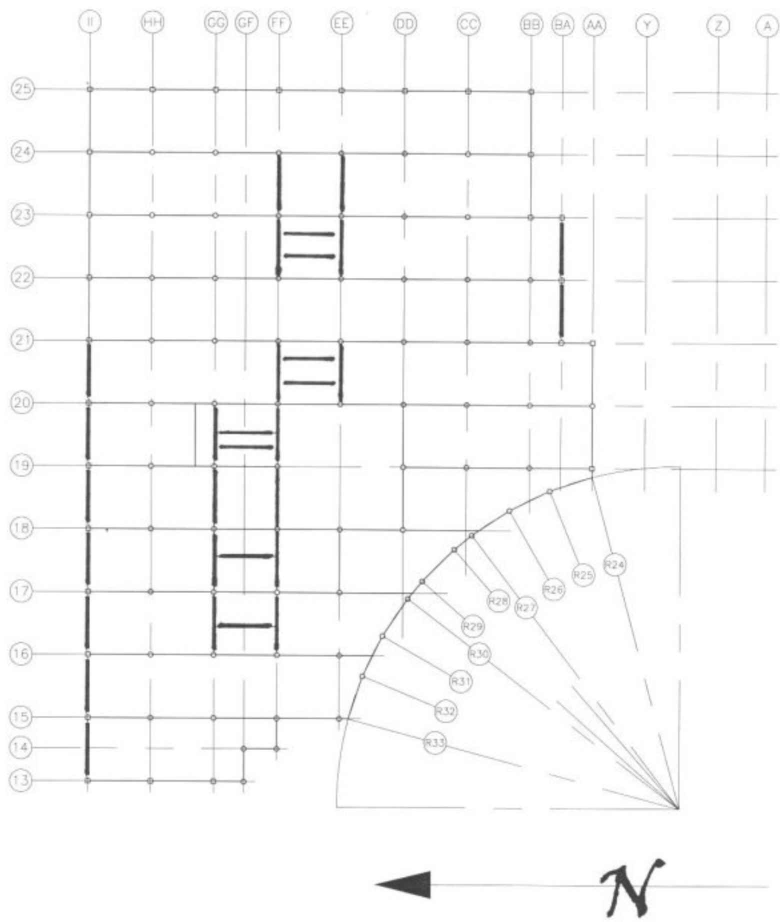


Figure I-5 Lateral Resistant System Layout

Even though the floor elevations match between each office building, the Medical Office Building's finished slab elevation is 6" lower than its neighbor's. The difference in the height of the slabs is compensated for by a raised floor system. This system creates a plenum for all the electrical and telecommunications wiring in the building. This has several positive benefits, particularly in laying out the areas of open office space, since cubicles do not need to be clustered around the columns to reach the electrical outlets. Also, the suspended ceilings only have to support the lighting and heating ventilating and air-conditioning (HVAC) system, thus eliminating sag issues that plague the two older buildings.

The main reason why ceiling sag is such an issue is because of the massive amounts of wiring utilized by the offices in the complex. The Medical Office Building alone has over $2.8 million in wiring. The daunting size of the wiring of the building is matched only by the massive redundancy of the electrical system (Figure I-6). Due to the importance of the information stored in the data center two 1500kVA power lines feed the complex. In addition, all the major circuits are protected by three hour uninterruptible power systems and by four diesel generators capable of providing power for two and a half days. Another benefit of the data center is that it acts as a free heat source.

Figure I-6 Switching board for the Medical Office Building

As an office, the Medical Office Building requires cooling year round from its HVAC system. This cooling is provide by four 50 ton, three 70 ton, and one 90 ton central heat pumps, which extract heat using a variable air volume (VAV) ventilation system. This system is networked to a central handling station, but can be overridden by local controls in each zone. In addition to the VAV system, the Medical Office Building takes advantage of the heat from the data center to control the building envelope heat transfer. This is accomplished through a heat recovery system, which uses heat from the data center to raise water to 100ºF before running through 311 perimeter heat pumps (Figure I-7). These heat pumps absorb most of the envelope heating load during the year.

Figure I-7 A disassembled perimeter heat pump, heat pumps such as these control the interior envelope temperature and absorb most of the envelope heating load.

The mechanical systems of the Medical Office Building also include two fire protection systems. The first fire protection system is a wet sprinkler system. Sprinklers are placed in every zone of the building on a 12' by 12' grid to protect the general office spaces. The atrium is protected by a water curtain system that is triggered by laser smoke sensors. Both of these systems are connected to a Simplex 4100 Annunciation panel that monitors and controls each sprinkler head. Fire doors are also interspersed in the office spaces to divide the building in case of disaster.

The technology used by the systems in the Medical Office Building largely address the technological, safety, and serviceability concerns of the owner. However, these systems are not without their drawbacks. One such example is that the electrical outlets on the raised floor often crack from foot traffic. Although this does not have a severe impact on the building, it shows that minor modifications to the building could improve its overall quality. With this philosophy in mind, the following report will explore alternative designs to the structural, mechanical, and lighting systems in the Medical Office Building.

1 Shear Wall Analysis

Introduction

The current lateral system in the Medical Office Building consists of cast-in-place (CIP) concrete moment frames and torsion beams. Although the frame system is effective for the Filigree beam system, it detracts from some of the benefits of the Filigree beams and suffers certain inefficiencies because it has to work around the Filigree beams. In particular, the frame beams, which are up to 48" deep, divide the channeled plenums created by the Filigree system. These same beams are also 30" lower than the floor system beams, which generally means that the ceilings most be hung lower to hide the frames. In addition, the frames themselves are placed in such ways that lateral loads can generate significant torsion in the building. A careful redesign could alleviate some torsion and lead to a more efficient system.

Solution Overview

One alternative to moment frames as a lateral system is shear walls. Properly located shear walls would reduce the number of plenum channels that are interrupted, eliminate the deep beams and thus potentially increase usable space, and move the center of stiffness of the building to alleviate torsion. Another notable feature of shear walls is that they are typically located at the building's edges or around the stairwells. Because the current frame system is located along the stairwells there are already several bays that could have shear walls added without affecting the rest of the Filigree system.

Design Criteria

When considering the effectiveness of the shear wall system, there are several factors that need to be addressed:

- Can the shear walls meet code?
- Can the shear walls be constructed at no greater cost?
- Will the shear walls introduce more problems than they correct?

The first question will be addressed by designing the shear walls based on the IBC 2003 Building code. The second question will be addressed by running a cost analysis based on data provided by RS Means. The last question will be addressed by comparing and contrasting the utility of the building with frames and with shear walls. Regardless of the final conclusion, if the shear walls cannot meet the code requirements, they will be discarded as a solution. The majority of the conclusion will be weighted on the answers to the latter two questions. A savings in cost and schedule in addition to the introduction of few problems will be considered a great success. Combinations of higher costs and fewer problems or lower costs, but more problems will be considered successes based on the relative severity of the costs and benefits.

Preliminary Analysis

One of the major considerations in the design of any lateral system is trying to keep the center of rigidity near the center of gravity to limit the torsional moment generated by uneven wind loads. In considering the use of shear walls, it is necessary to evaluate not only the center of rigidity, but the effects on the architectural design and the other building systems. In the case of the Medical Office Building, the architecture of the façade makes the use of exterior shear walls impossible. However, a sound lateral system should include resistance along the exterior surfaces to efficiently resist torsion. For this reason, the two moment frames on the exterior walls were retained and shear walls were investigated for several internal locations.

In order to minimize the impact on the other building systems and the architecture, the shear wall locations were chosen to be around the stairwells and bathrooms (Figure 1-1). Based on these locations it was possible to determine the height and maximum depth of the shear walls. Once the heights of the walls were determined, the required thickness could be calculated based on the slenderness criteria that the thickness be greater than or equal to 1/30 the height. Knowing the dimensions of the shear walls it was possible to determine their stiffness. A STAAD analysis of the two existing moment frames also revealed their stiffness, the full details of these analyses appear in Table 1-1.

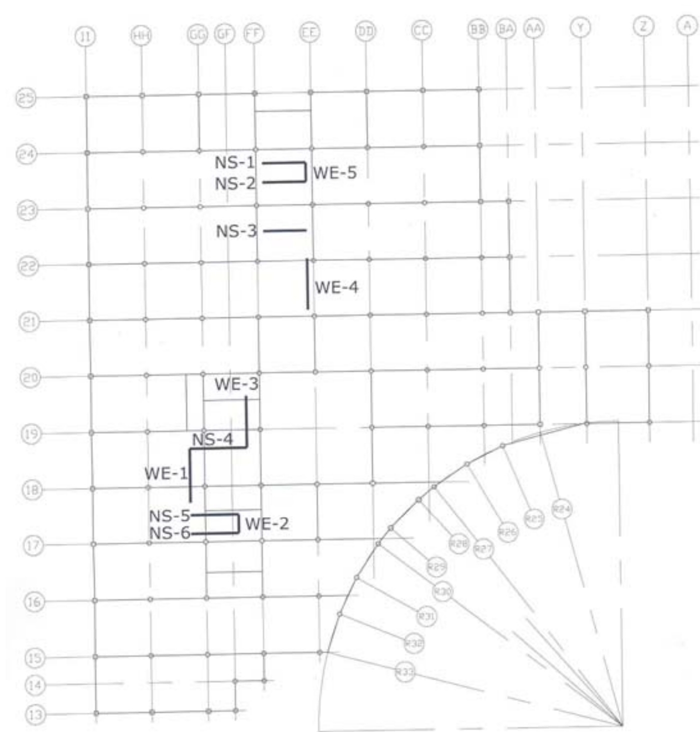


Figure 1-1 The schematic showing the potential shear walls in plan

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	k (k/in.)
N-Frame	-	-	-	-	-	111.00
S-Frame	-	-	-	-	-	36.00
NS-1	16.00	21.75	37.50	23706108.00	4176.00	1707.90
NS-2	16.00	21.75	37.50	23706108.00	4176.00	1707.90
NS-3	16.00	21.75	37.50	23706108.00	4176.00	1707.90
NS-4	16.00	28.46	37.50	53101997.83	5464.00	3370.93
NS-5	20.00	23.82	50.00	38938326.51	5717.50	1261.20
NS-6	20.00	23.82	50.00	38938326.51	5717.50	1261.20
WE-1	16.00	27.00	37.50	45349632.00	5184.00	2963.40
WE-2	20.00	9.58	50.00	2534791.67	2300.00	92.69
WE-3	16.00	26.08	37.50	40885729.33	5008.00	2719.79
WE-4	16.00	26.00	37.50	40495104.00	4992.00	2698.13
WE-5	16.00	9.58	37.50	2027833.33	1840.00	172.43

Table 1-1 Summary of shear wall and moment frame properties

Using the properties of the shear walls and moment frames it was possible to perform a stiffness analysis to determine the center of rigidity for various combinations of shear walls. The full excel spreadsheets detailing this analysis appear in Appendix I. A summary of the walls utilized in the analysis and their respective eccentricities appear in Table 1-2. Based on these results it can be seen that the least eccentricity results from the use of shear walls at the inside edges of the stairwells and around the bathroom walls. These walls were chosen for further analysis.

Walls	X-eccentricity	Y-eccentricity
All	-10.18’	1.22’
NS-1,2,5,6 & WE-2,5	-8.77’	-8.42’
NS-3,4 & WE-1,4	-10.08’	12.49’
NS-2,3,4,5 & WE-1,4,5	-9.21’	5.04’
NS-2,3,4,5 & WE-3,4	5.16’	5.04’

Table 1-2 Eccentricity Analysis of shear wall combinations

Secondary Analysis

Starting with the shear wall combination chosen from the preliminary analysis, a further evaluation of the least eccentric combination was performed to test the actual strength and size of the walls needed. Shear walls resist lateral loads on a building, predominantly those from wind. Earthquake forces also produce lateral loads, but the columns in the building would assist in carrying this load, and thus not be the controlling value in the design. The wind loads (Figure 1-2) on the Medical Office Building, as determined by guidelines in ASCE 7-02, are 267 kips in the North-South direction and 192 kips in the West-East direction.

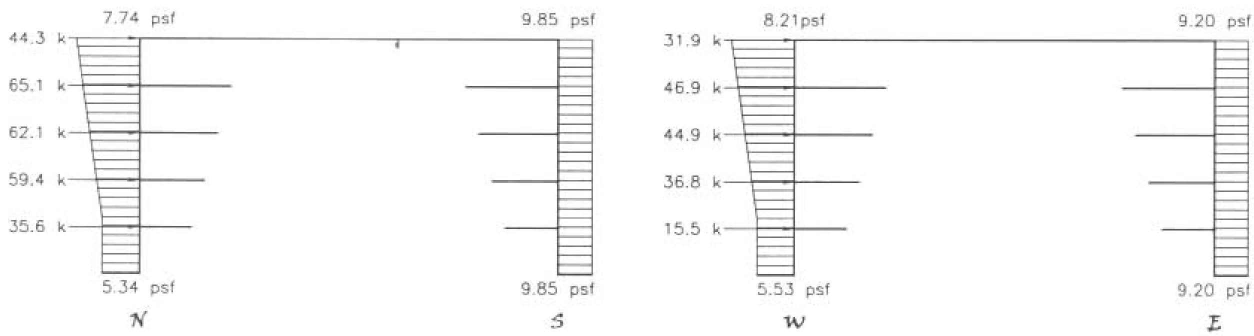


Figure 1-2 Wind profiles for The Medical Office Building

These loads were distributed to the shear walls and frames through a stiffness analysis. The loads in the shear wall were then evaluated against the strength of an unreinforced masonry wall, using 3000 psi CMU blocks fully grouted:

$$\phi V_n = 0.8 * 3.8 A_n \sqrt{f_m^{'}} \quad (1\text{-}1)$$

The walls were then resized to more closely match the depth required for strength. This redesign resulted in a change of stiffness, and thus the need for another distribution of the loads. Inevitably the process of redistributing the loads would result in the elimination of the shear walls altogether, as the reduced depths would mean more of the load enters the frames. For this reason, the frames were limited to carrying 10% of the shearing force from a symmetric load. In addition, the shear walls could not exceed an in-plane stress due to bending greater than 250 psi without reinforcing. With these requirements in place, several sizes of shear walls were checked using excel, the final results being shown in Table 1-3.

Wall	V_ult	f (psi)	ΦV_n
N-Frame	13.59	-	-
S-Frame	3.91	-	-
NS-2	75.48	54	174.56
NS-3	29.01	31	67.10
NS-4	118.05	230	273.01
NS-5	45.41	123	105.01
WE-3	109.14	231	252.40
WE-4	63.64	139	147.18

Table 1-3 Summary of shear wall analysis showing the carried load, the bending stress and the allowable shear

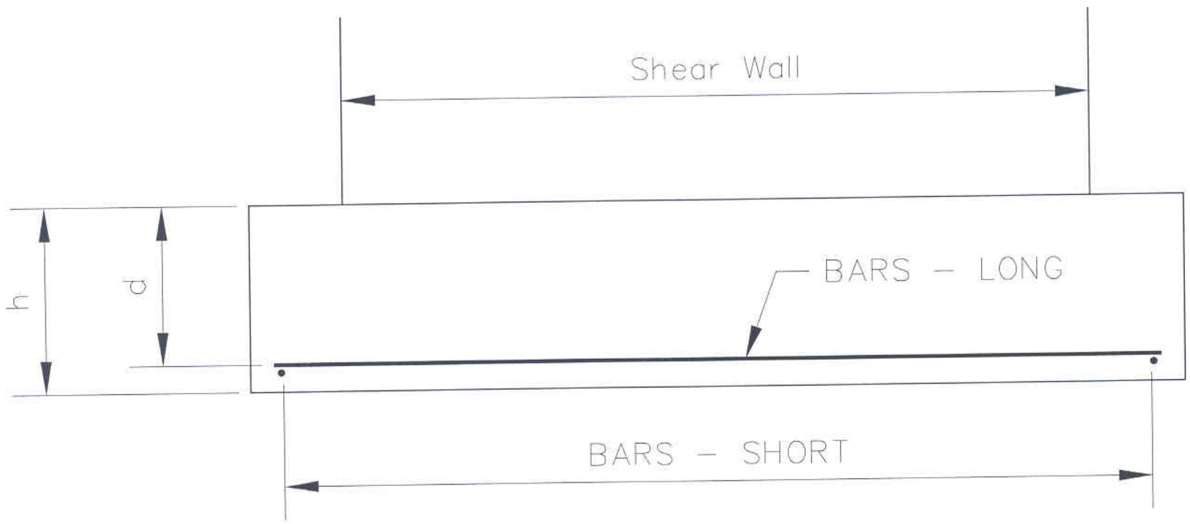
Final Design

In order for the shear walls to perform effectively they must have a proper foundation. In this case it was assumed that the shear walls would take a portion of the floor loads, as determined by tributary area, in addition to the lateral loads. Moments of overturning were approximated by applying the final shear at 2/3 the height of the shear wall. Based on the maximum stress due to the gravity loads and the moments, the initial size of the footings was determined. Once the initial size was known, an analysis of overturning was performed (Table 1-4).

