# Construction Study

- Cost Comparison
- Schedule Comparison

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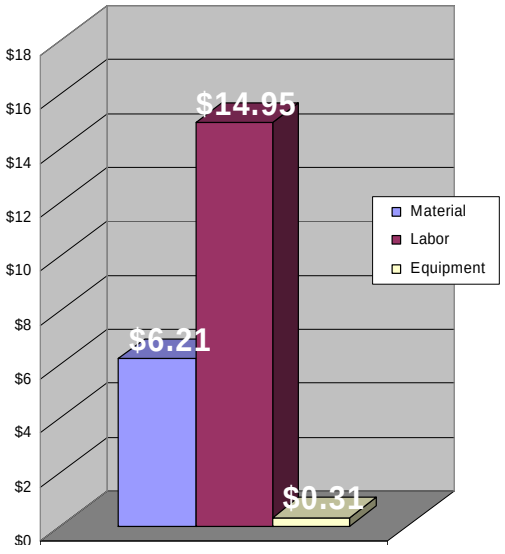
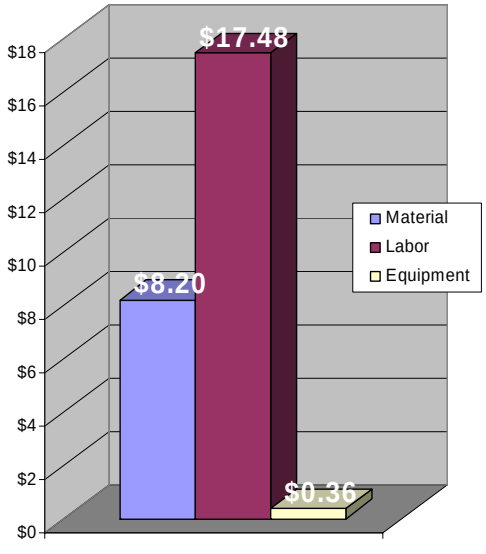
### Cost Comparison

The structural redesign of the flat plate system will produce significant implications with the overall construction cost. By observation alone, the proposed reinforced flat plate significantly increased concrete material quantities within the flat plate and columns. The adjustments to the lateral design also resulted in the addition of shear walls through the building. A cost analysis was performed to better understand the cost efficiency of the structural redesign. R.S. Means was used to develop the cost analysis for the system comparison. The analysis was simplified to a typical level for an average square foot cost of the entire tower structure.

Material take-offs for the analysis included the flat plate design, supporting columns, and shear walls on a typical level. The crews used for each system were matched for an equivalent comparison of labor costs and durations. A cost for each structural component was calculated and accumulated for an average cost per 21010 SF. The reinforced flat plate was a more expensive design at $26/SF, with the post-tensioned system at $21/SF. The redesign had higher material costs primarily resulting from increases in concrete and reinforcement in the flat plate. The reinforcement material and labor cost alone increased over 100% compared to tendons and reinforcement of the post-tensioned system. A break-down of square foot costs for each design are shown in the following charts and the system take-offs are included on the following pages.




*Post-Tensioned*




*Reinforced*

## Post-Tensioned Flat Plate

| Concrete Columns<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete | | | | | | | | | | | | |
| *Normal Wt., 5000psi* | 61.76 | | | | | C.Y | 96 | | | 96 | $5,929 | |
| Concrete in place | | | | | | | | | | | | |
| *Average Reinforcing* | | | | | | | | | | | | |
| 18"x 26" | 56.15 | 1 | C14A | 17.7 | 11.293 | C.Y | 345 | 385 | 41 | 771 | $43,292 | 3.2 |
| 20" | 4.52 | 1 | C14A | 24 | 8.316 | C.Y | 375 | 285 | 30.5 | 690.5 | $3,121 | 0.2 |
| 24" | 1.09 | 1 | C14A | 27 | 7.391 | C.Y | 375 | 253 | 27 | 655 | $714 | 0.0 |
| Placing, w/ Crane & Bucket | | | | | | | | | | | | |
| 18"x 26" | 56.15 | 1 | C-7 | 70 | 1.029 | C.Y | | 31 | 14.45 | 45.45 | $2,552 | 0.8 |
| 20" | 4.52 | 1 | C-7 | 60 | 1.2 | C.Y | | 37 | 17 | 54 | $244 | 0.1 |
| 24" | 1.09 | 1 | C-7 | 70 | 1.029 | C.Y | | 31 | 14.45 | 45.45 | $50 | 0.0 |
| | | | | | | | | | | | $55,901 | |

