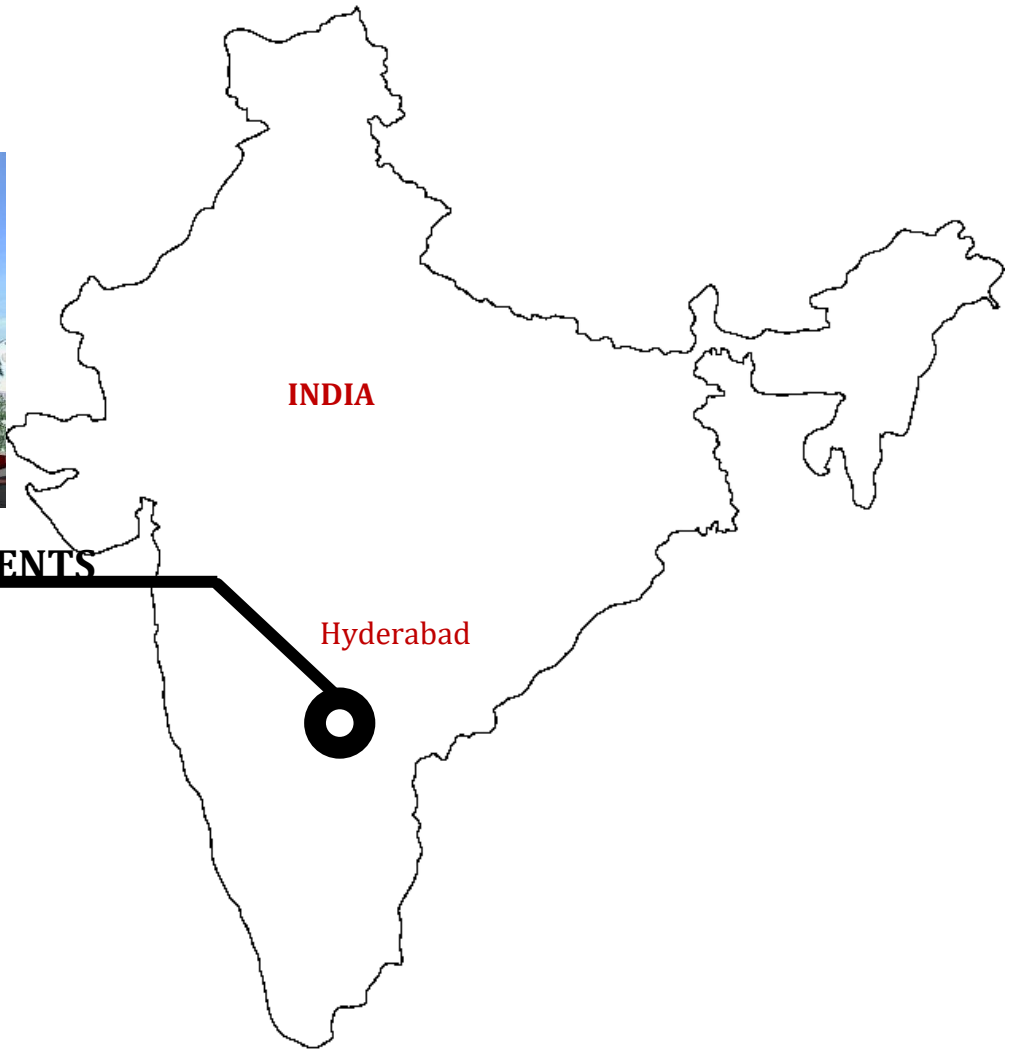
AE-481 W

FALL 2016

TECHNICAL REPORT 2



HANZA CREST APARTMENTS

Bhavana Reddy

Advisor: Dr. Robert Leicht

October 17th, 2016

EXCECUTIVE SUMMARY

Ambience Constructions firm was appetent about introducing their firm into the residential construction market through Hanza Crest apartments project and intensify the firm's reputation. They are designed for high-income earning demographic. The building contains 8 stories of residential floors which 2 basements, 5 floors with 2 apartments each floor and a club house. The project is built for $1.05 M in 32 months.

The schedule of Hanza Crest apartments had no scope of delay after excavation phase, as per the owner's requirements. There are total 7 milestones which have similar approach based on the phase. The approach followed for superstructure and finishes phases is preceding activity is scheduled along with succeeding activity working with a gap of consistent time period between them to accelerate the schedule. The other milestones have an approach designed based on the activities involved. The building will be turned over in June 2018.