Wall	M_o (ft-k)	P (k)	e (ft)	B (ft)	L (ft)	q (ksf)	kern
NS-2	1887.06	221.87	8.51	24.00	6.00	4.82	4.00
NS-3	725.36	158.48	4.58	15.00	6.00	4.98	2.50
NS-4	2951.34	253.57	11.64	26.00	7.50	4.79	4.33
NS-5	1513.60	304.98	4.96	24.00	6.00	4.75	4.00
WE-3	2728.54	316.96	8.61	30.00	6.00	4.79	5.00
WE-4	1591.04	253.57	6.27	23.00	6.00	4.85	3.83

Table 1-4 Overturning analysis of footings

Based on this analysis it becomes clear that overturning becomes a serious issue with the shear wall footings. There are several means of remediation for this problem, including using underpinning, increasing the size of the footing, or burying the footing. Increasing the footing size would be inefficient, and burying the footing would require excessive excavation, therefore, the best solution is to underpin the footings. The analysis of the necessary underpinning was not conducted as part of this work, but the footings were designed using the above loads after modification for strength design. A general schematic of the slab design, and the results of the analysis for each shear wall appear in Figure 1-3.



Wall	q_design (ksf)	d (in)	h (in)	A_s (in^2)		Bars – Long	Bars -Short
				Long	Short		
NS-2	8.62	36	39	0.84	0.84	#6's @ 6"	#6's @ 6"
NS-3	6.60	17	20	0.44	0.43	#6's @ 12"	#6's @ 12"
NS-4	7.85	45	48	1.04	1.04	#6's @ 5"	#6's @ 5"
NS-5	6.11	27	30	0.69	0.65	#6's @ 7"	#6's @ 8"
WE-3	7.07	29	32	0.73	0.69	#6's @ 7"	#6's @ 7"
WE-4	6.38	21	24	0.60	0.52	#6's @ 8"	#6's @ 9"

Figure 1-3 Footing Design for shear walls

Conclusions

The proposed shear wall design requires the construction of six masonry walls and their foundations. Each wall was designed using applicable code, and therefore meets the legal requirements for use. The existing system that can be removed as a result of the redesign includes 60 beams, from the moment frames, and their reinforcing. The columns and footings would be retained as party for the gravity structure, therefore, no savings can be recovered from the existing footings. A cost comparison through R.S. Means is presented in Table 1-5. This data shows that there is a $70,000 benefit from the use of the shear wall system.

	Shear Wall	Moment Frame
CMU Block	$35,728	$0
Footing Formwork	$4,301	$0
Footing Rebar	$2,895	$0
Footing Concrete & Placement	$21,904	$0
Beam Formwork	$0	$3,960
Beam Rebar	$0	$33,780
Beam Concrete & Placement	$0	$96,540
TOTAL	$64,828	$134,280

Table 1-5 Cost Comparison of Shear Walls to Moment Frames

Before drawing a final conclusion though, it is necessary to consider the effects the shears walls have on other systems. Although the shear walls were placed to avoid impact, they still represent an impenetrable barrier between certain areas. In one respect, this creates additional sound damping, particularly important around bathrooms and stairwells, where the walls were located. In another respect, the shear walls around the bathroom may interfere with runs of pipe, electrical lines, and mechanical ducts. There is no clear cost benefit to the improved sound damping, but there is a calculable deficit if additional amounts of mechanical, electrical, and plumbing work are required. The cost estimate also ignores the cost of underpinning the shear wall foundations to prevent overturning.

Despite the possible related costs to the shear walls, they are still the more economical system and are recommended as a replacement system for the moment frames.

2 Post-Tensioned Two-Way Slab

Introduction

The Filigree beam system creates a thin lightweight floor system that leaves plenty of open plenum space for mechanical and electrical equipment. However, the beams divide the plenum space into channels, reducing the overall utility. In addition, the system is designed by Filigree Incorporated, making it a black box for the engineer of record. A preliminary investigation showed that a conventional two-way slab system can provide slabs that are just as thin, and bring the design back into the hands of the engineer of record. It may be possible to achieve even thinner slabs by introducing pre-stressing or post-tensioning to the system.

Solution Overview

Proprietary systems have costs and benefits in addition to those assumed by conventional systems. In this case a conventional two-way slab provides a nearly identical product to the proprietary Filigree system. Considering that the two-way slab does not have the additional costs of using a proprietary system, it appears to provide a better value. This value can be improved by using pre-stressing or post-tensioning to reduce the overall slab depth, thus increasing the usable space. Therefore, a pre-stressed two-way slab may be a very effective alternative to the proprietary Filigree beam system. In addition to creating more usable space, the two-way slab system will also eliminate the channeling of the plenum and allow the free placement of lateral resisting systems.

Design Criteria

The following questions must be addressed regarding the effectiveness of the two-way slab:

- Can the two-way slab meet code?
- Can the two-way slab be constructed at no greater cost?
- Will the two-way slab introduce more problems than it corrects?

The code governing the design of the two-way slab will be IBC 2003. The cost analysis will be based on data provided by RS Means. The last question will be addressed by comparing the benefits and disadvantages of the two-way slab to the Filigree beam system. For the two-way slab to be considered, the first question must be answered in the affirmative. The remaining two questions should also be answered in the affirmative if the two-way slab is optimal. If the two-way slab is not optimal, then the relative success and failure compared to the Filigree system will determine the final decision on whether or not the two-way slab is a reasonable alternative.

Load Analysis

When considering two-way slabs in a post-tensioned system, it is important to perform an advanced analysis of the loads and their effects at different locations in the building. For the Medical Office Building, there were three locations considered to determine the worst case loading for a two-way slab system; the longest interior span, an exterior span with edge beams, and an exterior span without edge beams (Figure 2-1). Each of these areas has a different set of design criteria based on code, and has to be evaluated to ensure the safety of the slab at all locations. In order to simplify the construction of the design, modification of the design to respond specifically to each support was forgone in favor of evaluating only the maximum condition in each of the three slab areas and applying the resultant design to all similar locations.

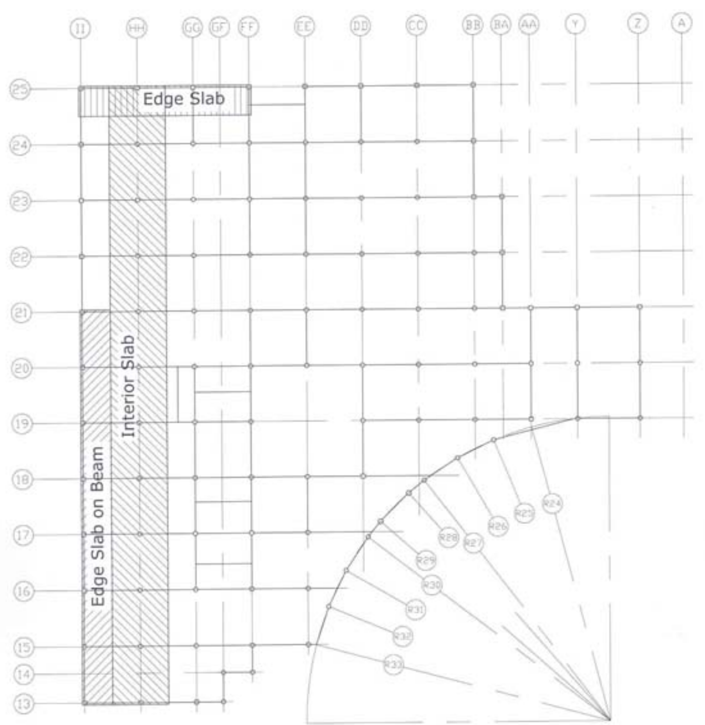


Figure 2-1 Typical floor plan highlighting the three areas of the slab evaluated for design

In order to determine the requisite loads for the slab an initial guess at the slab thickness was taken as 1/36th the clear span of the slab, which is 25’-10”. The resulting slab depth of 9” leads to a dead load for normal wiehgt concrete of 112.5 psf, an additional 15 psf was added for mechanical electrical and plumbing (MEP) equipment, and an additional 10 psf was added for the combined raised floor and hung ceiling weights. The live load for a typical office building is 80 psf according to ASCE 7-02, but this value was increased to 100 psf to account for additional loads related to open planning, such as movable partitions and corridors.

The evaluation of the three loads was performed using ADOSS, the full results can be found in Appendix II. A summary of the critical results for each section appears in Table 2-1.

Slab	M_{col} (ft-k)	M_{mid} (ft-k)	M_{beam} (ft-k)	v (psi)
Edge with beams	45.3 (-) 33.0 (+)	37.6 (-) 27.4 (+)	256.5 (-) 186.9 (+)	155.84
Edge without beams	233.3 (-) 136.5 (+)	77.8 (-) 91.0 (+)	-	330.69
Interior	399.3 (-) 216.5 (+)	133.1 (-) 144.3 (+)	-	328.03

Table 2-1 Critical Shear and Moment as calculated by ADOSS

ADOSS does not cover wide beam shear analysis, but a brief investigation reveals that the per foot strength is roughly 9.5 kips. Based on the aforementioned loads, the shear on a per foot basis is only 4.5 kips, so wide beam shear does not control.

Shearhead Investigation

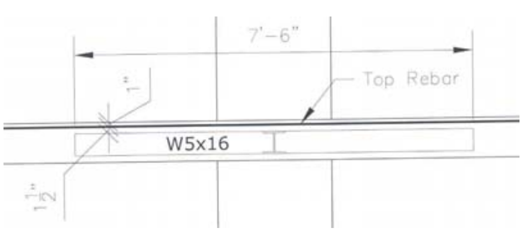
The ADOSS analysis showed that the majority of cross-sections did not meet the necessary requirements for shear strength. The ACI code states this strength as:

$$\phi v_n = 0.75 * 4\sqrt{f_c^{'}} \qquad (2\text{-}1)$$

For 5000 psi concrete, this value is 212.13 psi. The code also states that the strength can be taken as:

$$\phi v_n = 0.75 * 7\sqrt{f_c^{'}} \qquad (2\text{-}2)$$

if shearheads are used. The shear strength developed on the new shear plane created by the shearheads must still meet the first strength requirement. The new capacity for shear in 5000 psi concrete is thus 371.23 psi at the standard shear plane, and 212.12 psi at the extended shear plane. The size of the shearheads required to generate the necessary secondary shear plane were determined using a program written in EES (Appendix III). The results of this program show that the exterior shearheads must extend 4’-3” from the center of the columns, and that the interior shearheads must extend 3’-9” from the center of the columns (Figure 2-2).



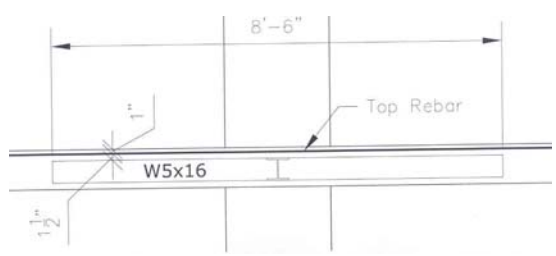


Figure 2-2 Shearhead details for interior (left) and exterior (right) columns

Post-Tension Investigation

Besides shear strength it is also important to consider the moment capacity of each of the sections. An analysis of the bulk cross section of each segment of slab is summarized in Table 2-2.

Segment		A_s (in^2)	Bars	Spacing (in)
Interior Column	Top	12.74	64 # 4's	2.55
Strip	Bot	6.66	34 # 4's	4.67
Interior Middle	Top	4.03	21 # 4's	7.30
Strip	Bot	4.38	22 # 4's	7.00
Exterior Beam	Top	1.56	8 # 4's	9.60
Column Strip	Bot	1.56	8 # 4's	9.60
Exterior Beam	Top	2.72	14 # 4's	10.50
Middle Strip	Bot	2.72	14 # 4's	10.50
Exterior Beams	Top	2.01	3 # 8's	5.00
	Bot	2.79	3 # 9's	5.00
Exterior	Top	13.60	68 # 4's	1.37
Column Strip	Bot	4.22	22 # 4's	4.00
Exterior Middle	Top	2.72	14 # 4's	10.50
Strip	Bot	2.74	14 # 4's	10.50

Table 2-2 Analysis of slab sections

From this analysis, it can be seen that the sections that will most benefit from post-tensioning are the column strips on the exterior surfaces without beams and in the interior. Tensioned reinforcement must provide the same force as the untensioned reinforcement for the design to be valid. The code limits the pressure allowed in tension cables in two ways:

$$f_{ps} = f_{pu}\left(1 - \frac{\gamma_p}{\beta}\left[\rho_p \frac{f_{pu}}{f_c^{'}} - \frac{d}{d_p}(w - w')\right]\right) \quad (2\text{-}3)$$

$$f_{ps} = f_{se} + 10 + \frac{f_c^{'}}{300\rho_p} \text{ ksi} \quad (2\text{-}4)$$

Using these limitations and choosing cables with an ultimate strength of 275 ksi and a yield strength of 240 ksi, an iterative design process was used to find the required area of cable and their post-tensioning force. This process found that for the interior columns, 4 in^2 of cable tensioned by 920 kips was adequate, and for exterior columns, 4 in^2 of cable tensioned by 900 kips was adequate. Both of these designs are detailed in Figure 2-3.

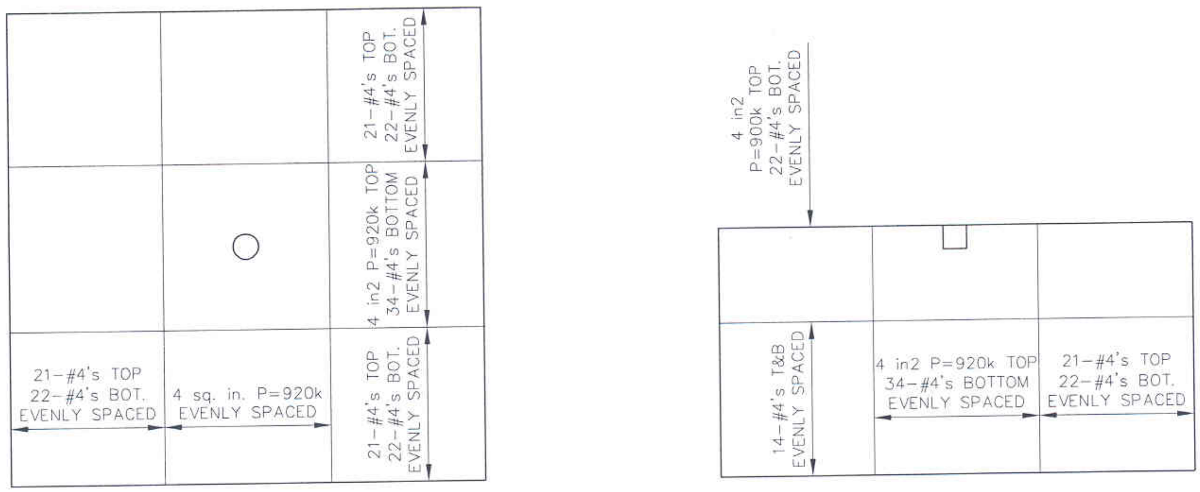


Figure 2-3 Details of the two-way slab: Interior (left), Exterior (right)

Deflection Analysis

The final consideration in the design of the two-way slabs is deflection. According to ADOSS, the interior spans due not meet the code requirements to neglect deflection. Therefore a deflection analysis was performed on the interior slab section to determine whether the slab meets the serviceability requirements. The tension in the cables generated an initial camber of 0.95" upward. This camber leads to an immediate and long-term deflection of 0.11" downward, which is less than the limits of 0.93" and 0.70" for immediate and long-term deflection respectively.