| Concrete Shear-Walls<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete 10" wall | | | | | | | | | | | | |
| *Normal Wt. , 4000psi* | 25.14 | | | | | C.Y. | 84 | | | 84 | $2,112 | |
| Placing, w/ Crane & Bucket | 25.14 | 1 | C-7 | 85 | 0.85 | C.Y. | | 24.5 | 11.35 | 35.85 | $901 | 0.3 |
| Reinforcment in Place | 1.28 | 1 | 4 Rodm | 3 | 10.667 | Ton | 760 | 405 | | 1165 | $1,491 | 0.4 |
| Forms in place, 4 use | 1705.6 | 1 | C2 | 450 | 0.107 | SFCA | 0.37 | 3.56 | | | $6,703 | 3.8 |
| Concrete 14" wall | | | | | | | | | | | | |
| *Normal Wt. , 4000psi* | 16.12 | | | | | C.Y. | 84 | | | 84 | $1,354 | |
| Placing, w/ Crane & Bucket | 16.12 | 1 | C-7 | 95 | 0.758 | C.Y. | | 22 | 10.1 | 32.1 | $517 | 0.2 |
| Reinforcment in Place | 1.22 | 1 | 4 Rodm | 3 | 10.667 | Ton | 760 | 405 | | 1165 | $1,421 | 0.4 |
| Forms in place, 4 use | 416.8 | 1 | C2 | 450 | 0.107 | SFCA | 0.37 | 3.56 | | | $1,638 | 0.9 |
| | | | | | | | | | | | $14,500 | |

| Concrete Flat Plate<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete | | | | | | | | | | | | |
| *Normal Wt., 5000psi* | 518.8 | | | | | C.Y. | 96 | | | 96 | $49,805 | |
| Placing, Elevated Slabs | | | | | | | | | | | | |
| *8" thick, w/ Crane & Bucket* | 518.8 | 2 | C-7 | 110 | 0.655 | C.Y. | | 11.9 | 4.65 | 16.55 | $14,760 | 2.4 |
| Reinforcment in place | | | | | | | | | | | | |
| *Elevated Slab, #3 to #7* | 14.2 | 2 | 4 Rodm | 2.9 | 11.034 | Ton | 905 | 435 | | 1340 | $25,205 | 2.4 |
| Post-Tensioning, ungrouted | | | | | | | | | | | | |
| *50' span, 25k* | 9025.12 | 1 | C-4 | 1275 | 0.025 | Lb. | 0.47 | 1 | 0.02 | 1.49 | $13,447 | 7.1 |
| *50' span, 300k* | 9037.6 | 1 | C-4 | 1475 | 0.022 | Lb. | 0.47 | 0.87 | 0.02 | 1.36 | $12,291 | 6.1 |
| Concrete in place, Flat Plate | | | | | | | | | | | | |
| *Forms (4 uses), Strip* | 20800 | 4 | C2 | 560 | 0.086 | S.F. | 1.3 | 2.86 | | 4.16 | $264,992 | 9.3 |
| | | | | | | | | | | | $380,500 | |

