Cinema-Dining Terrace Expansion

Suburbia, USA

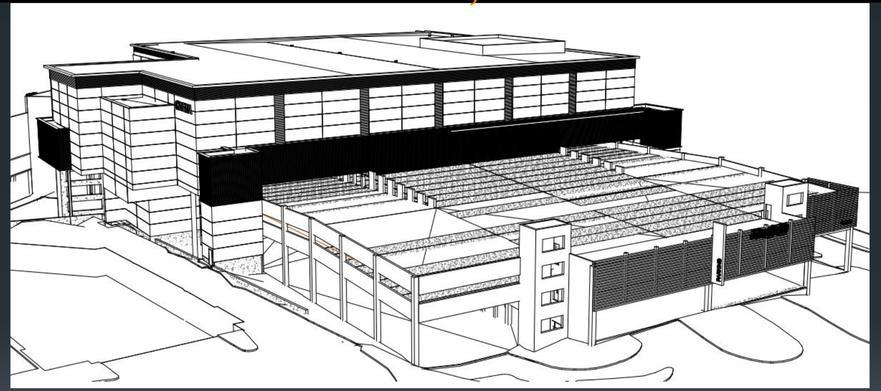


Image Courtesy of The Whiting-Turner Contracting Company

Penn State AE Senior Capstone Project
Nicholas J. Kline | Construction Option
Advisor | Mr. Ray Sowers

Cinema-Dining Terrace Expansion

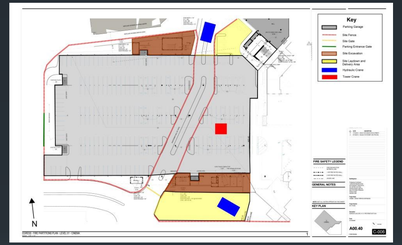
Suburbia, USA

Introduction

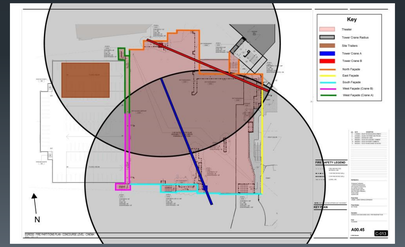
Project Background

Courtesy of Whiting-Turner

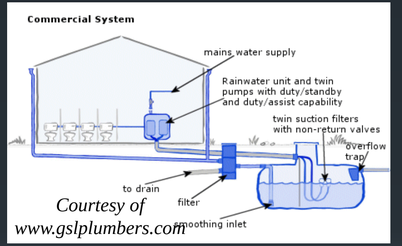
Analysis 1 | Site Logistics



Analysis 2 | Prefabrication of Exterior Envelope



Analysis 3 | Water Drainage Recycling



Courtesy of www.gslplumbers.com

Cinema-Dining Terrace Expansion

Suburbia, USA

Project Background

Building Name	Cinema-Dining Terrace Expansion
Location	Suburbia, USA
Building Occupant	ArchLight Cinema
Building Functions	Covered Mall Building Assembly, Business, Mercantile, Storage
Size	91,000 GSF 70,000 sqft 16 Screen Cinema 12,000 sqft Food Court Expansion 9,500 sqft Restaurants
Number of Stories	3 stories above grade
Project Timeline	June 2012 – August 2014
Cost	$50,223,763.00

Owner **|** Anonymous Owner

GC **|** The Whiting-Turner Contracting Company

Architect **|** Gensler

Structural Engineer **|** Robert Silman Associates

MEP Engineer **|** B&R Construction Services

Image Courtesy of The Whiting-Turner Contracting Company

Project Background

Nicholas Kline | Construction Option | AE Senior Thesis

Building Systems

Structural System

Foundation - Micro-piles with pile caps, sandwich footings, spread footings, and mat slabs

Structural Steel

Exterior Enclosure System

EIFS

Storefront Glazing

Metal Panels

Image Courtesy of The Whiting-Turner Contracting Company

Analysis 1 | Site Logistics Analysis

Opportunity:

The current site logistics requires extensive means and methods adding to the critical schedule.