Conclusions

The two-way slab meets all the design and serviceability requirements for code. Therefore, the system can be a reasonable alternative to the Filigree beam system. A direct cost comparison is not possible between the two systems because of the proprietary nature of the Filigree system. However, comparing the cost of the post-tensioned two-way slab to a typical banded beam system (Table 2-3) should provide a reasonable comparison.

	Two-way	Banded
Slab Formwork	$457,050	$457,050
Slab Reinforcing (w/ shearheads)	$161,020	$33,083
Slab Post-tensioning	$165,000	$0
Slab Concrete and Placement	$839,237	$839,237
Beam Formwork	$0	$173,765
Beam Reinforcing	$0	$63,000
Beam Concrete & Placement	$0	$275,229
TOTAL	$1,622,307	$1,841,364

Table 2-3 Cost comparison of a two-way slab and a banded beam system

The difference in cost between the two systems is $219,000, which is nearly the cost of the concrete in the beams. In fairness to the Filigree system, less concrete is used than in cast-in-place construction. Assuming that the Filigree beams use 30% less concrete, would result in a $334,000 savings. This makes the Filigree system more favorable by $115,000. However, factory costs, transportation costs, and other fees associated with the Filigree technology, including the charges of the contractor for working with an unfamiliar system may eat up these savings. Due to these speculative expenses, it is difficult to discern which system is of better economic value. Fortunately, the economic value alone is not a deciding factor.

Although the Filigree system provides a thin floor structure, it is still twice the overall depth of the two-way slab due to the beams. The direct consequence of the deeper system is the loss of usable space in the building. The indirect consequence of the beams hanging down is that they divide the plenum space of the building into strips, which means the ceilings must be hung deeper to allow enough clearance for ductwork and wiring in areas directly beneath the beams. Because the two-way slab system is flat, there is no division of the plenum, and the hung ceiling may be hung much closer to the bottom of the slab, thus recovering even more usable space.

Despite an uncertain cost advantage, the additional benefits of a two-way slab system make it an appealing alternative, particularly because they can be used to optimize the building for Underfloor Air Distribution.

3 Underfloor Air Distribution

Introduction

The Medical Office Building makes use of a raised floor system as an electrical and telecommunications plenum. It does not utilize this space as a mechanical plenum, instead sticking with a traditional overhead ventilation system to provide air for the space. Because the raised floor already exists in the building, it makes sense to maximize the use of this space by introducing an underfloor air distribution (UFAD) system.

Solution Overview

There are several varieties of underfloor air distribution systems. The system most adaptable to an existing raised floor would be a fully ducted system. However, this does not generate any savings compared to an overhead system, as just as many ducts, if not more, would be required. A better alternative is a pressurized plenum. Although this system may require a different raised floor to prevent leaks, it would not interfere with the current use of the plenum. Therefore the UFAD system redesign will be a pressurized plenum system.

Design Criteria

The purpose of heating ventilating and air conditioning (HVAC) systems is to provide for human health and comfort in buildings. For this reason the system should be judged on:

- The ability to provide a thermally comfortable environment
- The ability to provide enough air for a healthy environment

If the system can meet both of these requirements then it should be termed an acceptable alternative. The issue of cost is also important, but since the raised floor is already present in the building and there will be less ducts with a pressurized system, cost savings are already assumed.

Environmental Comfort

The design of UFAD systems takes into account the same loads as conventional HVAC systems. However, because UFAD systems rely on convection from heat sources in an occupied zone, the thermal load they are expected to remove is calculated only to a height of 6 ft. Any heating load that acts only in the unoccupied zone does not have to be taken into account when determining the amount of ventilation required for thermal comfort.

For the purposes of this investigation, an area of open office space (Figure 3-1) was chosen as a basis for the system design. For the sake of simplicity, it was assumed that the surrounding interior environments are kept at the same temperature as the open office, and therefore have a negligible effect on the loads in the space. The exterior window still effects the loads in the Medical Office Building through conduction from and infiltration of the outside air. A full list of the loads and their contribution to each of the zones is summarized in Table 3-1.

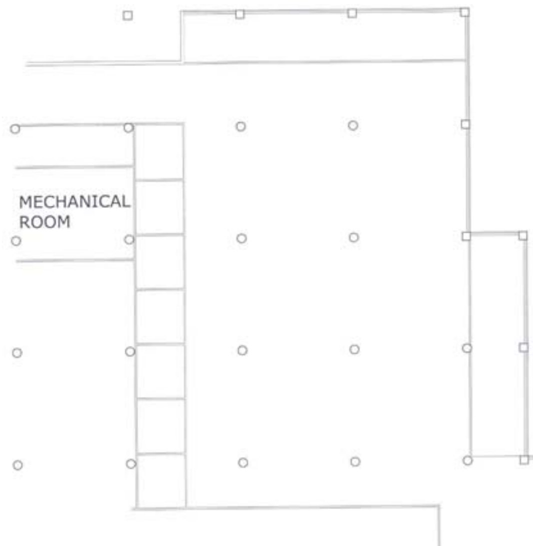


Figure 3-1 Plan of area for proposed UFAD system

Source	Unoccupied Load (Btu/hr)		Occupied Load (Btu/hr)	
	Winter	Summer	Winter	Summer
Lighting	7400	7400	29600	29600
Occupants	0	0	10800	10800
Computers	0	0	13226	13226
Infiltration	-586	199	-4102	1390
Conduction	-2213	750	-6935	2349
TOTAL	4601	8349	42589	57365

Table 3-1 Summary of loads in both the occupied and unoccupied zones

The amount of air required to remove heat from a space can be determined from:

$$q = 1.08\dot{V}\left(T_{\sup ply} - T_{exhaust}\right) \tag{3-1}$$

For typical UFAD systems, air is supplied at 65°F. On average, most people are comfortable in an environment that is 72°F, this condition will be assured if the exhaust temperature is at this temperature. Based on thermal comfort, the required ventilation for the space is 7588 cfm. However, thermal comfort alone does not make an adequate ventilation system. Human health is also an important requirement. ASHRAE Standard 62 sets a requirement that outdoor air be provided to maintain a healthy environment. For this office space, the required ventilation for human comfort is 585 cfm.

System Layout

Knowing the required ventilation for the office space, it is possible to layout a system of diffusers. There are several diffusers available on the market for UFAD systems. However, most of these systems require an 8” raised floor. The current raised floor in the Medical Office Building is only 6”, therefore it is necessary to raise the floor another 2” to accommodate the diffusers. Typically, this would be problematic, as higher ceilings are beneficial to UFAD systems. Fortunately, the use of two-way flat slabs can be used to provide an additional 9” of usable space. With the floor now at an appropriate height, a Trox swirl diffuser (Appendix IV) that can provide 110 cfm was chosen for the system. Assuming that these diffusers would operate at 100 cfm, it would be necessary to place 76 diffusers.

For the sake of even spacing in the floor grid 77 diffusers were distributed across the open office area. Because the chosen UFAD system operates based on a pressurized plenum, it is important that each diffuser have an equal pressure differential. Research has shown that the best way to ensure an even pressure differential is to limit the distance from the duct outlet to any diffuser to 80’ or less in an 8” plenum[1]. The dimensions of the open office area are small enough that a duct feeding the center of the space could meet this design requirement. A schematic of the final system showing the duct position and the diffusers appears in Figure 3-2.

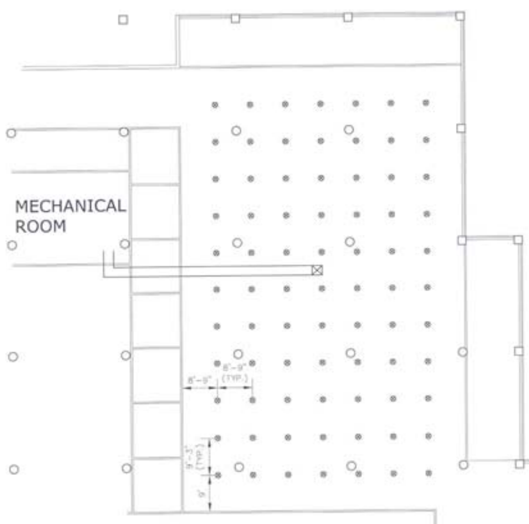


Figure 3-2 Layout of the final UFAD system for the open office area

Conclusions

The UFAD system provides an adequate level of thermal comfort and meets the standards for providing fresh air to the space. Based on the amount of ventilation for air quality compared to the amount required for thermal comfort, it would seem possible to recirculate as much as 94% of the indoor air. However, because of the stratification caused in rooms with UFAD the air in the unoccupied zone is not nearly as adequately ventilated as the air in the occupied zone. Even so, it would still be reasonable to introduce some level of recirculation to the UFAD system. This, along with the energy savings related to supplying air at 65°F instead of 55°F, make the UFAD air distribution a very good alternative to an overhead air system.

Unfortunately, simply applying a UFAD system indiscriminately could be disastrous. The design for this system took advantage of the higher ceiling created by switching to a two-way slab system. If the Filigree system were still in use, the floor to ceiling height would leave only 2'-6" in the unoccupied zone, instead of the 4'-6" in the new system. This would likely result in more circulation of contaminated air from the unoccupied zone into the occupied zone. Therefore, it is important that the UFAD system only be applied if the two-way slab system is introduced.

[1] Bauman, Fred S. Underfloor Air Distribution (UFAD) Design Guide. ASHRAE. Atlanta, GA. 2003

4 Auditorium Lighting

Introduction

One of the unique features of the Medical Office Building is its Auditorium. Located on the ground floor of the building, the auditorium is a general meeting place for stockholder conferences, employee workshops, and press conferences. The space is designed to be divided into three parts when necessary to allow for multiple smaller presentations, but is generally used as a whole space. The current lighting system of the auditorium (Figure 4-1) consists mainly of downlights assisted by recessed lighting in the coves to improve the light at the ceiling. This is a conventional and effective lighting solution to general use spaces such as this auditorium. However, a conventional system may not always be the best solution.

Figure 4-1 The existing lighting of the auditorium

Solution Overview

A direct-indirect lighting system may be able to create the same environment as the downlight system with coves. Properly placed, this system would not have a serious impact on the architecture, and would likely require less fixtures, making the maintenance of the space easier. However, this system may create an undesirable lighting effect for the presenter. In order to reap the benefits of a direct-indirect system and still maintain the quality lighting needed for presentations, a combined system is proposed. This combined system would include direct-indirect luminaires for the general lighting, and adjustable downlights for the presenter.

Design Criteria

The value of the lighting redesign is largely a decision of aesthetics. However, the system must still meet requirements for quality and energy consumption. The new lighting system will be deemed acceptable if it:

- Provides an environment with sufficient light quality (as set forth by IES)
- Consumes less than 1.0 W/ft^2

Based on these criteria, the system will be deemed acceptable. A direct comparison to the existing lighting system for cost and luminance was not possible due to insufficient information. However, a rough estimate of costs will also be considered using typical wattage values of downlights.

Lumen Method Analysis

The standard method for determining the level of luminance in a space through hand calculations is the Lumen Method. A worksheet in the IES Handbook (Appendix V) assists designers in using this method to decide how many luminaires to place in a given space. It is still left to the designer to select the luminaire and ensure that they are properly placed in the room based on the manufacturer's data for spacing. The luminaire chosen for consideration in this design was Lithonia's Avante Surface/Suspended luminaire. With the luminaire and room both known, the lumen method may be begun.

The first piece of information asked for in the lumen method is the lumens per a luminaire, 5700 for the Avante. The next piece of information involves the dimensions and reflectance of the room. Because the actual values of the reflectance were unknown, values of 80%, 50%, and 20% were chosen for the ceiling, walls, and roof respectively. These values represent average numbers for the materials in the room and are likely conservative because the existing lighting system takes advantage of indirect lighting, which requires higher reflectance. Once the values of the room are known, it is necessary to calculate the cavity ratios for the zones of the room. The cavity ratio for a space is defined as:

$$CR = \frac{5h(W + L)}{W * L} \qquad (4\text{-}1)$$

Once the cavity ratios have been determined, and the reflectance known, it is possible to determine the coefficient of utilization (CU) of the luminaire. The process involves the use of charts and tables found in the IES Handbook, the reproduction of these charts found in <u>Electrical Systems in Buildings</u> by S. David Hughes were used for this analysis. According to these charts the CU for the room is 0.74. Further charts and tables help to define the light loss factor, which is 0.63. At this point the only piece of information needed to complete the calculation is the required luminance, which is between 2 and 20 foot-candles for auditoriums.

Choosing the high end value of 20 foot-candles leads to the requirement of 39 luminaires. Spacing 39 luminaires evenly across the auditorium would be difficult, so 40 luminaires were chosen instead. The illuminance from 40 luminaires is 20.7 foot-candles, which is better than the most stringent requirements of IES.

System Layout

The Lumen Method analysis determined that 40 luminaires would be necessary to provide the desired illuminance in the auditorium. The spacing criteria of the manufacturer states that the luminaires must be within 1.14 their height above the work plane along the lamp, and 1.43 their height above the work plane perpendicular to the lamp. In the case of the auditorium, the work plane is the floor, which is roughly 15'-6" below the luminaire. This means that the luminaires should be arranged in at least a 3x5 pattern to fill the 61' x 84' area. With 40 luminaires, the nearest comparable arrangement is 5x8. This pattern is shown in Figure 4-2, with the lights shifted away from the south wall, where presentations occur.

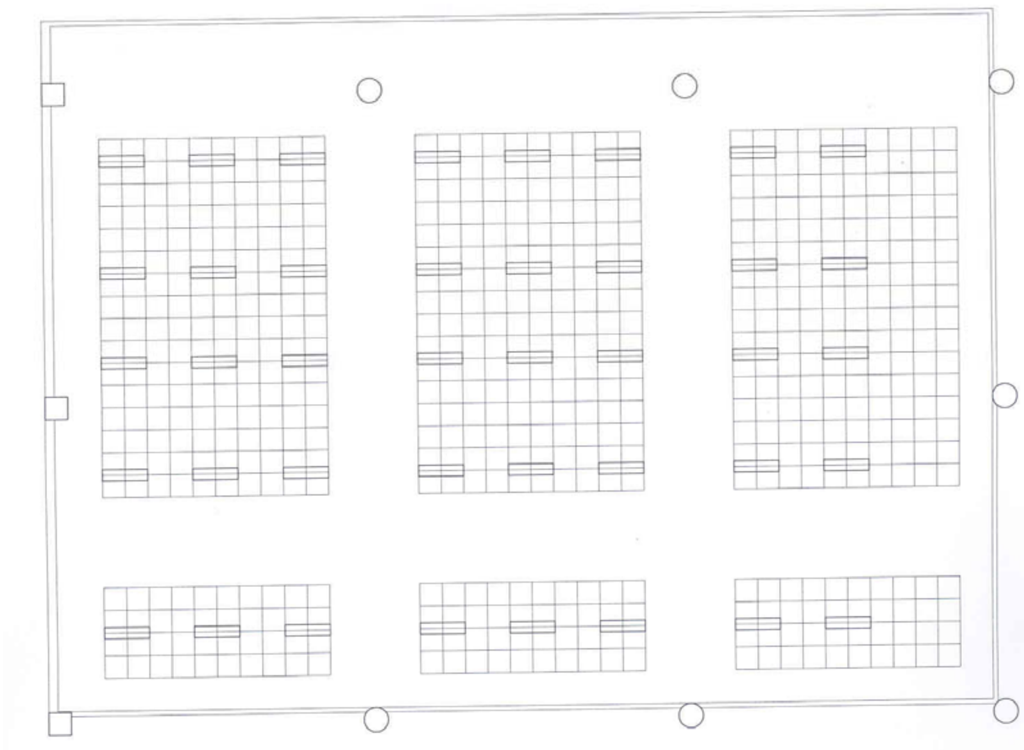


Figure 4-2 Layout of the direct-indirect lighting system

Task Lighting Layout

The goal of the task lighting within the space is to provide more lighting options for the presenter. As there are no calculable requirements for this space, the proposed design must be judged solely on appearance. Because of the projector, it is important to keep light off of the walls, in order to prevent washing the images. At the same time, having light on the podium can be dramatic and helpful to the speaker. Another nice touch for presentations would be having some simple stage lighting to control color and brightness at the podium. This could be hidden in the coves, which are no longer used in the direct-indirect system. The final design, with a single downlight for the podium and a small set of basic stage lights in the cove is presented in Figure 4-3.