| | |
|---|---|
| Total Cost | $450,902 |
| Cost/S.F. | $21 |

## Reinforced Flat Plate

| Concrete Columns<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete | | | | | | | | | | | | |
| *Normal Wt., 5000psi* | 70.77 | | | | | C.Y | 96 | | | 96 | $6,794 | |
| Concrete in place | | | | | | | | | | | | |
| *Average Reinforcing* | | | | | | | | | | | | |
| *18"x 26"* | 64.09 | 1 | C14A | 17.7 | 11.293 | C.Y | 345 | 385 | 41 | 771 | $49,413 | 3.6 |
| *24"* | 6.69 | 1 | C14A | 27 | 7.391 | C.Y | 375 | 253 | 27 | 655 | $4,382 | 0.2 |
| Placing, w/ Crane & Bucket | | | | | | | | | | | | |
| *18"x 26"* | 64.09 | 1 | C-7 | 70 | 1.029 | C.Y | | 31 | 14.45 | 45.45 | $2,913 | 0.9 |
| *24"* | 6.69 | 1 | C-7 | 70 | 1.029 | C.Y | | 31 | 14.45 | 45.45 | $304 | 0.1 |
| | | | | | | | | | | | $63,806 | |

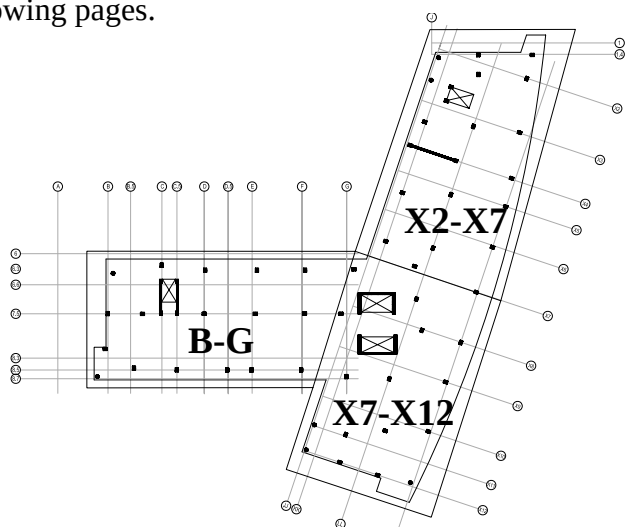
| Concrete Shear-Walls<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete 10" wall | | | | | | | | | | | | |
| *Normal Wt. , 4000psi* | 25.14 | | | | | C.Y. | 84 | | | 84 | $2,112 | |
| Placing, w/ Crane & Bucket | 25.14 | 1 | C-7 | 85 | 0.85 | C.Y. | | 24.5 | 11.35 | 35.85 | $901 | 0.3 |
| Reinforcment in Place | 2.01 | 1 | 4 Rodm | 3 | 10.667 | Ton | 760 | 405 | | 1165 | $2,342 | 0.7 |
| Forms in place, 4 use | 1705.6 | 1 | C2 | 450 | 0.107 | SFCA | 0.37 | 3.56 | | | $6,703 | 3.8 |
| Concrete 14" wall | | | | | | | | | | | | |
| *Normal Wt. , 4000psi* | 16.12 | | | | | C.Y. | 84 | | | 84 | $1,354 | |
| Placing, w/ Crane & Bucket | 16.12 | 1 | C-7 | 95 | 0.758 | C.Y. | | 22 | 10.1 | 32.1 | $517 | 0.2 |
| Reinforcment in Place | 1.64 | 1 | 4 Rodm | 3 | 10.667 | Ton | 760 | 405 | | 1165 | $1,911 | 0.5 |
| Forms in place, 4 use | 416.8 | 1 | C2 | 450 | 0.107 | SFCA | 0.37 | 3.56 | | | $1,638 | 0.9 |
| | | | | | | | | | | | $15,840 | |

| Concrete Flat Plate<br>Description | Take-Off Quantity | # of Crews | Crew | Daily Output | Labor Hours | Unit | 2006 BARE COSTS Mat. | Labor | Equip. | Total | Take-Off Total | Duration (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete | | | | | | | | | | | | |
| *Normal Wt., 5000psi* | 713.3 | | | | | C.Y. | 96 | | | 96 | $68,477 | |
| Placing, Elevated Slabs | | | | | | | | | | | | |
| *8" thick, w/ Crane & Bucket* | 713.3 | 2 | C-7 | 110 | 0.655 | C.Y. | | 11.9 | 4.65 | 16.55 | $20,293 | 3.2 |
| Reinforcment in place | | | | | | | | | | | | |
| *Elevated Slab, #3 to #7* | 42.4 | 4 | 4 Rodm | 2.9 | 11.034 | Ton | 905 | 435 | | 1340 | $112,148 | 3.7 |
| Concrete in place, Flat Plate | | | | | | | | | | | | |
| *Forms (4 uses), Strip* | 20800 | 4 | C2 | 560 | 0.086 | S.F. | 1.3 | 2.86 | | 4.16 | $264,992 | 9.3 |
| | | | | | | | | | | | $465,910 | |