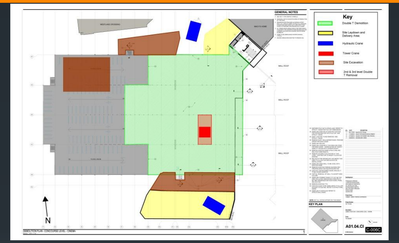
Cinema-Dining Terrace Expansion

Suburbia, USA

Nicholas Kline | Construction Option | AE Senior Thesis

Current Site Logistics

Demolition Phase



Steel Erection Phase

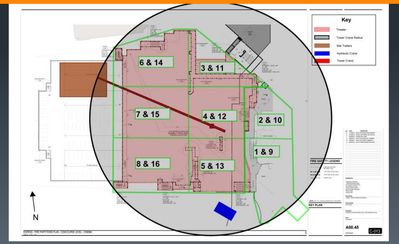
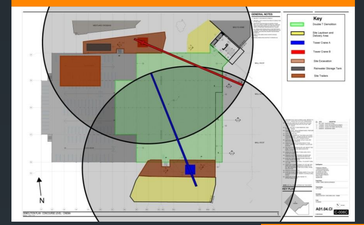


Image Courtesy of The Whiting-Turner Contracting Company

New Site Logistics

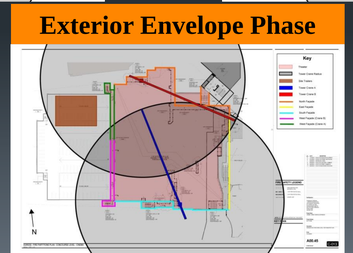
Nicholas Kline | Construction Option | AE Senior Thesis