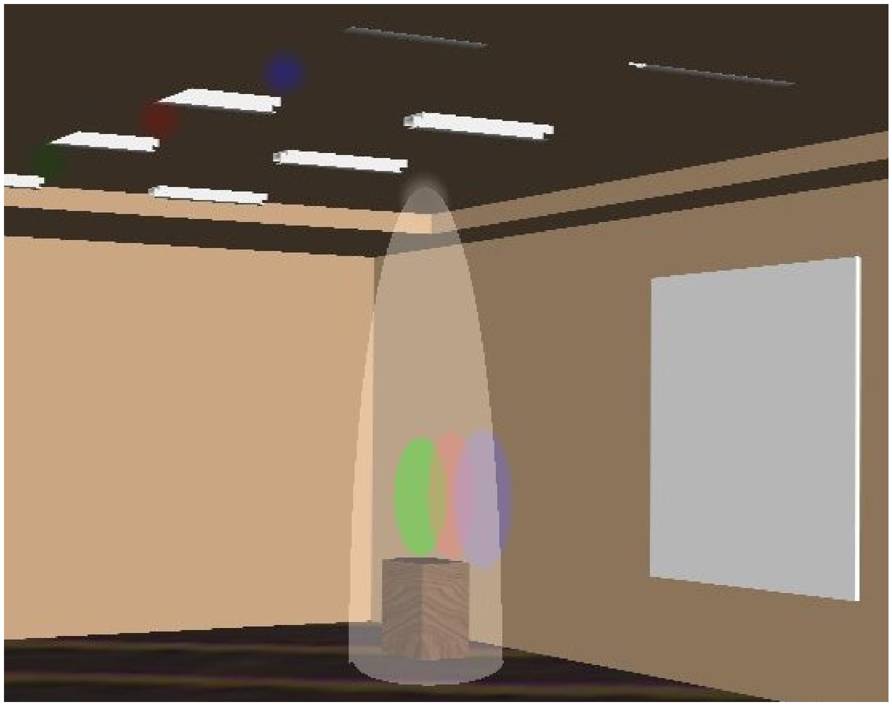


Figure 4-3 Rendering of the proposed task lighting design

Conclusions

The analysis of the new lighting system has shown that the auditorium will have a lighting level acceptable for auditoriums. An evaluation of the power usage also reveals that for the Avante Luminaires alone the power density is only .45 W/ft2. Since the system meets both of the design criteria it is an acceptable alternative. In addition to meeting the design criteria, the new system may also be of greater value. The current design uses 112 downlights. Using data for a typical Lithonia downlight with compact fluorescent bulbs (~25 W per downlight) the current power density would be .55 W/ft2. The energy savings alone are ample justification to change the system, but even more money could be saved because only a third of the luminaires and ballasts would have to be installed.

The additional savings resultant from the new system can be used to justify the expense of the presenter specific task lighting. Given that this lighting adds value to the auditorium space and can be bought back by savings in the general lighting system, there is no financial reason why the new system should not be chosen. However, the new system does place luminaires in the auditorium space, and although they are a small intrusion, they do somewhat detract from the overall appearance compared to the original design. The final evaluation of this system should rest with the owner and their perception, as the difference in cost is relatively small.

Overall Conclusions

This report presented the analysis of several different systems in the Medical Office Building, including the lateral resistance system, the floor system, the mechanical system, and the lighting system. For each system an alternative solution was proposed, designed, and compared to the existing system. In all of the analyses, the relative costs and benefits of the new system did not make it clearly superior to the existing system. Certain qualifications were necessary to make any decision regarding the systems chosen for the building.

In the case of the lateral resistance system, the shear walls showed a clear cost advantage to the concrete moment frames. However, the foundations under the shear walls are subject to large overturning moments and would thus require potentially expensive underpinning. In addition, the shear walls interfere with plumbing and mechanical systems in ways that the beams of a moment frame do not. However, under the condition that the cost of underpinning does not exceed the savings from using shear walls, the shear walls are the optimum system.

In the case of the floor design, the existing Filigree beam system was compared to a post-tensioned two-way slab. Because the Filigree system is proprietary, there is no specific cost data available for it, therefore a banded beam system was analyzed as a close replica. The cost comparison between the two-way slab and the banded beam system, favors the two-way slab, but when the consideration that the Filigree system uses less concrete is considered, the Filigree system wins out. However, since there may be additional costs associated with the Filigree system, it is unclear which system is more economical. In this case, the advantages of the two-way slab system in decreasing the overall floor depth and creating a more open plenum space give it an edge. Nevertheless, unless the owner is planning to take advantage of the higher ceilings, there is no incentive to change the system.

The mechanical system of the Medical Office Building is presently an overhead air distribution system. Since the building already has raised floors, it seemed logical to test the effectiveness of an underfloor air distribution (UFAD) system. Some of the benefits of a UFAD system are that air is supplied at a higher temperature, it is possible to build with few ducts, and less air is required because of natural convection effects. The analysis showed that the UFAD system could be effectively implemented, but only if the two-way slab system was used. If the Filigree system were retained, there may not be sufficient height in the office area to effectively remove air contaminants by natural convection.

The lighting system in the auditorium follows conventional design practices and uses downlights to provide illuminance. As an alternative to downlighting, a direct-indirect lighting system was implemented. The new system provided the same quality environment as the existing lighting system and at a lower power density. These energy saving were applied to add more task specific lighting for the presentation area. Unfortunately, the new system seems out of place in the auditorium. Therefore, unless the owner sees an advantage to having the new task lighting, it is probably better to retain the existing lighting system.

Appendix I

Center of Mass	x=	89.308	f'm=	3000 psi
	y=	128.136	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	kx (k/in.)	ky (k/in.)	x (ft.)	y (ft.)	kx*x	ky*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
NS-1	16.00	21.75	37.50	23706108.00	4176.00	0.00	1707.90	0.00	44.50	0	76001.77
NS-2	16.00	21.75	37.50	23706108.00	4176.00	0.00	1707.90	0.00	54.08	0	92369.19
NS-3	16.00	21.75	37.50	23706108.00	4176.00	0.00	1707.90	0.00	68.83	0	117560.8
NS-4	16.00	28.46	37.50	53101997.83	5464.00	0.00	3370.93	0.00	177.00	0	596654.9
NS-5	20.00	23.82	50.00	38938326.51	5717.50	0.00	1261.20	0.00	210.29	0	265220.4
NS-6	20.00	23.82	50.00	38938326.51	5717.50	0.00	1261.20	0.00	219.88	0	277306.9
WE-1	16.00	27.00	37.50	45349632.00	5184.00	2963.40	0.00	48.75	0.00	144465.8	0
WE-2	20.00	9.58	50.00	2534791.67	2300.00	92.69	0.00	72.57	0.00	6726.654	0
WE-3	16.00	26.08	37.50	40885729.33	5008.00	2719.79	0.00	77.21	0.00	209990.3	0
WE-4	16.00	26.00	37.50	40495104.00	4992.00	2698.13	0.00	114.21	0.00	308149.4	0
WE-5	16.00	9.58	37.50	2027833.33	1840.00	172.43	0.00	109.63	0.00	18902.15	0
						8793.44	11017.05			695794.2	1425114

e_x= -10.1815
e_y= 1.219297

All Walls

Center of Mass	x=	89.308	P_x=	267.05	f'm=	3000 psi
	y=	128.136	P_y=	191.99	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
						147.00	0.00			7560	0

e_x= -37.8794 T_x= -7272.47
e_y= #DIV/0! T_y= #DIV/0!

Frames Only

Center of Mass	x=	89.308	P_x=	267.05	f'm=	3000 psi
	y=	128.136	P_y=	191.99	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
NS-1	16.00	21.75	37.50	2.37E+07	4176.00	0.00	1707.90	0.00	44.50	0	76001.77
NS-2	16.00	21.75	37.50	2.37E+07	4176.00	0.00	1707.90	0.00	54.08	0	92369.19
NS-5	20.00	23.82	50.00	3.89E+07	5717.50	0.00	1261.20	0.00	210.29	0	265220.4
NS-6	20.00	23.82	50.00	3.89E+07	5717.50	0.00	1261.20	0.00	219.88	0	277306.9
WE-2	20.00	9.58	50.00	2.53E+06	2300.00	92.69	0.00	72.57	0.00	6726.654	0
WE-5	16.00	9.58	37.50	2.03E+06	1840.00	172.43	0.00	109.63	0.00	18902.15	0
						412.11	5938.21			33188.8	710898.3

e_x= -8.77489 T_x= -1684.69
e_y= -8.42018 T_y= -2248.61

Stairwell

Center of Mass	x=	89.308	P_x=	267.05	f'm=	3000 psi
	y=	128.136	P_y=	191.99	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
NS-3	16.00	21.75	37.50	2.37E+07	4176.00	0.00	1707.90	0.00	68.83	0	117560.8
NS-4	16.00	28.46	37.50	5.31E+07	5464.00	0.00	3370.93	0.00	177.00	0	596654.9
WE-1	16.00	27.00	37.50	4.53E+07	5184.00	2963.40	0.00	48.75	0.00	144465.8	0
WE-4	16.00	26.00	37.50	4.05E+07	4992.00	2698.13	0.00	114.21	0.00	308149.4	0
						5808.53	5078.84			460175.2	714215.7

e_x= -10.084 T_x= -1936.03
e_y= 12.48985 T_y= 3335.414

Bath-Mech

Center of Mass	x=	89.308	P_x=	267.05	f'm=	3000 psi
	y=	128.136	P_y=	191.99	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
NS-2	16.00	21.75	37.50	23706108.00	4176.00	0.00	1707.90	0.00	54.08	0	92369.19
NS-3	16.00	21.75	37.50	23706108.00	4176.00	0.00	1707.90	0.00	68.83	0	117560.8
NS-4	16.00	28.46	37.50	53101997.83	5464.00	0.00	3370.93	0.00	177.00	0	596654.9
NS-5	20.00	23.82	50.00	38938326.51	5717.50	0.00	1261.20	0.00	210.29	0	265220.4
WE-1	16.00	27.00	37.50	45349632.00	5184.00	2963.40	0.00	48.75	0.00	144465.8	0
WE-4	16.00	26.00	37.50	40495104.00	4992.00	2698.13	0.00	114.21	0.00	308149.4	0
WE-5	16.00	9.58	37.50	2027833.33	1840.00	172.43	0.00	109.63	0.00	18902.15	0
						5980.96	8047.94			479077.3	1071805

e_x=	-9.2076	T_x=	-1767.77
e_y=	5.041526	T_y=	1346.34

Stair-Bath

Center of Mass	x=	89.308	P_x=	267.05	f'm=	3000 psi
	y=	128.136	P_y=	191.99	E=	2700 ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	111.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	36.00	0.00	210.00	0.00	7560	0
NS-2	16.00	21.75	37.50	2.37E+07	4176.00	0.00	1707.90	0.00	54.08	0	92369.19
NS-3	16.00	21.75	37.50	2.37E+07	4176.00	0.00	1707.90	0.00	68.83	0	117560.8
NS-4	16.00	28.46	37.50	5.31E+07	5464.00	0.00	3370.93	0.00	177.00	0	596654.9
NS-5	20.00	23.82	50.00	3.89E+07	5717.50	0.00	1261.20	0.00	210.29	0	265220.4
WE-3	16.00	26.08	37.50	4.09E+07	5008.00	2719.79	0.00	77.21	0.00	209990.3	0
WE-4	16.00	26.00	37.50	4.05E+07	4992.00	2698.13	0.00	114.21	0.00	308149.4	0
						5564.92	8047.94			525699.6	1071805

e_x=	5.158677	T_x=	990.4144
e_y=	5.041526	T_y=	1346.34

Wall	ky	kx	k	x	y	d	k*d	k*d^2	P_x	P_y	P_Tx	P_Ty	V_Px	V_Py
N-Frame	111.00	0.00	111.00	-89.31	-128.14	-89.31	-9.91E+03	8.85E+05	0.00	3.83	0.28	-0.38	0.28	3.45
S-Frame	36.00	0.00	36.00	120.69	-128.14	120.69	4.34E+03	5.24E+05	0.00	1.24	-0.12	0.17	0.12	1.41
NS-2	0.00	1707.90	1707.90	-89.31	-74.05	-74.05	-1.26E+05	9.37E+06	56.67	0.00	3.54	-4.81	60.21	4.81
NS-3	0.00	1707.90	1707.90	-89.31	-59.30	-59.30	-1.01E+05	6.01E+06	56.67	0.00	2.83	-3.85	59.50	3.85
NS-4	0.00	3370.93	3370.93	-89.31	48.86	48.86	1.65E+05	8.05E+06	111.86	0.00	-4.61	6.26	107.25	6.26
NS-5	0.00	1261.20	1261.20	-89.31	82.16	82.16	1.04E+05	8.51E+06	41.85	0.00	-2.90	3.94	38.95	3.94
WE-3	2719.79	0.00	2719.79	-12.10	-128.14	-12.10	-3.29E+04	3.98E+05	0.00	93.83	0.92	-1.25	0.92	92.58
WE-4	2698.13	0.00	2698.13	24.90	-128.14	24.90	6.72E+04	1.67E+06	0.00	93.09	-1.88	2.55	1.88	95.64
	5564.92	8047.94	13612.87					3.54E+07						

Wall	V_ult	A_n (in^2)	D (ft.)
N-Frame	3.45	47.95	-
S-Frame 2	1.41	19.54	-
NS-2	60.21	836.24	4.36
NS-3	59.50	826.46	4.30
NS-4	107.25	1489.57	7.76
NS-5	38.95	541.00	2.25
WE-3	92.58	1285.86	6.70
WE-4	95.64	1328.33	6.92

South-West

Center of Mass	x=	89.308 P_x=	267.05 f'm=	3000	psi
	y=	128.136 P_y=	191.99 E=	2700	ksi

Wall	b (in.)	d (ft.)	h(ft.)	I (in^4)	Aw(in^2)	ky (k/in.)	kx (k/in.)	x (ft.)	y (ft.)	ky*x	kx*y
N-Frame	-	-	-	-	-	200.00	0.00	0.00	0.00	0	0
S-Frame	-	-	-	-	-	39.00	0.00	210.00	0.00	8190	0
NS-2	16.00	14.00	37.50	6.32E+06	2688.00	0.00	512.34	0.00	54.08	0	27709.16
NS-3	16.00	10.00	37.50	2.30E+06	1920.00	0.00	195.16	0.00	68.83	0	13433.17
NS-4	16.00	16.00	37.50	9.44E+06	3072.00	0.00	744.65	0.00	177.00	0	131802.6
NS-5	20.00	14.00	50.00	7.90E+06	3360.00	0.00	281.04	0.00	210.29	0	59100.11
WE-3	16.00	20.00	37.50	1.84E+07	3840.00	1367.97	0.00	77.21	0.00	105618.5	0
WE-4	16.00	16.00	37.50	9.44E+06	3072.00	744.65	0.00	114.21	0.00	85044.93	0
						2351.62	1733.18			198853.5	232045

e_x=	-4.74763	T_x=	-911.498
e_y=	5.747737	T_y=	1534.933

Wall	ky	kx	k	x	y	d	k*d	k*d^2	P_x	P_y	P_Tx	P_Ty	V_Px	V_Py
N-Frame	200.00	0.00	200.00	-89.31	-128.14	-89.31	-1.79E+04	1.60E+06	0.00	16.33	-1.63	-2.74	1.63	13.59
S-Frame	39.00	0.00	39.00	120.69	-128.14	120.69	4.71E+03	5.68E+05	0.00	3.18	0.43	0.72	0.43	3.91
NS-2	0.00	512.34	512.34	-89.31	-74.05	-74.05	-3.79E+04	2.81E+06	78.94	0.00	-3.46	-5.83	75.48	5.83
NS-3	0.00	195.16	195.16	-89.31	-59.30	-59.30	-1.16E+04	6.86E+05	30.07	0.00	-1.06	-1.78	29.01	1.78
NS-4	0.00	744.65	744.65	-89.31	48.86	48.86	3.64E+04	1.78E+06	114.74	0.00	3.32	5.59	118.05	5.59
NS-5	0.00	281.04	281.04	-89.31	82.16	82.16	2.31E+04	1.90E+06	43.30	0.00	2.11	3.55	45.41	3.55
WE-3	1367.97	0.00	1367.97	-12.10	-128.14	-12.10	-1.66E+04	2.00E+05	0.00	111.68	-1.51	-2.54	1.51	109.14
WE-4	744.65	0.00	744.65	24.90	-128.14	24.90	1.85E+04	4.62E+05	0.00	60.79	1.69	2.85	1.69	63.64
	2351.62	1733.18	4084.80					1.00E+07						