| | |
|---|---|
| Total Cost | $545,556 |
| Cost/S.F. | $26 |

**Schedule Comparison**

The construction schedules were also investigated for a comparison of the designs. The flat plate designs will have similar construction sequences for formwork, reinforcement placement, and concrete placement. The construction sequence of a typical residential level will be completed in three equally sized floor sections. A sectioned construction sequence will increase the rate of floor completion by limiting multiple trades working in the same section at once. The floor sections are depicted below and are referenced by their respective column lines in the schedules included on the following pages.




Schedule issues of the post-tensioned design include the placement and jacking of the post-tensioned tendons. The tendons need to be draped throughout the floor plan with precision adding construction time and labor costs. Also, the removal of formwork and jacking of tendons is only permitted after the concrete plate has reached 75% of its 28 day strength. The durations for completing each section were resolved from the daily output calculated in the cost analysis. The components were given a total duration for the forming, reinforcing, and placement of concrete denoted (F/R/P) in the schedules. The slab was given a cure time of two days until it was post-tensioned and the formwork was removed. A construction schedule over three levels was created for each system to determine an average duration. The post-tensioned system required 8 days to complete an entire floor and the reinforced flat plate system required 7. The extended construction schedule was the result of added duration time for tendon placement and tensioning.

**Post-Tensioned Flat Plate**

| Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|
| Level 1 Construction | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| Columns | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| F/R/P Columns 1 (X2-X7) | 2 days | Thu 3/23/06 | Fri 3/24/06 | |
| F/R/P Columns 1 (X7-X12) | 2 days | Fri 3/24/06 | Mon 3/27/06 | 3SS+1 day |
| F/R/P Columns 1 (B-G) | 2 days | Mon 3/27/06 | Tue 3/28/06 | 4SS+1 day |
| CIP Shear Walls | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| F/R/P Shear Wall 1 (D) | 2 days | Thu 3/23/06 | Fri 3/24/06 | 3SS |
| F/R/P Shear Wall 1 (A,B) | 2 days | Fri 3/24/06 | Mon 3/27/06 | 4SS |