Demolition Phase

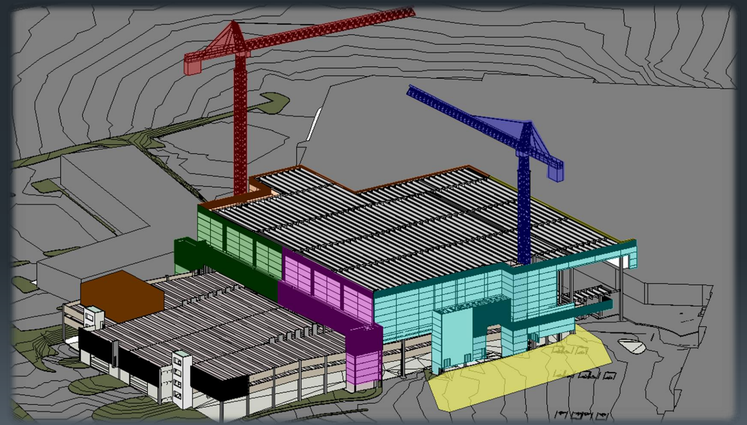


Steel Erection Phase

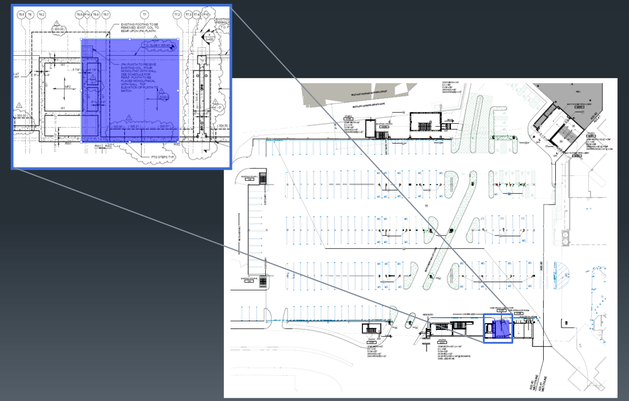
Exterior Envelope Phase



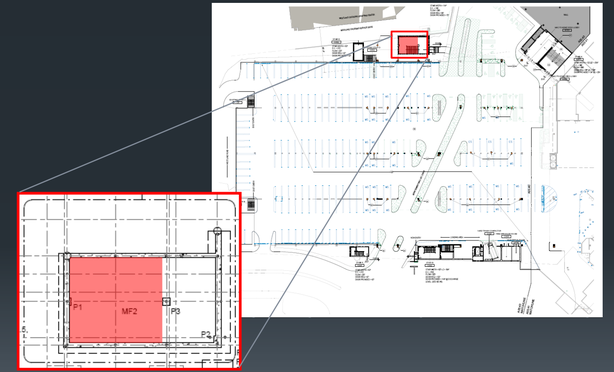
New Site Phasing



Tower Crane A Foundation



Tower Crane B Foundation



Cinema-Dining Terrace Expansion

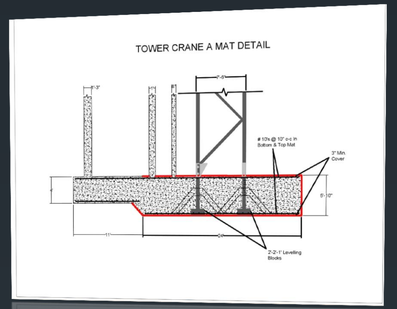
Suburbia, USA

Structural Breadth

Tower Crane A

Tower Crane Specifications

- Model: Linden Comansa 21LC550
- Hook Height: 136.8 ft
- Jib Reach: 262.4 ft

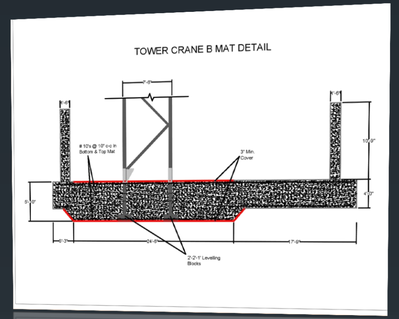


Foundation Specifications						
Concrete Strength (f'c)	W	L	T	Rebar Size & Spacing (Both Directions)		Weight of FDN.
				Bottom	Top	
5,000 psi	22'-6"	24'-0"	5'-10"	#10@10"	#10@10"	472 kips

Tower Crane B

Tower Crane Specifications

- Model: Linden Comansa 21LC550
- Hook Height: 172.9 ft
- Jib Reach: 262.4 ft



Foundation Specifications						
Concrete Strength (f'c)	W	L	T	Rebar Size & Spacing (Both Directions)		Weight of FDN.
				Bottom	Top	
5,000 psi	24'-6"	24'-6"	5'-10"	#10@10"	#10@10"	525 kips

Schedules

Original Site Logistics Schedule

Original Schedule Summary			
Activities	Duration	Start	Finish
Cinema-Dining Terrace Expansion	**538**	**1-Jun-12**	**8-Jul-14**
Owner Internal Review/Approvals	162	1-Jun-12	29-Jul-13
Preconstruction	220	18-Sep-12	29-Jul-13
Dining Terrace Work	209	9-Jan-13	31-Oct-13
Site Work	171	10-Jan-13	12-Sep-13
Garage Demolition	56	11-Mar-13	28-May-13
Garage Expansion Substructure Area 1	101	5-Mar-13	25-Jul-13
Garage Expansion Substructure Area 2	62	5-Mar-13	30-May-13
Theater Structural Steel Erection	55	17-May-13	5-Aug-13
Dining Terrace Structure	75	3-Jun-13	17-Sep-13
Theater Service Area Structure	51	1-May-13	12-Jul-13
Stair Structure	68	17-Apr-13	23-Jul-13
Theater Roof	37	23-Jul-13	12-Sep-13
Dining Terrace Roof	26	19-Jul-13	23-Aug-13
Elevations Envelope	133	8-Jul-13	13-Jan-14
Stairway Finishes	115	12-Jun-13	21-Nov-13
Garage Rough-Ins & Finishes	229	8-Jul-13	10-Jun-14
Expansion Rough-Ins & Finishes	108	29-May-13	29-Oct-13
Theater Rough-Ins & Finishes	213	11-Jun-13	9-Apr-14
Theater Fit-Out	64	10-Apr-14	8-Jul-14
Project Completion	0		8-Jul-14