Wall	V_ult	A_n (in^2)	D (ft.)	M (ft k)	f (psi)	V_n
N-Frame	13.59	188.69	-	-	-	-
S-Frame	3.91	54.26	-	-	-	-
NS-2	75.48	1048.37	5.46	1887.06	54	174.56
NS-3	29.01	402.98	2.10	725.36	31	67.10
NS-4	118.05	1639.63	8.54	2951.34	230	273.01
NS-5	45.41	630.67	2.63	1513.60	123	105.01
WE-3	109.14	1515.86	7.90	2728.54	231	252.40
WE-4	63.64	883.91	4.60	1591.04	139	147.18
Refined						

Appendix II

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   1
 6:44:15 PM Licensed to: ae, university park, PA




                pppppp    ccccc    aaaaa
                p     p  c     c  a     a
                p     p  c     c        a
                p     p  c         aaaaaa
                p     p  c     c  a     a
                p     p  c     c  a     a
                pppppp    ccccc    aaaaaa
                p
                p


         AAA    DDDDD      OOO     SSSSS    SSSSS
        A   A   D    D    O   O   S     S  S     S
       A     A  D     D  O     O  S        S
       AAAAAAA  D     D  O     O   SSSSS    SSSSS
       A     A  D     D  O     O        S        S    ( ttttt mm   mm  )
       A     A  D    D    O   O   S     S  S     S   (    t   m m m m   )
       A     A  DDDDD      OOO     SSSSS    SSSSS     (   t   m  m  m  )



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 Computer program for ANALYSIS AND DESIGN OF SLAB SYSTEMS

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   2
 6:44:15 PM Licensed to: ae, university park, PA

FILE NAME             E:\THESIS\SLAB\EQFR1.ADS

PROJECT ID.           Medical Office Building
                      -----------------------------------
SPAN ID.              East Exterior
                      -------------------

ENGINEER              Brendon Burley

DATE                  03/21/05
TIME                  10:06:38

UNITS                 U.S. in-lb
CODE                  ACI 318-89

SLAB SYSTEM           FLAT PLATE
FRAME LOCATION        EXTERIOR

DESIGN METHOD         STRENGTH DESIGN
MOMENTS AND SHEARS    NOT PROPORTIONED

NUMBER OF SPANS  4

CONCRETE FACTORS        SLABS         BEAMS         COLUMNS
  DENSITY(pcf  )        145.0         145.0          145.0
  TYPE               NORMAL WGT    NORMAL WGT    NORMAL WGT
  f'c    (ksi)            5.0           5.0            5.0
  fct    (psi)          473.8         473.8          473.8
  fr     (psi)          530.3         530.3          530.3


REINFORCEMENT DETAILS: NON-PRESTRESSED
  YIELD STRENGTH Fy  =  60.00 ksi
  DISTANCE TO RF CENTER FROM TENSION FACE:
       AT SLAB TOP    =   1.25 in  OUTER LAYER
       AT SLAB BOTTOM =   1.25 in  OUTER LAYER
  MINIMUM FLEXURAL BAR SIZE:
       AT SLAB TOP    =  # 4
       AT SLAB BOTTOM =  # 4
  MINIMUM SPACING:
       IN SLAB =   4.00 in

**SLAB THICKNESS IN SPAN  2 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH = 10.5 in

**SLAB THICKNESS IN SPAN  3 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH = 10.5 in

**TOTAL UNFACTORED DEAD LOAD =         141.139 kips
                   LIVE LOAD =         106.500 kips
  ----------------------------------------------------------------------------
```

03-28-** ADOSS(tm) 6.01 Proprietary Software of PORTLAND CEMENT ASSN. Page 3
6:44:15 PM Licensed to: ae, university park, PA

DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS FROM SUPPORTS
****

COL NUM	LOAD TYPE	CROSS SECTN		DESIGN MOMENT (ft-k)	DISTANCE CR.SECTN (ft)	LOAD PTRN	MAX.I.P. DISTANCE (ft)	LOAD PTRN
1	TOTL	LEFT	TOP	-1.5	.175	4	1.000	1
			BOT	.0	.000	0	.000	0
		RGHT	TOP	130.9	1.000	3	2.800	2
			BOT	.0	.000	0	.000	0
2	TOTL	LEFT	TOP	-311.0	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	293.6	1.000	1	9.800	3
			BOT	.0	.000	0	.000	0
3	TOTL	LEFT	TOP	-333.2	1.000	1	7.000	4
			BOT	.0	.000	0	.000	0
		RGHT	TOP	406.2	1.000	4	14.000	1
			BOT	.0	.000	0	.000	0

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   4
 6:44:15 PM Licensed to: ae, university park, PA
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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS ALONG SPANS
****

SPAN NUM	LOAD TYPE	CRITICAL SECTION (ft)		DESIGN MOMENT (ft-k)	LOAD PTRN	MAX. I.P. DIST LEFT (ft)	LOAD PTRN	MAX. I.P. DIST RGHT (ft)	LOAD PTRN
2	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	227.4	3	10.500	1	9.100	3
3	TOTL	14.700	TOP	-.8	3	.000	0	.000	0
			BOT	176.4	2	9.100	2	7.700	2

03-28-** ADOSS(tm) 6.01 Proprietary Software of PORTLAND CEMENT ASSN. Page 5
6:44:15 PM Licensed to: ae, university park, PA

COLUMN STRIP MOMENT DISTRIBUTION FACTORS AT SUPPORTS
****

COLM NUM	CROSS SECTN	L2/L1	ALPHA1	ALPHA1 *L2/L1	BETA(T)	STRIP FACT	BEAM FACT
1	LEFT	.54	.000	.000	.204	.980	.000
	RGHT	.54	.000	.000	.204	.980	.000
2	LEFT	.54	.000	.000	.000	.750	.000
	RGHT	.54	.000	.000	.000	.750	.000
3	LEFT	.54	.000	.000	.204	.980	.000
	RGHT	.54	.000	.000	.204	.980	.000

COLUMN STRIP MOMENT DISTRIBUTION FACTORS IN SPANS
****

SPAN NUM	L2/L1	ALPHA1	ALPHA1 *L2/L1	STRIP FACT	BEAM FACT
2	.54	.000	.000	.600	.000
3	.54	.000	.000	.600	.000

03-28-** ADOSS(tm) 6.01 Proprietary Software of PORTLAND CEMENT ASSN. Page 6
6:44:15 PM Licensed to: ae, university park, PA

DISTRIBUTION OF DESIGN MOMENTS AT SUPPORTS
****

COL NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
1	LEFT	TOP	-1.5	.0 (0)	-1.5 (97)	.0 (0)	.0 (2)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	130.9	.0 (0)	128.2 (97)	.0 (0)	2.7 (2)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
2	LEFT	TOP	-311.0	.0 (0)	-233.3 (75)	.0 (0)	-77.8 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	293.6	.0 (0)	220.2 (75)	.0 (0)	73.4 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
3	LEFT	TOP	-333.2	.0 (0)	-326.4 (97)	.0 (0)	-6.8 (2)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	406.2	.0 (0)	397.9 (97)	.0 (0)	8.3 (2)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)

DISTRIBUTION OF DESIGN MOMENTS IN SPANS
****

SPAN NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
2	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	227.4	.0 (0)	136.5 (60)	.0 (0)	91.0 (39)
3	14.70	TOP	-.8	.0 (0)	-.5 (60)	.0 (0)	-.3 (40)
		BOT	176.4	.0 (0)	105.8 (60)	.0 (0)	70.6 (40)

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   7
 6:44:15 PM Licensed to: ae, university park, PA

                          S H E A R   A N A L Y S I S
                          ***************************

    NOTE--Allowable shear stress in slabs = 282.84 psi when ratio
          of col. dim. (long/short) is less than 2.0.

        --Wide beam shear (see "CODE") is not computed, check manually.

        --After the column numbers, C = Corner, E = Exterior, I = Interior.
```

D I R E C T   S H E A R   W I T H   T R A N S F E R   O F   M O M E N T
- - - - - - - - - - -   A R O U N D   C O L U M N   - - - - - - - - - - -

COL. NO.	ALLOW. STRESS (psi)	PATT NO.	REACTION (kips)	SHEAR STRESS (psi)	PATT NO.	REACTION (kips)	UNBAL. MOMENT (ft-k)	SHEAR TRANSFR (ft-k)	SHEAR STRESS (psi)
1C	282.84	1	65.6	178.72	3	64.5	142.2	56.9	330.69*
2E	282.84	1	143.5	249.01	4	137.2	-43.9	-18.3	269.27
3E	282.84	1	137.9	239.19	3	103.2	186.0	77.3	311.47*

* - Shear stress exceeded.

* Program completed as requested *

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   1
 6:42:04 PM Licensed to: ae, university park, PA




                pppppp    ccccc    aaaaa
                p     p  c     c  a     a
                p     p  c     c        a
                p     p  c         aaaaaa
                p     p  c     c  a     a
                p     p  c     c  a     a
                pppppp    ccccc    aaaaaa
                p
                p


         AAA    DDDDD      OOO     SSSSS    SSSSS
        A   A   D    D    O   O   S     S  S     S
       A     A  D     D  O     O  S        S
       AAAAAAA  D     D  O     O   SSSSS    SSSSS
       A     A  D     D  O     O        S        S    ( ttttt mm   mm  )
       A     A  D    D    O   O   S     S  S     S   (    t   m m m m   )
       A     A  DDDDD      OOO     SSSSS    SSSSS     (   t   m  m  m  )



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 Computer program for ANALYSIS AND DESIGN OF SLAB SYSTEMS

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03-28-** ADOSS(tm) 6.01  Proprietary Software of PORTLAND CEMENT ASSN. Page   2
 6:42:04 PM Licensed to: ae, university park, PA

FILE NAME            E:\THESIS\SLAB\EQFR2.ADS

PROJECT ID.          Medical Office Building
                     -----------------------------------
SPAN ID.             North Exterior
                     -------------------

ENGINEER             Brendon Burley

DATE                 03/21/05
TIME                 10:06:38

UNITS                U.S. in-lb
CODE                 ACI 318-89

SLAB SYSTEM          BEAM-SUPPORTED SLAB
FRAME LOCATION       EXTERIOR

DESIGN METHOD        STRENGTH DESIGN
MOMENTS AND SHEARS   NOT PROPORTIONED

NUMBER OF SPANS  9

CONCRETE FACTORS      SLABS         BEAMS        COLUMNS
  DENSITY(pcf  )      145.0         145.0         145.0
  TYPE             NORMAL WGT    NORMAL WGT    NORMAL WGT
  f'c    (ksi)          5.0           5.0           5.0
  fct    (psi)        473.8         473.8         473.8
  fr     (psi)        530.3         530.3         530.3


REINFORCEMENT DETAILS: NON-PRESTRESSED
  YIELD STRENGTH (flexural) Fy  =  60.00 ksi
  YIELD STRENGTH (stirrups) Fyv =  60.00 ksi
  DISTANCE TO RF CENTER FROM TENSION FACE:
       AT SLAB TOP    =   1.25 in  OUTER LAYER
       AT SLAB BOTTOM =   1.25 in  OUTER LAYER
       AT BEAM TOP    =   1.50 in  OUTER LAYER
       AT BEAM BOTTOM =   1.50 in
  FLEXURAL BAR SIZES:    MINIMUM | MAXIMUM
       AT SLAB TOP    =   # 4
       AT SLAB BOTTOM =   # 4
       AT BEAM TOP    =   # 4       #14
       IN BEAM BOTTOM =   # 4       #14
  MINIMUM SPACING:
       IN SLAB =   4.00 in
       IN BEAM =   1.00 in

**TOTAL UNFACTORED DEAD LOAD =         443.238 kips
                   LIVE LOAD =         297.001 kips
  ----------------------------------------------------------------------------
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03-28-** ADOSS(tm) 6.01 Proprietary Software of PORTLAND CEMENT ASSN. Page 3
6:42:04 PM Licensed to: ae, university park, PA

DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS FROM SUPPORTS
****

COL NUM	LOAD TYPE	CROSS SECTN		DESIGN MOMENT (ft-k)	DISTANCE CR.SECTN (ft)	LOAD PTRN	MAX.I.P. DISTANCE (ft)	LOAD PTRN
1	TOTL	LEFT	TOP	-1.5	.175	4	1.000	1
			BOT	.0	.000	0	.000	0
		RGHT	TOP	115.0	1.000	3	2.800	2
			BOT	.0	.000	0	.000	0
2	TOTL	LEFT	TOP	-339.3	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	323.4	1.000	1	9.800	3
			BOT	.0	.000	0	.000	0
3	TOTL	LEFT	TOP	-295.4	1.000	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	297.6	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
4	TOTL	LEFT	TOP	-301.7	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	301.2	1.000	1	8.400	3
			BOT	.0	.000	0	.000	0
5	TOTL	LEFT	TOP	-301.2	1.000	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	301.7	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
6	TOTL	LEFT	TOP	-297.6	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	295.4	1.000	1	8.400	3
			BOT	.0	.000	0	.000	0
7	TOTL	LEFT	TOP	-323.4	1.000	1	9.800	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	339.3	1.000	1	8.400	2
			BOT	.0	.000	0	.000	0

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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS FROM SUPPORTS
****

COL NUM	LOAD TYPE	CROSS SECTN		DESIGN MOMENT (ft-k)	DISTANCE CR.SECTN (ft)	LOAD PTRN	MAX.I.P. DISTANCE (ft)	LOAD PTRN
8	TOTL	LEFT	TOP	-115.0	1.000	3	2.800	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	1.5	.175	4	1.000	1
			BOT	.0	.000	0	.000	0

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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS ALONG SPANS
****

SPAN NUM	LOAD TYPE	CRITICAL SECTION (ft)		DESIGN MOMENT (ft-k)	LOAD PTRN	MAX. I.P. DIST LEFT (ft)	LOAD PTRN	MAX. I.P. DIST RGHT (ft)	LOAD PTRN
2	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	247.2	3	10.500	1	9.100	3
3	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	195.9	2	9.100	2	7.700	1
4	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	206.2	3	7.700	1	9.100	3
5	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	203.9	2	9.100	2	7.700	2
6	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	206.2	3	9.100	3	7.700	1
7	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	195.9	2	7.700	1	9.100	2
8	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	247.2	3	9.100	3	10.500	1

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COLUMN STRIP MOMENT DISTRIBUTION FACTORS AT SUPPORTS
****

COLM NUM	CROSS SECTN	L2/L1	ALPHA1	ALPHA1 *L2/L1	BETA(T)	STRIP FACT	BEAM FACT
1	LEFT	.54	2.602	1.394	.204	.991	.850
	RGHT	.54	2.602	1.394	.204	.991	.850
2	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
3	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
4	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
5	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
6	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
7	LEFT	.54	2.602	1.394	.000	.889	.850
	RGHT	.54	2.602	1.394	.000	.889	.850
8	LEFT	.54	2.602	1.394	.204	.991	.850
	RGHT	.54	2.602	1.394	.204	.991	.850

COLUMN STRIP MOMENT DISTRIBUTION FACTORS IN SPANS
****

SPAN NUM	L2/L1	ALPHA1	ALPHA1 *L2/L1	STRIP FACT	BEAM FACT
2	.54	2.602	1.394	.889	.850
3	.54	2.602	1.394	.889	.850
4	.54	2.602	1.394	.889	.850