| F/R/P Shear Wall 1 (C,C1) | 2 days | Mon 3/27/06 | Tue 3/28/06 | 5SS |
| Level 2 Construction | 8 days? | Mon 3/27/06 | Wed 4/5/06 | |
| Flat Plate | 8 days? | Mon 3/27/06 | Wed 4/5/06 | |
| F/R/P Flat Plat 2 (X2-7) | 4 days | Mon 3/27/06 | Thu 3/30/06 | 3 |
| PT/Strip/RS Flat Plate 2 (X2-X7) | 1 day? | Mon 4/3/06 | Mon 4/3/06 | 12FS+1 day |
| F/R/P Flate Plate 2 (X7-X12) | 4 days | Tue 3/28/06 | Fri 3/31/06 | 4 |
| PT/Strip/RS Flat Plate 2 (X7-X12) | 1 day? | Tue 4/4/06 | Tue 4/4/06 | 14FS+1 day |
| F/R/P Flat Plate 2 (B-G) | 4 days | Wed 3/29/06 | Mon 4/3/06 | 5 |
| PT/Strip/RS Flat Plate 2 (B-G) | 1 day? | Wed 4/5/06 | Wed 4/5/06 | 16FS+1 day |
| Columns | 4 days | Wed 3/29/06 | Mon 4/3/06 | |
| F/R/P Columns 2 (X2-X7) | 2 days | Wed 3/29/06 | Thu 3/30/06 | 12SS+2 days |
| F/R/P Columns 2 (X7-X12) | 2 days | Thu 3/30/06 | Fri 3/31/06 | 14SS+2 days |
| F/R/P Columns 2 (B-G) | 2 days | Fri 3/31/06 | Mon 4/3/06 | 16SS+2 days |
| CIP Shear Walls | 4 days | Wed 3/29/06 | Mon 4/3/06 | |
| F/R/P Shear Wall 2 (D) | 2 days | Wed 3/29/06 | Thu 3/30/06 | 19SS |
| F/R/P Shear Wall 2 (A,B) | 2 days | Thu 3/30/06 | Fri 3/31/06 | 20SS |
| F/R/P Shear Wall 2 (C,C1) | 2 days | Fri 3/31/06 | Mon 4/3/06 | 21SS |
| Level 3 Construction | 8 days? | Fri 3/31/06 | Tue 4/11/06 | |
| Flat Plate | 8 days? | Fri 3/31/06 | Tue 4/11/06 | |
| F/R/P Flat Plat 3 (X2-X7) | 4 days | Fri 3/31/06 | Wed 4/5/06 | 12 |
| PT/Strip/RS Flat Plate 3 (X2-X7) | 1 day? | Fri 4/7/06 | Fri 4/7/06 | 28FS+1 day |
| F/R/P Flate Plate 3 (X7-X12) | 4 days | Tue 4/4/06 | Fri 4/7/06 | 13 |
| PT/Strip/RS Flat Plate 3 (X7-X12) | 1 day? | Tue 4/11/06 | Tue 4/11/06 | 30FS+1 day |
| F/R/P Flat Plate 3 (B-G) | 4 days | Mon 4/3/06 | Thu 4/6/06 | 14 |
| PT/Strip/RS Flat Plate 3 (B-G) | 1 day? | Mon 4/10/06 | Mon 4/10/06 | 32FS+1 day |
| Columns | 4 days | Tue 4/4/06 | Fri 4/7/06 | |
| F/R/P Columns 3 (X2-X7) | 2 days | Tue 4/4/06 | Wed 4/5/06 | 28SS+2 days |
| F/R/P Columns 3 (X7-X12) | 2 days | Thu 4/6/06 | Fri 4/7/06 | 30SS+2 days |
| F/R/P Columns 3 (B-G) | 2 days | Wed 4/5/06 | Thu 4/6/06 | 32SS+2 days |
| CIP Shear Walls | 4 days | Tue 4/4/06 | Fri 4/7/06 | |
| F/R/P Shear Wall 3 (D) | 2 days | Tue 4/4/06 | Wed 4/5/06 | 35SS |
| F/R/P Shear Wall 3 (A,B) | 2 days | Thu 4/6/06 | Fri 4/7/06 | 36SS |
| F/R/P Shear Wall 3 (C,C1) | 2 days | Wed 4/5/06 | Thu 4/6/06 | 37SS |