Original Duration | 538 Days

New Site Logistics Schedule

New Schedule Summary			
Activities	Duration	Start	Finish
Cinema-Dining Terrace Expansion	**497**	**1-Jun-12**	**12-May-14**
Owner Internal Review/Approvals	162	1-Jun-12	29-Jul-13
Preconstruction	220	18-Sep-12	29-Jul-13
Dining Terrace Work	209	9-Jan-13	31-Oct-13
Site Work	*179*	10-Jan-13	20-Sep-13
Garage Demolition	*46*	25-Mar-13	28-May-13
Garage Expansion Substructure Area 1	41	21-Feb-13	18-Apr-13
Garage Expansion Substructure Area 2	62	5-Mar-13	30-May-13
Theater Structural Steel Erection	*31*	15-Apr-13	28-May-13
Dining Terrace Structure	*48*	29-May-13	5-Aug-13
Theater Service Area Structure	30	15-Apr-13	24-May-13
Stair Structure	*73*	15-Apr-13	26-Jul-13
Theater Roof	37	28-May-13	18-Jul-13
Dining Terrace Roof	26	5-Aug-13	10-Sep-13
Elevations Envelope	*72*	3-Jun-13	12-Sep-13
Stairway Finishes	115	15-Apr-13	25-Sep-13
Garage Rough-Ins & Finishes	229	12-Jun-13	2-May-14
Expansion Rough-Ins & Finishes	108	29-May-13	29-Oct-13
Theater Rough-Ins & Finishes	213	15-Apr-13	12-Feb-14
Theater Fit-Out	64	12-Feb-14	12-May-14
Project Completion	0		12-May-14

New Duration | 497 Days

Savings | 41 workdays
57 total days

Costs

Original Site logistics Costs

Original Tower Crane Logistics Costs			
Activity	Duration	Unit	Total
Tower Crane Erection	3	days	$ 28,536.00
Demolition	15	days	$ 249,360.00
Steel Erection (1A-6A & 1B-6B)	52	days	$ 616,512.00
Steel Erection (7A, 8A)	47	days	$ 306,816.00
Curtain Wall Installation	122	days	$ 573,888.00
			$ 1,775,112.00
Tower Crane Foundation	56	hrs	$ 73,278.00
			$ 1,848,390.00

New Site logistics Costs

New Tower Crane Logistics Costs			
Activity	Duration	Unit	Total
Tower Crane Erection	3	days	$ 57,072.00
Demolition	15	days	$ 135,360.00
Steel Erection (1A-6A & 1B-6B)	25	days	$ 326,400.00
Steel Erection (7A, 8A)	47	days	$ 306,816.00
Curtain Wall Installation	37	days	$ 333,888.00
			$ 1,159,536.00
Tower Crane Foundation A	56	hrs	$ 74,478.00
Tower Crane Foundation B	56	hrs	$ 80,978.00
			$ 1,314,992.00

Savings | $533,398.00
Additional Savings | $500,000.00/month = $1,000,000.00
Total Estimated Savings | $1,533,398.00

Analysis 2 | Exterior Envelope Prefab

Opportunity:

Stick building the exterior envelope is time consuming and labor intensive.

Analysis 2 | Exterior Envelope Prefab

Nicholas Kline | Construction Option | AE Senior Thesis

Original | Stick Built

Image Courtesy of The Whiting-Turner Contracting Company

Laborers | 8

Duration | 120 days

Materials:
- EIFS
- Framing and Sheathing

Redesign | Prefabrication

Image Courtesy of KHS&S

Laborers | 2

Equipment | Tower Crane

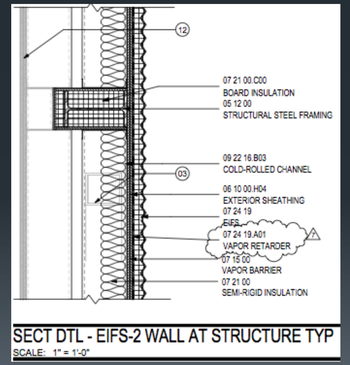
Duration | 37 days

Materials:
- EIFS Panels
- Framing and Sheathing Panels

Cinema-Dining Terrace Expansion
Suburbia, USA

Analysis 2 | Exterior Envelope Prefab

Original Exterior



NORTH ELEVATION		
28250	N: EXT WALL FRAMING THEATER	15
28260	N: EXT WALL SHEATHING THEATER	15
28270	N: AIR BARRIER/INSULATION	5
28280	N: VERTICAL CORROGATED METAL	5
28290	N: EIFS THEATER	20
28300	N: SMOOTH METAL PANELS	3

New Site Exterior

Largest Dryvit installer in the US

EIFS Panels | finish, framing, sheathing, air barrier, and insulation

Image Courtesy of KHS&S

- Accelerates enclosing the building
- Fabrication is done to exact specifications
- Fabrication is done in a controlled environment
- Panels are delivered ready to install