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COLUMN STRIP MOMENT DISTRIBUTION FACTORS IN SPANS
****

SPAN NUM	L2/L1	ALPHA1	ALPHA1 *L2/L1	STRIP FACT	BEAM FACT
5	.54	2.602	1.394	.889	.850
6	.54	2.602	1.394	.889	.850
7	.54	2.602	1.394	.889	.850
8	.54	2.602	1.394	.889	.850

```
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                DISTRIBUTION OF DESIGN MOMENTS AT SUPPORTS
                ******************************************
--------------------------------------------------------------------------------
 COL  CROSS      TOTAL    TOTAL-VERT   COLUMN STRIP     BEAM       MIDDLE STRIP
 NUM  SECTN      MOMENT   DIFFERENCE     MOMENT        MOMENT        MOMENT
                 (ft-k)  (ft-k) ( % )  (ft-k) ( % )  (ft-k) ( % )  (ft-k) ( % )
--------------------------------------------------------------------------------
   1  LEFT TOP     -1.5       .0 (  0)      -.2 ( 14)     -1.3 ( 84)       .0 (  0)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    115.0       .0 (  0)     17.1 ( 14)     96.8 ( 84)      1.0 (  0)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   2  LEFT TOP   -339.3       .0 (  0)    -45.3 ( 13)   -256.5 ( 75)    -37.6 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    323.4       .0 (  0)     43.1 ( 13)    244.4 ( 75)     35.8 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   3  LEFT TOP   -295.4       .0 (  0)    -39.4 ( 13)   -223.3 ( 75)    -32.7 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    297.6       .0 (  0)     39.7 ( 13)    225.0 ( 75)     33.0 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   4  LEFT TOP   -301.7       .0 (  0)    -40.2 ( 13)   -228.0 ( 75)    -33.4 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    301.2       .0 (  0)     40.2 ( 13)    227.6 ( 75)     33.3 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   5  LEFT TOP   -301.2       .0 (  0)    -40.2 ( 13)   -227.6 ( 75)    -33.3 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    301.7       .0 (  0)     40.2 ( 13)    228.0 ( 75)     33.4 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   6  LEFT TOP   -297.6       .0 (  0)    -39.7 ( 13)   -225.0 ( 75)    -33.0 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    295.4       .0 (  0)     39.4 ( 13)    223.3 ( 75)     32.7 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

   7  LEFT TOP   -323.4       .0 (  0)    -43.1 ( 13)   -244.4 ( 75)    -35.8 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)

      RGHT TOP    339.3       .0 (  0)     45.3 ( 13)    256.5 ( 75)     37.6 ( 11)
           BOT       .0       .0 (  0)       .0 (  0)       .0 (  0)       .0 (  0)
```

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DISTRIBUTION OF DESIGN MOMENTS AT SUPPORTS
****

COL NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
8	LEFT	TOP	-115.0	.0 (0)	-17.1 (14)	-96.8 (84)	-1.0 (0)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	1.5	.0 (0)	.2 (14)	1.3 (84)	.0 (0)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)

DISTRIBUTION OF DESIGN MOMENTS IN SPANS
****

SPAN NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
2	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	247.2	.0 (0)	33.0 (13)	186.9 (75)	27.4 (11)
3	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	195.9	.0 (0)	26.1 (13)	148.1 (75)	21.7 (11)
4	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	206.2	.0 (0)	27.5 (13)	155.8 (75)	22.8 (11)
5	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	203.9	.0 (0)	27.2 (13)	154.1 (75)	22.6 (11)
6	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	206.2	.0 (0)	27.5 (13)	155.8 (75)	22.8 (11)
7	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	195.9	.0 (0)	26.1 (13)	148.1 (75)	21.7 (11)
8	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	247.2	.0 (0)	33.0 (13)	186.9 (75)	27.4 (11)

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S H E A R   A N A L Y S I S
****

NOTE--Allowable shear stress in slabs = 282.84 psi when ratio of col. dim. (long/short) is less than 2.0.

--Wide beam shear (see "CODE") is not computed, check manually.

--After the column numbers, C = Corner, E = Exterior, I = Interior.

D I R E C T   S H E A R   W I T H   T R A N S F E R   O F   M O M E N T - - - - - - - - - - -   A R O U N D   C O L U M N   - - - - - - - - - - -

COL. NO.	ALLOW. STRESS (psi)	PATT NO.	REACTION (kips)	SHEAR STRESS (psi)	PATT NO.	REACTION (kips)	UNBAL. MOMENT (ft-k)	SHEAR TRANSFR (ft-k)	SHEAR STRESS (psi)
1C	282.84	1	68.3	114.40	1	68.3	106.0	42.4	153.52
2E	282.84	1	154.8	149.48	1	154.8	-20.9	-8.7	155.84
3E	282.84	1	146.6	141.55	1	146.6	2.9	1.2	142.44
4E	282.84	1	147.7	142.67	1	147.7	-.7	-.3	142.88
5E	282.84	1	147.7	142.67	1	147.7	.7	.3	142.88
6E	282.84	1	146.6	141.55	1	146.6	-2.9	-1.2	142.44
7E	282.84	1	154.8	149.48	1	154.8	20.9	8.7	155.84
8C	282.84	1	68.3	114.40	1	68.3	-106.0	-42.4	153.52

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B E A M S H E A R R E Q U I R E M E N T S (kips, sq.in./in., ft.)
****

NOTE--Allowable shear stress in beams = 141.42 psi (see "CODE").

BEAM SPAN NO.	PATT. NO.	LEFT SIDE Vu@d SHEAR	Av/s @d	Av/s .175	Av/s .375	Av/s .625	Av/s .825	RIGHT SIDE Av/s @d	Vu@d SHEAR	LEFT Vc/2. DIST.
1 * *			Span length equal to column size or zero							* *
2	3	51.3	.015*	.015*	.000	.000	.015*	.015*	-62.9	9.10
2	1	47.8	.015*	.015*	.000	.015*	.015*	.015	-66.4	9.10
3	1	61.5	.015*	.015*	.000	.000	.015*	.015*	-52.7	10.50
3	1	54.7	.015*	.015*	.000	.000	.015*	.015*	-59.5	10.50
4	1	60.2	.015*	.015*	.000	.000	.015*	.015*	-54.1	10.50
4	1	53.7	.015*	.015*	.000	.000	.015*	.015*	-60.5	10.50
5	1	60.3	.015*	.015*	.000	.000	.015*	.015*	-53.9	10.50
5	1	53.9	.015*	.015*	.000	.000	.015*	.015*	-60.3	10.50
6	1	60.5	.015*	.015*	.000	.000	.015*	.015*	-53.7	10.50
6	1	54.1	.015*	.015*	.000	.000	.015*	.015*	-60.2	10.50
7	1	59.5	.015*	.015*	.000	.000	.015*	.015*	-54.7	10.50
7	1	52.7	.015*	.015*	.000	.000	.015*	.015*	-61.5	10.50
8	1	66.4	.015	.015*	.015*	.000	.015*	.015*	-47.8	11.90
8	3	62.9	.015*	.015*	.000	.000	.015*	.015*	-51.3	11.90
9 * *			Span length equal to column size or zero							* *

NOTES: 1.) To obtain stirrup spacing, divide stirrup area by Av/s value above.
2.) To obtain stirrup area, multiply spacing by Av/s value.
3.) Local effects due to loadings applied at other segments along beam span must be calculated manually.
4.) Symbols following Av/s values:
* - minimum shear 50*bw/Fyv - based on beam dimensions.
x - Vs exceeds 2*Vc, maximum stirrup spacing must be halved.
+ - Av/s value at segment located within effective depth.

* Program completed as requested *

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                pppppp    ccccc    aaaaa
                p     p  c     c  a     a
                p     p  c     c        a
                p     p  c         aaaaaa
                p     p  c     c  a     a
                p     p  c     c  a     a
                pppppp    ccccc    aaaaaa
                p
                p


         AAA    DDDDD      OOO     SSSSS    SSSSS
        A   A   D    D    O   O   S     S  S     S
       A     A  D     D  O     O  S        S
       AAAAAAA  D     D  O     O   SSSSS    SSSSS
       A     A  D     D  O     O        S        S    ( ttttt mm   mm  )
       A     A  D    D    O   O   S     S  S     S   (    t   m m m m   )
       A     A  DDDDD      OOO     SSSSS    SSSSS     (   t   m  m  m  )



*********************************************************

 Computer program for ANALYSIS AND DESIGN OF SLAB SYSTEMS

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Licensee stated above acknowledges that Portland Cement Association(PCA) is not and cannot be responsible for either the accuracy or adequacy of the material supplied as input for processing by the ADOSS(tm) computer program. Furthermore, PCA neither makes any warranty expressed nor implied with respect to the correctness of the output prepared by the ADOSS(tm) program. Although PCA has endeavored to produce ADOSS(tm) error free the program is not and cannot be certified infallible. The final and only responsibility for analysis, design and engineering documents is the licensees. Accordingly, PCA disclaims all responsibility in contract, negligence or other tort for any analysis, design or engineering documents prepared in connection with the use of the ADOSS(tm) program.

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FILE NAME            P:\THESIS\EQFR3.ADS

PROJECT ID.          Medical Office Building
                     -----------------------------------
SPAN ID.
                     -------------------

ENGINEER             Brendon Burley

DATE                 03/21/05
TIME                 10:06:38

UNITS                U.S. in-lb
CODE                 ACI 318-89

SLAB SYSTEM          FLAT PLATE
FRAME LOCATION       INTERIOR

DESIGN METHOD        STRENGTH DESIGN
MOMENTS AND SHEARS   NOT PROPORTIONED

NUMBER OF SPANS 13

CONCRETE FACTORS      SLABS         BEAMS        COLUMNS
  DENSITY(pcf  )      145.0         145.0         145.0
  TYPE              NORMAL WGT    NORMAL WGT    NORMAL WGT
  f'c    (ksi)          5.0           5.0           5.0
  fct    (psi)        473.8         473.8         473.8
  fr     (psi)        530.3         530.3         530.3


REINFORCEMENT DETAILS: NON-PRESTRESSED
  YIELD STRENGTH Fy  =  60.00 ksi
  DISTANCE TO RF CENTER FROM TENSION FACE:
       AT SLAB TOP    =   1.25 in  OUTER LAYER
       AT SLAB BOTTOM =   1.25 in  OUTER LAYER
  MINIMUM FLEXURAL BAR SIZE:
       AT SLAB TOP    =  # 4
       AT SLAB BOTTOM =  # 4
  MINIMUM SPACING:
       IN SLAB =   3.00 in

**SLAB THICKNESS IN SPAN  3 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN  4 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN  5 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN  6 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in
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**SLAB THICKNESS IN SPAN  7 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN  8 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN  9 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN 10 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**SLAB THICKNESS IN SPAN 11 IS INADEQUATE W/O A DEFLECTION CHECK
  REQUIRED DEPTH =  9.6 in

**TOTAL UNFACTORED DEAD LOAD =        1170.208 kips
                   LIVE LOAD =         868.000 kips
  ----------------------------------------------------------------------------
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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS FROM SUPPORTS
****

COL NUM	LOAD TYPE	CROSS SECTN		DESIGN MOMENT (ft-k)	DISTANCE CR.SECTN (ft)	LOAD PTRN	MAX.I.P. DISTANCE (ft)	LOAD PTRN
1	TOTL	LEFT	TOP	-4.9	.175	4	1.000	1
			BOT	.0	.000	0	.000	0
		RGHT	TOP	404.1	1.000	3	5.600	3
			BOT	.0	.000	0	.000	0
2	TOTL	LEFT	TOP	-532.4	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	529.0	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
3	TOTL	LEFT	TOP	-521.3	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	523.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
4	TOTL	LEFT	TOP	-525.6	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	525.3	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
5	TOTL	LEFT	TOP	-524.9	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	525.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
6	TOTL	LEFT	TOP	-525.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	525.0	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
7	TOTL	LEFT	TOP	-525.0	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	525.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0

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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS FROM SUPPORTS
****

COL NUM	LOAD TYPE	CROSS SECTN		DESIGN MOMENT (ft-k)	DISTANCE CR.SECTN (ft)	LOAD PTRN	MAX.I.P. DISTANCE (ft)	LOAD PTRN
8	TOTL	LEFT	TOP	-525.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	524.9	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
9	TOTL	LEFT	TOP	-525.3	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	525.6	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
10	TOTL	LEFT	TOP	-523.0	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
		RGHT	TOP	521.3	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
11	TOTL	LEFT	TOP	-529.0	.960	1	8.400	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	532.4	.960	1	8.400	2
			BOT	.0	.000	0	.000	0
12	TOTL	LEFT	TOP	-404.1	1.000	3	5.600	3
			BOT	.0	.000	0	.000	0
		RGHT	TOP	4.9	.175	4	1.000	1
			BOT	.0	.000	0	.000	0

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DESIGN MOMENT ENVELOPES AT CRITICAL SECTIONS ALONG SPANS
****

SPAN NUM	LOAD TYPE	CRITICAL SECTION (ft)		DESIGN MOMENT (ft-k)	LOAD PTRN	MAX. I.P. DIST LEFT (ft)	LOAD PTRN	MAX. I.P. DIST RGHT (ft)	LOAD PTRN
2	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	358.9	3	10.500	2	7.700	1
3	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	351.5	2	9.100	1	7.700	1
4	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	360.8	3	9.100	1	7.700	1
5	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	360.6	2	9.100	1	7.700	1
6	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	360.8	3	9.100	1	7.700	1
7	TOTL	14.700	TOP	.0	0	.000	0	.000	0
			BOT	360.8	2	9.100	1	7.700	1
8	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	360.8	3	7.700	1	9.100	1
9	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	360.6	2	7.700	1	9.100	1
10	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	360.8	3	7.700	1	9.100	1
11	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	351.5	2	7.700	1	9.100	1
12	TOTL	13.300	TOP	.0	0	.000	0	.000	0
			BOT	358.9	3	7.700	1	10.500	2

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COLUMN STRIP MOMENT DISTRIBUTION FACTORS AT SUPPORTS
****

COLM NUM	CROSS SECTN	L2/L1	ALPHA1	ALPHA1 *L2/L1	BETA(T)	STRIP FACT	BEAM FACT
1	LEFT	1.00	.000	.000	.658	.934	.000
	RGHT	1.00	.000	.000	.658	.934	.000
2	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
3	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
4	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
5	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
6	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
7	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
8	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
9	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
10	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
11	LEFT	1.00	.000	.000	.000	.750	.000
	RGHT	1.00	.000	.000	.000	.750	.000
12	LEFT	1.00	.000	.000	.658	.934	.000
	RGHT	1.00	.000	.000	.658	.934	.000

2	1.00	.000	.000	.600	.000
3	1.00	.000	.000	.600	.000

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COLUMN STRIP MOMENT DISTRIBUTION FACTORS IN SPANS
****

SPAN NUM	L2/L1	ALPHA1	ALPHA1 *L2/L1	STRIP FACT	BEAM FACT
4	1.00	.000	.000	.600	.000
5	1.00	.000	.000	.600	.000
6	1.00	.000	.000	.600	.000
7	1.00	.000	.000	.600	.000
8	1.00	.000	.000	.600	.000
9	1.00	.000	.000	.600	.000
10	1.00	.000	.000	.600	.000
11	1.00	.000	.000	.600	.000
12	1.00	.000	.000	.600	.000

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DISTRIBUTION OF DESIGN MOMENTS AT SUPPORTS

COL NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
1	LEFT	TOP	-4.9	.0 (0)	-4.6 (93)	.0 (0)	-.3 (6)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	404.1	.0 (0)	377.5 (93)	.0 (0)	26.6 (6)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
2	LEFT	TOP	-532.4	.0 (0)	-399.3 (75)	.0 (0)	-133.1 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	529.0	.0 (0)	396.7 (75)	.0 (0)	132.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
3	LEFT	TOP	-521.3	.0 (0)	-391.0 (75)	.0 (0)	-130.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	523.0	.0 (0)	392.3 (75)	.0 (0)	130.8 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
4	LEFT	TOP	-525.6	.0 (0)	-394.2 (75)	.0 (0)	-131.4 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	525.3	.0 (0)	394.0 (75)	.0 (0)	131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
5	LEFT	TOP	-524.9	.0 (0)	-393.7 (75)	.0 (0)	-131.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	525.0	.0 (0)	393.7 (75)	.0 (0)	131.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
6	LEFT	TOP	-525.0	.0 (0)	-393.8 (75)	.0 (0)	-131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	525.0	.0 (0)	393.8 (75)	.0 (0)	131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
7	LEFT	TOP	-525.0	.0 (0)	-393.8 (75)	.0 (0)	-131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	525.0	.0 (0)	393.8 (75)	.0 (0)	131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)

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DISTRIBUTION OF DESIGN MOMENTS AT SUPPORTS
****

COL NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
8	LEFT	TOP	-525.0	.0 (0)	-393.7 (75)	.0 (0)	-131.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	524.9	.0 (0)	393.7 (75)	.0 (0)	131.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
9	LEFT	TOP	-525.3	.0 (0)	-394.0 (75)	.0 (0)	-131.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	525.6	.0 (0)	394.2 (75)	.0 (0)	131.4 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
10	LEFT	TOP	-523.0	.0 (0)	-392.3 (75)	.0 (0)	-130.8 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	521.3	.0 (0)	391.0 (75)	.0 (0)	130.3 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
11	LEFT	TOP	-529.0	.0 (0)	-396.7 (75)	.0 (0)	-132.2 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	532.4	.0 (0)	399.3 (75)	.0 (0)	133.1 (25)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
12	LEFT	TOP	-404.1	.0 (0)	-377.5 (93)	.0 (0)	-26.6 (6)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
	RGHT	TOP	4.9	.0 (0)	4.6 (93)	.0 (0)	.3 (6)
		BOT	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)

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DISTRIBUTION OF DESIGN MOMENTS IN SPANS
****

SPAN NUM	CROSS SECTN		TOTAL MOMENT (ft-k)	TOTAL-VERT DIFFERENCE (ft-k) (%)	COLUMN STRIP MOMENT (ft-k) (%)	BEAM MOMENT (ft-k) (%)	MIDDLE STRIP MOMENT (ft-k) (%)
2	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	358.9	.0 (0)	215.3 (60)	.0 (0)	143.6 (40)
3	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	351.5	.0 (0)	210.9 (60)	.0 (0)	140.6 (39)
4	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.8	.0 (0)	216.5 (60)	.0 (0)	144.3 (40)
5	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.6	.0 (0)	216.3 (60)	.0 (0)	144.2 (40)
6	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.8	.0 (0)	216.5 (60)	.0 (0)	144.3 (39)
7	14.70	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.8	.0 (0)	216.5 (60)	.0 (0)	144.3 (40)
8	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.8	.0 (0)	216.5 (60)	.0 (0)	144.3 (39)
9	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.6	.0 (0)	216.3 (60)	.0 (0)	144.2 (39)
10	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	360.8	.0 (0)	216.5 (60)	.0 (0)	144.3 (40)
11	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	351.5	.0 (0)	210.9 (60)	.0 (0)	140.6 (39)
12	13.30	TOP	.0	.0 (0)	.0 (0)	.0 (0)	.0 (0)
		BOT	358.9	.0 (0)	215.3 (60)	.0 (0)	143.6 (39)

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S H E A R A N A L Y S I S

NOTE--Allowable shear stress in slabs = 282.84 psi when ratio of col. dim. (long/short) is less than 2.0.