**Reinforced Flat Plate**

| Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|
| Level 1 Construction | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| Columns | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| F/R/P Columns 1 (X2-X7) | 2 days | Thu 3/23/06 | Fri 3/24/06 | |
| F/R/P Columns 1 (X7-X12) | 2 days | Fri 3/24/06 | Mon 3/27/06 | 3SS+1 day |
| F/R/P Columns 1 (B-G) | 2 days | Mon 3/27/06 | Tue 3/28/06 | 4SS+1 day |
| CIP Shear Walls | 4 days | Thu 3/23/06 | Tue 3/28/06 | |
| F/R/P Shear Wall 1 (D) | 2 days | Thu 3/23/06 | Fri 3/24/06 | 3SS |
| F/R/P Shear Wall 1 (A,B) | 2 days | Fri 3/24/06 | Mon 3/27/06 | 4SS |
| F/R/P Shear Wall 1 (C,C1) | 2 days | Mon 3/27/06 | Tue 3/28/06 | 5SS |
| Level 2 Construction | 7 days? | Mon 3/27/06 | Tue 4/4/06 | |
| Flat Plate | 7 days? | Mon 3/27/06 | Tue 4/4/06 | |
| F/R/ P Flat Plat 2 (X2-X7) | 3 days | Mon 3/27/06 | Wed 3/29/06 | 3 |
| Strip/RS Flat Plate 2 (X2-X7) | 1 day? | Fri 3/31/06 | Fri 3/31/06 | 12FS+1 day |
| F/R/P Flate Plate 2 (X7-X12) | 3 days | Tue 3/28/06 | Thu 3/30/06 | 4 |
| Strip/RS Flat Plate 2 (X7-X12) | 1 day? | Mon 4/3/06 | Mon 4/3/06 | 14FS+1 day |
| F/R/P Flat Plate 2 (B-G) | 3 days | Wed 3/29/06 | Fri 3/31/06 | 5 |
| Strip/RS Flat Plate 2 (B-G) | 1 day? | Tue 4/4/06 | Tue 4/4/06 | 16FS+1 day |
| Columns | 4 days | Tue 3/28/06 | Fri 3/31/06 | |
| F/R/P Columns 2 (X2-X7) | 2 days | Tue 3/28/06 | Wed 3/29/06 | 12SS+1 day |
| F/R/P Columns 2 (X7-X12) | 2 days | Wed 3/29/06 | Thu 3/30/06 | 14SS+1 day |
| F/R/P Columns 2 (B-G) | 2 days | Thu 3/30/06 | Fri 3/31/06 | 16SS+1 day |
| CIP Shear Walls | 4 days | Tue 3/28/06 | Fri 3/31/06 | |
| F/R/P Shear Wall 2 (D) | 2 days | Tue 3/28/06 | Wed 3/29/06 | 19SS |
| F/R/P Shear Wall 2 (A,B) | 2 days | Wed 3/29/06 | Thu 3/30/06 | 20SS |
| F/R/P Shear Wall 2 (C,C1) | 2 days | Thu 3/30/06 | Fri 3/31/06 | 21SS |
| Level 3 Construction | 7 days? | Thu 3/30/06 | Fri 4/7/06 | |
| Flat Plate | 7 days? | Thu 3/30/06 | Fri 4/7/06 | |
| F/R/ P Flat Plat 3 (X2-X7) | 3 days | Thu 3/30/06 | Mon 4/3/06 | 12 |
| Strip/RS Flat Plate 3 (X2-X7) | 1 day? | Wed 4/5/06 | Wed 4/5/06 | 28FS+1 day |
| F/R/P Flate Plate 3 (X7-X12) | 3 days | Mon 4/3/06 | Wed 4/5/06 | 13 |
| Strip/RS Flat Plate 3 (X7-X12) | 1 day? | Fri 4/7/06 | Fri 4/7/06 | 30FS+1 day |
| F/R/P Flat Plate 3 (X7- X12) | 3 days | Fri 3/31/06 | Tue 4/4/06 | 14 |
| Strip/RS Flat Plate 3 (X7-X12) | 1 day? | Thu 4/6/06 | Thu 4/6/06 | 32FS+1 day |
| Columns | 4 days | Fri 3/31/06 | Wed 4/5/06 | |
| F/R/P Columns 3 (X2-X7) | 2 days | Fri 3/31/06 | Mon 4/3/06 | 28SS+1 day |
| F/R/P Columns 3 (X7-X12) | 2 days | Tue 4/4/06 | Wed 4/5/06 | 30SS+1 day |
| F/R/P Columns 3 (B-G) | 2 days | Mon 4/3/06 | Tue 4/4/06 | 32SS+1 day |
| CIP Shear Walls | 4 days | Fri 3/31/06 | Wed 4/5/06 | |
| F/R/P Shear Wall 3 (D) | 2 days | Fri 3/31/06 | Mon 4/3/06 | 35SS |
| F/R/P Shear Wall 3 (A,B) | 2 days | Tue 4/4/06 | Wed 4/5/06 | 36SS |
| F/R/P Shear Wall 3 (C,C1) | 2 days | Mon 4/3/06 | Tue 4/4/06 | 37SS |