Schedules

Original Exterior Installation Schedule

Original Schedule Summary			
Activities	Duration	Start	Finish
Cinema-Dining Terrace Expansion	**538**	**1-Jun-12**	**8-Jul-14**
Owner Internal Review/Approvals	162	1-Jun-12	29-Jul-13
Preconstruction	220	18-Sep-12	29-Jul-13
Dining Terrace Work	209	9-Jan-13	31-Oct-13
Site Work	171	10-Jan-13	12-Sep-13
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Expansion Rough-Ins & Finishes	108	29-May-13	29-Oct-13
Theater Rough-Ins & Finishes	213	11-Jun-13	9-Apr-14
Theater Fit-Out	64	10-Apr-14	8-Jul-14
Project Completion	0		8-Jul-14

Workdays | 122 days

Duration | 133 days (8-*Jul-13* to *13-Jan-14*)

New Exterior Installation Schedule

Tower Crane A			
Activities	Duration	Start	Finish
	164	**29-Jan-13**	**20-Sep-13**
Excavations	17	29-Jan-13	20-Feb-13
FRP and Cure Foundations	17	21-Feb-13	15-Mar-13
Erect Crane	5	18-Mar-13	22-Mar-13
Demolition Level 4 Precast	15	25-Mar-13	12-Apr-13
Steel Erection - Theater	31	15-Apr-13	28-May-13
Steel Erection - Dining Terrace	48	29-May-13	5-Aug-13
Exterior Enclosure - West	6	12-Aug-13	19-Aug-13
Exterior Enclosure - South	8	20-Aug-13	29-Aug-13
Exterior Enclosure - East	9	30-Aug-13	12-Sep-13
Deconstruct Crane	5	16-Sep-13	20-Sep-13

Tower Crane B			
Activities	Duration	Start	Finish
	102	**29-Jan-13**	**24-Jun-13**
Excavations	17	29-Jan-13	20-Feb-13
FRP and Cure Foundations	16	21-Feb-13	14-Mar-13
Erect Crane	5	18-Mar-13	22-Mar-13
Demolition Level 4 Precast	15	25-Mar-13	12-Apr-13
Steel Erection - Theater	31	15-Apr-13	28-May-13
Exterior Enclosure - North	6	3-Jun-13	7-Jun-13
Exterior Enclosure - West	8	10-Jun-13	17-Jun-13
Deconstruct Crane	5	18-Jun-13	24-Jun-13

Workdays | 37 days

Duration | 72 days (*12-Aug-13* to *17-Jun-13*)

Costs

Original Exterior Costs

Original Curtain Wall Costs				
Theater Shell				
Activity/Material	Qty	Unit	Cost	Total
Exterior Metal Studs & Sheathing	56,686	SF	$18.50	$1,048,691.00
Grooved EIFS	8,600	SF	$12.00	$103,200.00
EIFS	48,086	SF	$9.00	$432,774.00
				$1,584,665.00
Food Court Renovation				
Activity/Material	Qty	Unit	Cost	Total
Framing and Sheathing	13,400	SF	$13.00	$174,200.00
EIFS	13,400	SF	$9.00	$120,600.00
				$294,800.00
				$1,879,465.00

New Exterior Costs

Exterior Metal Studs & Sheathing Panels | $35.00/SF

EIFS Panels | $45.00/SF

Total New Cost | $2,857,955.00

Analysis 3 | Water Drainage Recycling

Opportunity:

Rainwater recycling can add sustainability and cost savings to the project.

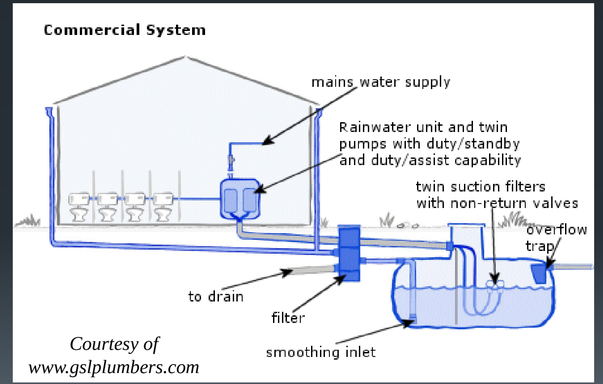
Analysis 3 | Water Drainage Recycling

Nicholas Kline | Construction Option | AE Senior Thesis

Rainwater Recycling

- **Free source of non-potable water**
- **Primary use |** Toilet and Urinal Fixtures
- **Equipment |** Storage Tank with Accessories, Filtration system, pump system, and added piping
- **Large Flat Roof**