--Wide beam shear (see "CODE") is not computed, check manually.

--After the column numbers, C = Corner, E = Exterior, I = Interior.

D I R E C T S H E A R W I T H T R A N S F E R O F M O M E N T
A R O U N D C O L U M N

COL. NO.	ALLOW. STRESS (psi)	PATT NO.	REACTION (kips)	SHEAR STRESS (psi)	PATT NO.	REACTION (kips)	UNBAL. MOMENT (ft-k)	SHEAR TRANSFR (ft-k)	SHEAR STRESS (psi)
1E	282.84	1	140.4	135.58	3	137.4	492.7	189.4	363.54*
2I	282.84	1	261.7	322.53*	4	256.0	-22.0	-8.8	328.03*
3I	282.84	1	259.7	320.05*	1	259.7	2.2	.9	321.28*
4I	282.84	1	260.4	321.01*	1	260.4	-.3	-.1	321.20*
5I	282.84	1	260.3	320.85*	1	260.3	.1	.0	320.89*
6I	282.84	1	260.3	320.88*	1	260.3	.0	.0	320.89*
7I	282.84	1	260.3	320.88*	1	260.3	.0	.0	320.89*
8I	282.84	1	260.3	320.85*	1	260.3	-.1	.0	320.89*
9I	282.84	1	260.4	321.01*	1	260.4	.3	.1	321.20*
10I	282.84	1	259.7	320.05*	1	259.7	-2.2	-.9	321.28*
11I	282.84	1	261.7	322.53*	4	256.0	22.0	8.8	328.03*
12E	282.84	1	140.4	135.58	3	137.4	-492.7	-189.4	363.54*

* - Shear stress exceeded.

```
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     T R A N S V E R S E   B E A M   S H E A R   A N D   T O R S I O N
               R E Q U I R E M E N T S (kips, ft-k, SQ.in, /,in.)
     *********************************************************************

  ------------------------------  LEFT   SIDE  -------------------------------
  BEAM  PATT.   Vu@d     Vc@d     Tu@d     Tc@d      Av/s   At/s  Atot/s   Al
  No.   NO.     SHEAR    SHEAR   TORSION  TORSION     @d     @d     @d     @d
  ----------------------------------------------------------------------------
    1      3     33.9      7.6    207.1     46.6    .024x  .118x  .259x  8.24
    2   * *                  Transverse beam not specified                  * *
    3   * *                  Transverse beam not specified                  * *
    4   * *                  Transverse beam not specified                  * *
    5   * *                  Transverse beam not specified                  * *
    6   * *                  Transverse beam not specified                  * *
    7   * *                  Transverse beam not specified                  * *
    8   * *                  Transverse beam not specified                  * *
    9   * *                  Transverse beam not specified                  * *
   10   * *                  Transverse beam not specified                  * *
   11   * *                  Transverse beam not specified                  * *
   12      3     33.9      7.6    207.1     46.6    .024x  .118x  .259x  8.24

  ------------------------------  RIGHT   SIDE  ------------------------------
  BEAM  PATT.   Vu@d     Vc@d     Tu@d     Tc@d      Av/s   At/s  Atot/s   Al
  No.   NO.     SHEAR    SHEAR   TORSION  TORSION     @d     @d     @d     @d
  ----------------------------------------------------------------------------
    1      3     33.9      7.6    207.1     46.6    .024x  .118x  .259x  8.24
    2   * *                  Transverse beam not specified                  * *
    3   * *                  Transverse beam not specified                  * *
    4   * *                  Transverse beam not specified                  * *
    5   * *                  Transverse beam not specified                  * *
    6   * *                  Transverse beam not specified                  * *
    7   * *                  Transverse beam not specified                  * *
    8   * *                  Transverse beam not specified                  * *
    9   * *                  Transverse beam not specified                  * *
   10   * *                  Transverse beam not specified                  * *
   11   * *                  Transverse beam not specified                  * *
   12      3     33.9      7.6    207.1     46.6    .024x  .118x  .259x  8.24
   ---------------------------------------------------------------------------

NOTES: 1.) Deep beam analysis not considered.
       2.) Loads assumed applied from above beam.
       3.) Moment and shear at concentrated load must be checked manually
           if located along transverse beam.
       4.) Symbols following Av/s values:
           * - Minimum shear 50.*bw/Fyv - based on beam dimensions.
           x - Vs exceeds 4*Vc, increase member section.
       5.) Symbols following At/s values:
           * - Minimum torsion 50.*bw/Fyv - based on beam dimensions.
           x - Ts exceeds 4*Tc, increase member section.
       6.) Symbols following Atot/s values:
           * - Minimum torsion 50.*bw/Fyv - based on beam dimensions.
       7.) Redistribution of torque is not considered.
       8.) Detail first stirrup @ 3 inches.
```

```
* PROGRAM DESIGN LIMITS EXCEEDED! ...REVISE SLAB DATA

                            Program terminated.
```

Appendix III

Shearheads.EES

```
A_trib = 28*28
c_1 = 23.04/12
c_2 = 23.04/12
d = 7.75/12
w = 295

A_1 = (c_1+d)*(c_2+d)
b_o1 = 2*(c_1+d)+2*(c_2+d)

A_2 = A_1+(3/4*l_v1-(c_1+d)/2)*(c_2+d)+(3/4*l_v2-(c_2+d)/2)*(c_1+d)
b_o2 = 4*sqrt((3/4*l_v1-(c_1+d)/2)^2+((c_2+d)/2)^2)+4*sqrt((3/4*l_v2-(c_2+d)/2)^2+((c_1+d)/2)^2)

l_v1 = 3.75
l_v2 = 3.75

V_1 = w*(A_trib-A_1)
V_2 = w*(A_trib-A_2)

u_1 = V_1/(b_o1*d)/144
u_2 = V_2/(b_o2*d)/144

u_des_1 = 328.04

u_1/u_des_1 = u_2/u_des_2
```

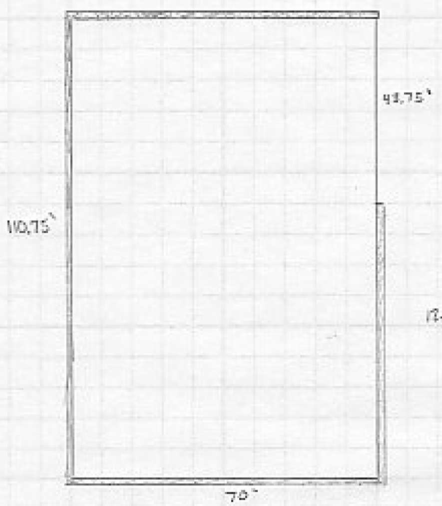
Shearheads-Ext.EES

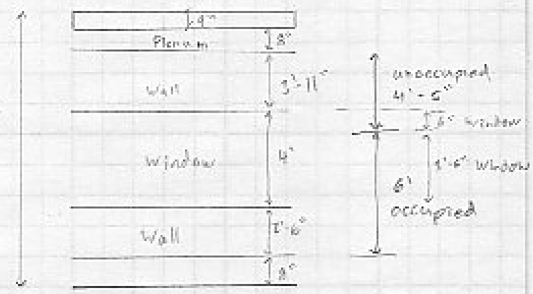
```
A_trib = 14*28
c_1 = 2
c_2 = 2
d = 7.75/12
w = 325

A_1 = (c_1+d)*(c_2+d)/2
b_o1 = (c_1+d)+(c_2+d)

A_2 = A_1+((3/4*l_v1-(c_1+d)/2)*(c_2+d)+(3/4*l_v2-(c_2+d)/2)*(c_1+d))/2
b_o2 = 2*sqrt((3/4*l_v1-(c_1+d)/2)^2+((c_2+d)/2)^2)+2*sqrt((3/4*l_v2-(c_2+d)/2)^2+((c_1+d)/2)^2)

l_v1 = 4.25
l_v2 = 4.25

V_1 = w*(A_trib-A_1)
V_2 = w*(A_trib-A_2)

u_1 = V_1/(b_o1*d)/144
u_2 = V_2/(b_o2*d)/144

u_des_1 = 363.54

u_1/u_des_1 = u_2/u_des_2
```

Appendix IV

Heating/Cooling Loads

Assume: 1) Perfect Mixing in zones
2) Surrounding rooms at same temperature as space



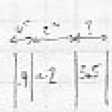


Sources
24 cubicles (24 occupants, 323 ft^2/cubicle) ∴ Light Office ($450 \frac{Btu}{hr \cdot occ}$, $0.5 \frac{W}{ft^2}$)
Lighting (117 luminaires) ∴ 4000 W, used 18 hrs/day, Quad (2) 18W

Unoccupied:
Lights $q = 3.41\ W\ F_{ul} F_{sa} = 3.41\ (4000)(0.75)(1.06) = 10843.8\ W$
$= 37000 \frac{Btu}{hr}$ (7400)
80% of lights go to occupied zone as radiation

Occupied:
Occupants $q = 24\ (450) = 10800 \frac{Btu}{hr}$
Computers $q = 0.5\ (70 \times 110.75) = 3876.25\ W = 13226 \frac{Btu}{hr}$
Lights $q = 29600 \frac{Btu}{hr}$

Boundaries
Infiltration (0.4 cfm/ft^2 window)
Conduction ($U_{window} = 0.64 \frac{Btu}{hr \cdot ft^2 \cdot °F}$, $R_{wall} = 5.5 \frac{°F \cdot hr \cdot ft^2}{Btu}$, $R_{brick} = 0.1 \frac{°F \cdot ft^2 \cdot hr}{Btu \cdot in}$)
↳ doubleglazed, aluminum ↳ 2×4 Metal studs, 16" o.c., R-11 insulation



$R_{build} = \sum R = 7.9 \frac{°F \cdot ft^2 \cdot hr}{Btu}$

$q = \frac{A}{R} (T_o - T_i)$ $q = 1.08\ V\ (T_o - T_i)$

Unoccupied:
Infiltration: $q_{sum} = 1.08(43.75 \times 4.5 \times .4)(93-72) = 199 \frac{Btu}{hr}$ $q_{win} = -586 \frac{Btu}{hr}$
Conduction: $q_{sum} = \left(\frac{3.92 \times 43.75}{7.9} + 0.64(.5 \times 43.75)\right)(93-72) = 750 \frac{Btu}{hr}$ $q_{win} = -2213 \frac{Btu}{hr}$

Occupied:
Infiltration: $q_{sum} = 1.08(43.75 \times 3.5 \times .4)(93-72) = 1390 \frac{Btu}{hr}$ $q_{win} = -4102 \frac{Btu}{hr}$
Conduction: $q_{sum} = \left(\frac{2.5 \times 43.75}{7.9} + 0.64(3.5 \times 43.75)\right)(93-72) = 2349 \frac{Btu}{hr}$ $q_{win} = -6935 \frac{Btu}{hr}$

Heating / Cooling Loads

Combined

Unoccupied: $q_{sum} = 8349 \frac{Btu}{hr}$ ← design case

$q_{win} = 4601 \frac{Btu}{hr}$

Occupied: $q_{sum} = 57365 \frac{Btu}{hr}$ ← design case

$q_{win} = 42589 \frac{Btu}{hr}$ ∴ always cooling

$T_{supply} = 65°F$

$T_{room} = 72°F$

$$V = \frac{57365}{1.08(72-65)} = 7588 \text{ cfm}$$

$$T_{exhaust} = \frac{8349}{1.08(7588)} + 72 = 73.0°F$$

Chosen diffuser operates at 110 cfm max. Use 100 cfm/diffuser as an operable ventilation rate.

∴ Need 76 diffusers

Ventilation Requirements

$$V_{bz} = R_p P_z + R_a A_z$$

$P_z = 24$

$A_z = 110.75 \times 70 = 7752.5 \text{ ft}^2$

Table 6-1

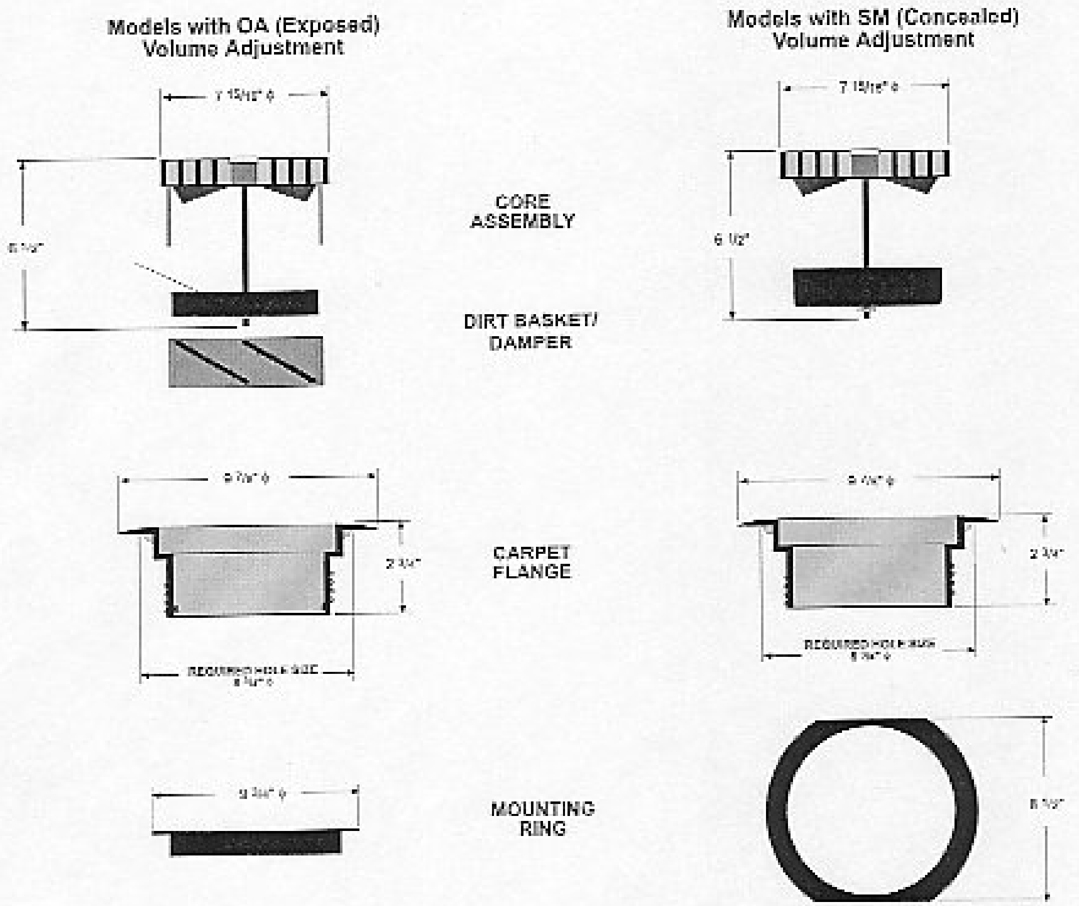
$R_p = 5 \text{ cfm/person}$

$R_a = 0.06 \text{ cfm/ft}^2$

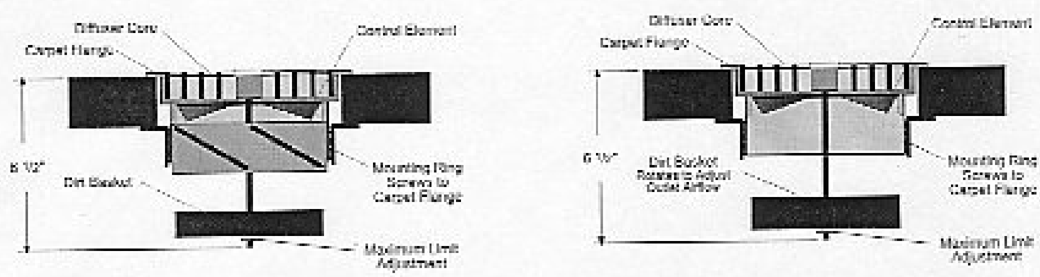
$$V_{bz} = 5(24) + 0.06(7752.5) = 585 \text{ cfm}$$