Basic Commercial Rainwater Recycling System

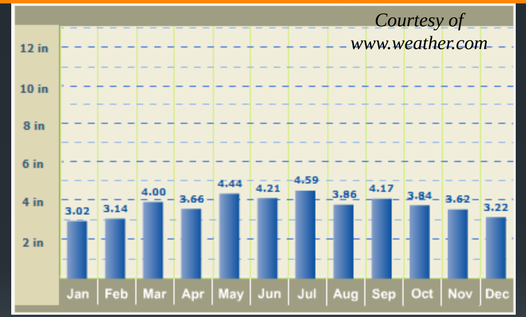


Courtesy of www.gslplumbers.com

Cinema-Dining Terrace Expansion
Suburbia, USA

Mechanical Breadth

Rainwater Supply



Roof | 86,640 SF **Monthly Avg. (in.) |** 3.81

CF to Gallon Factor | 7.48 CF/G

$$86{,}64 * \left(\frac{3.81}{12}\right) * (.9) * 7.48 = 185{,}185.2\ \textit{Gallons per month}$$

$$= \mathbf{2{,}222{,}222.4\ \textit{Gallons per year}}$$

Water Demand

Courtesy of the International Plumbing Code **PLUMBING FIXTURE OR FIXTURE FITTING**	**MAXIMUM FLOW RATE OR QUANTITY[b]**
Lavatory, private	2.2 gpm at 60 psi
Lavatory, public (metering)	0.25 gallon per metering cycle
Lavatory, public (other than metering)	0.5 gpm at 60 psi
Shower head[a]	2.5 gpm at 80 psi
Sink faucet	2.2 gpm at 60 psi
Urinal	1.0 gallon per flushing cycle
Water closet	1.6 gallons per flushing cycle

Toilets | 120 flushes per day **Urinals |** 75 flushes per day

Toilets | 1.6 gallons per flush **Urinals |** 1.0 gallon per flush

$$(46 * 120 * 1.6) + (10 * 75 * 1.0) = 9{,}582\ \textit{Gallons per day}$$

$$= 239{,}550\ \textit{Gallons per month}$$

$$= \mathbf{2{,}874{,}600\ \textit{Gallons per year}}$$

Cinema-Dining Terrace Expansion

Suburbia, USA

Mechanical Breadth

Pump

Total Dynamic Head Calculator

Courtesy of www.pumpworld.com

Pump Flow Rate	Pipe Diameter(ID)	Pipe Length	Differential Elevation	Pipe Material	Total Dynamic Head(TDH)
US GPM	in.	ft.	ft.	New Steel	ft.
200	4	600	40		64.27855981850

Compute Total Dynamic Head(TDH) | Reset

Pump Details

SKV/SKS3006-3600-5.00

Specifications

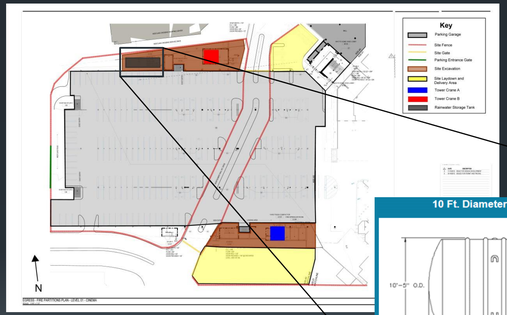
Flow: 200
Head: 64
RPM: 3600
Imp Dia.: 5.25
Size: 3 x 3
Design Hz 53.55

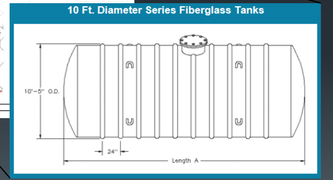
Eff 68%
NOL HP 5.00
NPSH 15 ft
Control Head 25.6
Control Head Hz 30.31

Courtesy of www.taco-hvac.com

Pump | 5 HP Selfsensing Variable Speed Pump

Storage Tank





Courtesy of www.darcoinc.com

Size | 20,000 gal

Length | 35’ 0”

Diameter | 10’ 0”

Costs

Equipment Costs

Underground Tank Project Estimate

You are looking for an underground tank system to store 20,000 gallons of water.

Here is your fiberglass tank estimate.

10' Diameter 20,000 Gallon storage tank	Included
Accessories (Average)	Included
Shipping	Included
Total Estimated Cost	**$31,630.00**
Required Deposit *(Balance COD)*	**$10,437.90**
Lead Time: 7 to 9 weeks	

Courtesy of www.darcoinc.com

Estimated new piping | $50,000

Estimated total system costs | $81,630.00

Water Costs

Domestic Water Annual Demand | ($6.76/1000G) * 2,874,600G = $19,432.29

Annual Water Savings | ($6.76/1000G) * 2,222,222.4G = $15,022.22

Total Annual Cost | $19,432.29 - $15,022.22 = $4,410.07

7 year system payback period

Original Annual Water Costs							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Costs	$ (19,432.29)	$ (19,432.29)	$ (19,432.29)	$ (19,432.29)	$ (19,432.29)	$ (19,432.29)	$ (19,432.29)
Savings	$ -	$ -	$ -	$ -	$ -	$ -	

New Annual Water Costs							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Costs	$ (86,040.07)	$ (4,410.07)	$ (4,410.07)	$ (4,410.07)	$ (4,410.07)	$ (4,410.07)	$ (4,410.07)
Savings	($66,607.78)	($51,585.56)	($36,563.34)	($21,541.12)	($6,518.90)	$8,503.32	$15,022.22

Conclusions

Analysis 1 | Site Logistics Analysis

Total Original Costs | $1,848,390.00

Total New Costs | $1,314,992.00

Total Savings | $533,398.00

Estimated Owner Savings | $1,000,000.00

Original Schedule Duration | 538 workdays

New Schedule Duration | 497 workdays

Total Savings | 41 workdays or about 2 months

Estimated Owner Savings | $500,000.00/month

Analysis 2 | Exterior Envelope Prefabrication

Original Costs | ~ $2,453,353.00

Prefabricated Costs | ~ $3,191,843.00

Total Added Costs | $738,490.00

Original Schedule| 122 workdays

Prefabricated Schedule| 37 workdays

Total Savings | 85 workdays

Analysis 3 | Water Drainage Recycling

System Costs | ~ $80,000

Water Cost Savings | ~ $15,000/year

7 year payback period

Recommendations

Analysis 1 | Site Logistics Analysis

Yes recommended | Benefits to both cost and schedule

Analysis 2 | Exterior Envelope Prefabrication

Not recommended | Costs outweigh schedule improvements

Analysis 3 | Water Drainage Recycling

Yes recommended | Water Cost Savings

Acknowledgements

Academic Acknowledgements

Mr. Ray Sowers | CM Faculty Advisor
Prof. Kevin Parfitt
Prof. Charles Cox
Prof. Moses Ling
Penn State AE Faculty

Special Thanks

The Whiting-Turner Project Team
My Family and Friends

Questions?

Structural Breadth

Tower Crane A **Structural Breadth** **Foundation Calculations**

Tower Crane Mat Design:

CRANE CONFIGURATION:
Model: LINDEN COMANSA 21 LC 550
Hook Height: 136.8 ft Crane Mast Base Plan Dimension, Bc = 7.5 ft
Jib Reach: 262.4 ft

BASE FORCES AT TOP OF MAT:

	M	H	V	Md
In Operation	3672 ft-kips	7 kips	277 kips	564 ft-kips
Out of Operation	3831 ft-kips	21 kips	257 kips	0 ft-kips
GOVERNING LOAD CONDITION:	3831 ft-kips	21 kips	277 kips	564 ft-kips