Dimensional and Installation Information

DIMENSIONAL INFORMATION



DIFFUSER INSTALLATION



NOTE: Diffuser Requires an 8 3/4" Diameter Hole for Mounting

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Specification and Ordering Information

Furnish and install **TROX** (FBA 200 aluminum, FBK 200 plastic) floor diffusers as indicated on plans. Diffusers shall incorporate a removeable core section, which consists of a series of concentric rings and deflection vanes to distribute the air in a 360° "swirl" pattern

An integral carpet flange shall support the diffuser core and prevent fraying of the carpet, providing a minimum 1/2" overlap. This flange shall mount to the floor system by means of a threaded mounting ring, allowing location upon completion of the raised floor /carpet installation without removal of carpet or floor tiles.

A catch basin shall be furnished to facilitate removal of dust, spills, and other objects that penetrate the outlet face.

Outlet airflow rates shall be limited to those resulting in a maximum terminal velocity of 50 fpm four feet directly above the diffuser face.

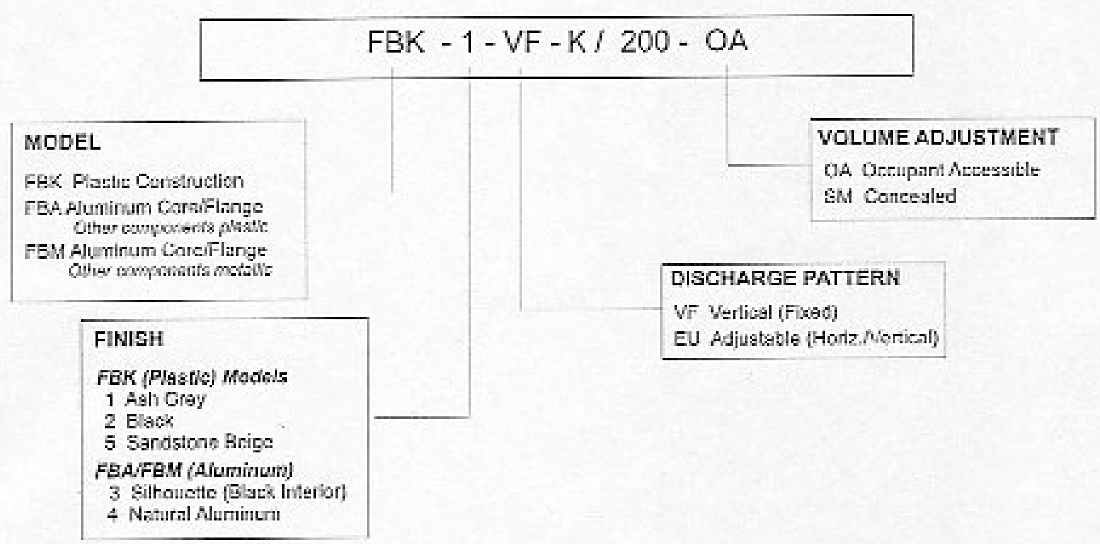
The diffuser core and trim ring shall be constructed of (aluminum for FBA, plastic for FBK) and their finish shall be (FBA: Brushed aluminum, FBK: Ash Grey,Black or Sandstone Beige). The catch basin and mounting ring shall be constructed of UL-94-V plastic (note: steel material is optional for model FBA).

Models with OA Volume Adjustment Only

The assembly shall allow occupant adjustment of the outlet airflow without necessitating the removal of any diffuser components. Adjustment shall require rotation of the diffuser face and be accomplished by hand without the use of tools or other devices. A visible indicator on the diffuser face shall provide evidence of the damper position at all times.

The outlet shall incorporate a means of imposing a maximum airflow setting without compromising the individual's ability to adjust the delivered airflow, except to the extent of the set limit.

DIFFUSER ORDER CODE



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Appendix V

9-30 LIGHTING CALCULATIONS

GENERAL INFORMATION

Project identification. Auditorium - Medical Office Building
(Give name of area and/or building and room number)

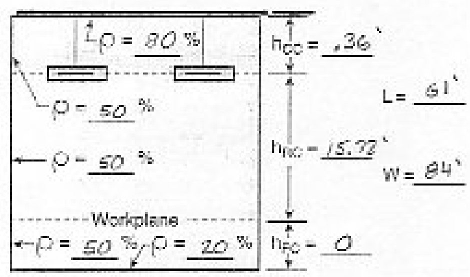
Average maintained illuminance for design: 200 lux or 20 footcandles

Lamp data:
Type and color: T-8
Number per luminaire: 2
Total lumens per luminaire: 5700

Luminaire data:
Manufacturer: Lithonia
Catalog number: F32T8/SP835

SELECTION OF COEFFICIENT OF UTILIZATION

Step 1: Fill in sketch at right



Step 2: Determine Cavity Ratios

Room Cavity Ratio, RCR = 2.23
Ceiling Cavity Ratio, CCR = 0.05
Floor Cavity Ratio, FCR = 0

Step 3: Obtain Effective Ceiling Cavity Reflectance (ρ_{CC}) ρ_{CC} = .77

Step 4: Obtain Effective Floor Cavity Reflectance (ρ_{FC}) ρ_{FC} = .20

Step 5: Obtain Coefficient of Utilization (CU) from Manufacturer's Data CU = .74

SELECTION OF LIGHT LOSS FACTORS

Nonrecoverable		Recoverable	
Luminaire ambient temperature	1.0	Room surface dirt depreciation RSDD	0.94
Voltage to luminaire	1.0	Lamp lumen depreciation LLD	0.90
Ballast factor	0.95	Lamp burnouts factor LBO	1.0
Luminaire surface depreciation	1.0	Luminaire dirt depreciation LDD	0.88

Total light loss factor, LLF (product of individual factors above) = 0.63

CALCULATIONS

(Average Maintained Illuminance)

$$\text{Number of Luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per Luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$= \frac{20 \times (61 \times 84)}{5700 \times 0.74 \times 0.63} = 38.6 \rightarrow 40 \text{ luminaires}$$

$$\text{Illuminance} = \frac{(\text{Number of Luminaires}) \times (\text{Lumens per Luminaire}) \times (\text{CU}) \times (\text{LLF})}{(\text{Area})}$$

$$= \frac{40 \times (5700) \times 0.74 \times 0.63}{(61 \times 84)} = 20.7 \text{ fc}$$

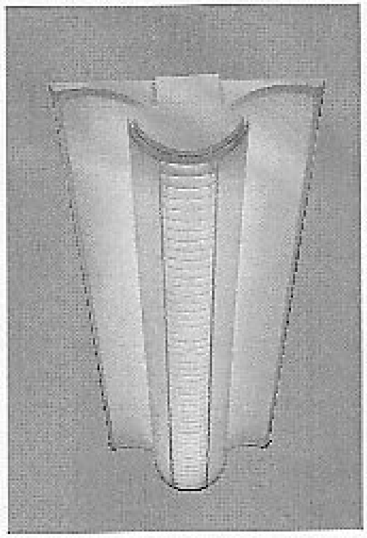
Calculated by: Brendon J. Burley Date: 3/28/2005

Figure 9-25. Average illuminance calculation sheet.

Architectural Lighting

Avante®

Surface/Suspended



Direct/Indirect Lighting

Intended Use

1x2 – ideal for general or task lighting in alcoves, narrow corridors and small spaces. *1x4* – suitable for general area or task-specific lighting in both new construction and remodeling. Especially suited for conference rooms, reception areas, health care institutions, education facilities and offices.

Features

Contemporary, low-profile construction, suitable for surface and suspended mounting, providing direct or semi-direct light distribution.

Rugged steel housing in 2', 4' or 8' field-joinable units for continuous rows.

Injection molded joiners with snap-on finished ends.

Available with popular Avante 1x4 shieldings - MDR, MDM and SBL.

Reflectors finished with high-reflectance, matte-white polyester powder paint for uniform light distribution.

Reflector option includes steel reflectors with or without semi-perforated option or diffuse Aluminum Stepped Reflector.

T5HO or T8 lamping configurations available.

Listings – UL Listed (standard). CSA Certified or NOM Certified (see Options).

Ordering Information

Example: **AVSM 2 32 MDR DLS MVOLT GEB10IS**

Series

- **AVSM** 1" wide, symmetric distribution
- **TAVSM** 1" wide lamps in tandem

Number of lamps

1,2[1]

Not included.

Lamp type

17	17W	T8 (24")
32	32W	T8 (48")
14T5	14W	T5 (22")
28T5	28W	T5 (46")
24T5HO	24W	T5 (22")
CF40	40W	TT5 (24")
CF50	50W	TT5 (24")
CF55	55W	TT5 (24")
54T5HO	54W	T5 (46")

Diffuser

- **MDR** Metal diffuser, round holes
- **MDM** Metal diffuser, mini slots
- **SBL** Straight blade louver, round holes

Others available.

Light distribution

- **ULR** Uplight, round hole, perforated band[2]
- **DLS** Downlight, solid

Voltage

120
277
347
MVOLT*

Others available.

* 120-277V. Must specify GEB10IS or GEB10PS.

Options

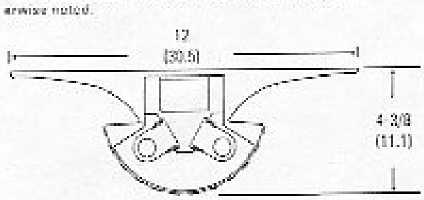
- **GEB** T8 electronic ballast, ≤20% THD
- **GEB10IS** T8 electronic ballast, ≤10% THD, instant start
- **GEB10PS** T5 electronic ballast, ≤10% THD, program start
- **GEB10RS** T8 electronic ballast, <10% THD, rapid start
- **ALG** Acrylic litter guard
- **GLR** Internal fast-blow fuse[3]
- **LP_** Lamped. Specify lamp type and color
- **NYC** New York City approved
- **CSA** CSA Certified
- **NOM** NOM Certified

Reflector Options

- **ASR** Aluminum Stepped Reflector[4]

NOTES:
1 Available with straight-tube T5 or T8 lamps only.
2 For suspended mounting only.
3 Not available with MVOLT.
4 Not available with ULR.
5 Specify ballast manufacturer.

Dimensions shown in **inches (centimeters)** unless otherwise noted.



Availability and Dimensions

Nominal size	Series	Number of lamps	Lamp type	Length
1x2	AVSM	1, 2 1	17, 14T5, 24T5HO CF40, CF50, CF55	2'
1x4	AVSM	1, 2	32, 28T5, 54T5HO	4'
1x8	TAVSM	1, 2	32, 28T5, 54T5HO	8'

Ballast/Lamp Compatibility

	17	32	14T5	28T5	24T5HO	CF40	CF50	CF55	54T5HO
GEB	■	■					■[5]	■[5]	
GEB10IS		■							
GEB10PS			■	■	■				■
GEB10RS	■								

24 *Fluorescent / PS68*

www.lithonia.com
keyword: AVSM

LITHONIA LIGHTING

TEST:	LTL9551
MANUFAC:	LITHONIA LIGHTING
LUMCAT:	AVSM 2 32 SBL DLS
LUMINAIRE:	1X4 AVante, Surface or suspended Mount, 2 lamp T8 32 watt, Straight Blade Louver w/ perf'd sides, backed w/ acrylic overlay, Down Light Solid white steel reflector.
LAMPCAT:	F32T8/SP835
LAMP:	TWO 32-WATT T8 LINEAR FLUORESCENT.
_PRODUCTGROUP:	ARCHITECTURAL FLUORESCENT
_INFOLINK:	www.lithonia.com/visual/ies/ies.asp?vfile=
Number Lamps:	2
Lumens Per Lamp:	2850
Photometric Type:	Type C
Luminous Width:	1 ft
Luminous Length:	4 ft
Luminous Height:	0.33 ft
Ballast Factor:	1
Input Watts:	58
Efficiency (Total):	66.5 %
Efficiency (Up):	8.0 %
Efficiency (Down):	58.5 %

Spacing Criteria

Angle	Value
0	1.14
90	1.43

Candela Values:

0	22.5	45	67.5	90

0	925	925	925	925	925
2.5	905	907	936	927	933
5	900	903	930	924	931
7.5	893	896	926	920	929
10	878	884	917	915	922
12.5	867	872	909	913	924
15	845	854	897	907	921
17.5	826	837	885	902	916
20	805	820	872	894	914
22.5	784	799	857	885	907
25	755	774	839	873	899
27.5	728	751	821	859	889
30	701	727	799	849	883
32.5	666	696	777	835	871
35	636	670	757	820	859
37.5	601	638	732	805	845
40	568	610	711	787	831
42.5	528	579	685	768	814
45	495	550	666	752	797
47.5	457	515	635	730	778
50	417	483	610	709	757
52.5	379	451	585	688	738
55	340	419	557	667	722
57.5	303	386	532	652	702
60	263	350	507	633	685
62.5	232	322	486	617	666
65	202	292	464	596	642

67.5	180	267	446	582	626
70	152	243	426	562	605
72.5	130	223	408	542	584
75	108	204	391	523	563
77.5	88	188	374	506	544
80	69	177	361	490	527
82.5	50	163	346	475	512
85	33	151	326	451	485
87.5	18	144	315	439	476
90	6	133	302	427	464
92.5	14	123	286	412	448
95	15	108	270	393	433
97.5	14	72	253	377	419
100	12	35	222	354	399
102.5	9	24	181	326	374
105	11	16	110	284	336
107.5	6	12	66	226	287
110	6	9	44	139	207
112.5	2	6	24	93	132
115	3	5	13	69	101
117.5	3	4	3	43	68
120	0	0	0	0	0
122.5	0	0	0	0	0
125	0	0	0	0	0
127.5	0	0	0	0	0
130	0	0	0	0	0
132.5	0	0	0	0	0

135	0	0	0	0	0
137.5	0	0	0	0	0
140	0	0	0	0	0
142.5	0	0	0	0	0
145	0	0	0	0	0
147.5	0	0	0	0	0
150	0	0	0	0	0
152.5	0	0	0	0	0
155	0	0	0	0	0
157.5	0	0	0	0	0
160	0	0	0	0	0
162.5	0	0	0	0	0
165	0	0	0	0	0
167.5	0	0	0	0	0
170	0	0	0	0	0
172.5	0	0	0	0	0
175	0	0	0	0	0
177.5	0	0	0	0	0
180	0	0	0	0	0

	Average Luminance (cd/sq.m)		
	0	45	90
55	1,427	1,845	2,302
65	1,093	1,818	2,394
75	859	1,946	2,623
85	524	2,322	3,138

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