ALLOWABLE SOIL BEARING CAPACITY 4000 psf

MAT MATERIALS:
f'c= 5000 psi **Fy=** 60 ksi ASTM A615 Grade 60
Min. Cover 3 in

MAT SIZE ASSUMPTIONS:
Plan Size B x L **B=** 22.5 ft **L=** 24 ft
Thickness **D=** 5.833 ft
Mat Dead Load **Wm=** 472 kips (150 pcf x L x B x D)
Overturning Moment **Mot=** M+(Vd)(D) = 3831+(257*5.83)
Mot= 3953 ft-kips
Loading Eccentricity **e=** Mot/(V+Wm)<B/6 3953/(277+472)<20/6
e= 5.26 ft <B/6 5.75 => OK
Max Soil Stress **fbr max=** (2e)(V+Wm)/(bLxB/2-e)) = (2*(277+472))/(3*24*(22.5/2-5.28))
fbr max= 3480 psf < Allowable Soil Bearing Capacity =>OK

COMPUTE SOIL STRESS @ FACE OF MAST
Edge Distance **Ed=** .5(B-Bc) = .5(22.5-7.5) **Lfbr =** .5(B/2-e) = .5(22.5/2-5.28)
Ed= 7.50 ft **Lfbr =** 17.02 ft
L2 Ed/2 = 7.50/2 **L1=** 2/3(B/2 - Bc/2) = 2/3(22.5/2 - 7.5/2)
L2 3.75 **L1=** 5.00 ft
fbrmast= fbrmax(Lfbr-B/2+Bc/2)/Lfbr = 3772/(17.92-22.5/2+7.5/2)/17.92
fbrmast= 2920.41 psf

RESISTANCE TO OVERTURNING
Resisting Moments Mr= (Wm+V)B/2 = (472+277)22.5/2
Mr= 8431.571 ft-kips
Factor of Safety for Overturning (FSot)= Mr/Mot >= 1.5 = 8431.57/3953
FSot= 2.13
FSot= 2.13 => OK for Overturning

Tower Crane B **Structural Breadth** **Foundation Calculations**

Tower Crane Mat Design:

CRANE CONFIGURATION:
Model: LINDEN COMANSA 21 LC 550
Hook Height: 172.9 ft Crane Mast Base Plan Dimension, Bc = 7.5 ft
Jib Reach: 262.4 ft

BASE FORCES AT TOP OF MAT:

	M	H	V	Md
In Operation	4112 ft-kips	8 kips	296 kips	564 ft-kips
Out of Operation	4770 ft-kips	26 kips	277 kips	0 ft-kips
GOVERNING LOAD CONDITION:	4770 ft-kips	26 kips	296 kips	564 ft-kips

ALLOWABLE SOIL BEARING CAPACITY 4000 psf

MAT MATERIALS:
f'c= 5000 psi **Fy=** 60 ksi ASTM A615 Grade 60
Min. Cover 3 in

MAT SIZE ASSUMPTIONS:
Plan Size B x L **B=** 24.5 ft **L=** 24.5 ft
Thickness **D=** 5.833 ft
Mat Dead Load **Wm=** 525 kips (150 pcf x L x B x D)
Overturning Moment **Mot=** M+(Vd)(D) = 4770+(296*5.83)
Mot= 6492 ft-kips
Loading Eccentricity **e=** Mot/(V+Wm)<B/6 = 6492/(296+525)<24.5/6
e= 4.90 ft <B/6 4.08 => OK
Max Soil Stress **fbr max=** (2e)(V+Wm)/(bLxB/2-e)) = (2*(296+525))/(3*24.5*(24.5/2-5.99))
fbr max= 3571 psf < Allowable Soil Bearing Capacity =>OK

COMPUTE SOIL STRESS @ FACE OF MAST
Edge Distance **Ed=** .5(B-Bc) = .5(24.5-7.5) **Lfbr =** .5(B/2-e) = .5(24.5/2-5.99)
Ed= 8.50 ft **Lfbr =** 18.77 ft
L2 Ed/2 = 8.5/2 **L1=** 2/3(B/2 - Bc/2) = 2/3(24.5/2 - 7.5/2)
L2 4.25 **L1=** 5.67 ft
fbrmast= fbrmax(Lfbr-B/2+Bc/2)/Lfbr = 3571/(18.77-24.5/2+7.5/2)/18.77
fbrmast= 1954.11 psf

RESISTANCE TO OVERTURNING
Resisting Moments Mr= (Wm+V)B/2 = (525+296)24.5/2
Mr= 10059.563 ft-kips
Factor of Safety for Overturning (FSot)= Mr/Mot >= 1.5 = 10059.56/4922
FSot= 2.04
FSot= 2.04 => OK for Overturning

New Project Schedule