The project's structural system is made with steel and Roller-compacted concrete (RCC) structure. This type of concrete construction is preferred in India since it is highly durable. The total cost for foundation and structural system is $2.2 M based on the detailed estimate report and the actual cost is $315,167. The cost to construct similar foundation and structural system in USA would cost 6.6 times higher compared to India.

The construction method for the structural system is to follow a 14 to 22 days pattern of raising the system by dividing each floor into 3 sections. The design standards is concentrated on the concrete strength and type of reinforced bars used for the system. The key equipment required are concrete trucks curing tanks and cement mortars.

The site of this project is located in a very space restricted location. Considering this constraint, the site located opposite to the project's site has been utilized for various purposes at different phases. This created few challenges for site logistics specifically for delivering the materials.

TABLE OF CONTENTS

SYSTEM CONSTRUCTION MEANS AND METHODS

The superstructure of the Hanza Crest apartments is completely cast-in-place concrete. . The structural system of the building is made up of steel and Roller-compacted concrete (RCC). This type of concrete does not require joints. A typical apartment is made of concrete columns, slabs and beams. There are two types of form work used for the structural system, Metal sheets and plywood.

Construction for structural system, will finish entire floor and proceed to the next floor. Each floor is divided into 3 sections due to the labor, site logistics and equipment constraints. There is a standard pattern followed for the superstructure phase. Each floor will be finished within 14 to 22 days. The reinforcing columns are pre- fabricated and are delivered on site. These reinforced bars are bind together with stirrups on the required day. The columns are filled with concrete with the usage of metal sheets formwork. The concrete is cured with the help of vertical props.

M35 grade of concrete which has a strength of 5000 psi is used for all columns and slabs. Since the load is evenly distributes same grade of concrete is used throughout the structural system and the slabs strength is equal to the columns strength. This is most important design standards for a quality outcome along with the usage of thermos mechanically treated (TMT) bars s which have resistance towards steel corrosion with a Fe500 grade. Mild steel bars are also used but very minimal.

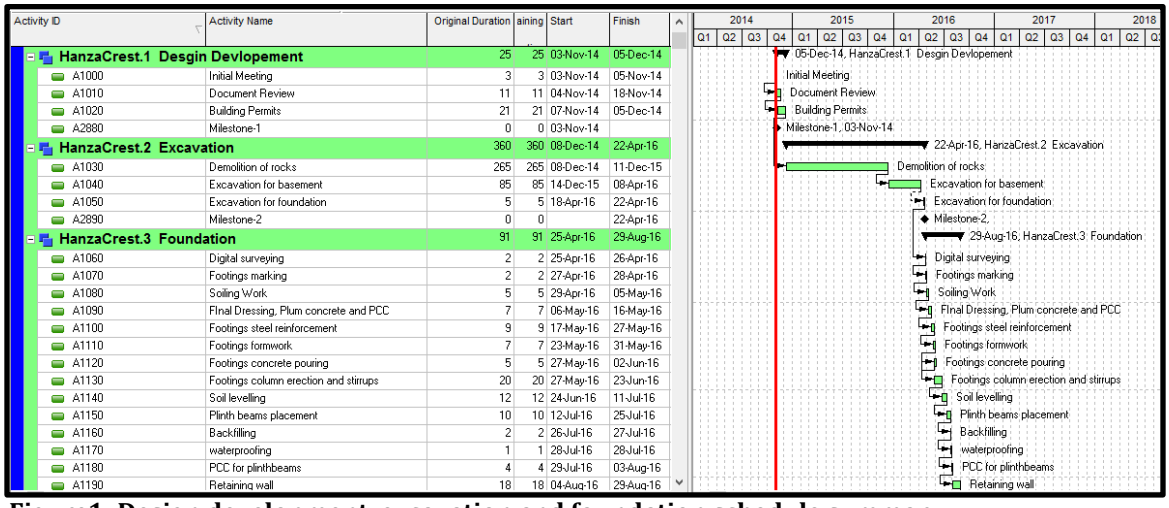
The construction process is monitored and quality check is inspected by field engineer and assistant field engineer. Before the concrete is being poured and after de shuttering the slab or column, there is an inspection conducted by the field engineer to make sure the concrete is poured appropriately and treated well to continue with the next dependent task. Typically, iron workers, concrete workers and foremen are the involved workforce along with a field engineer. The detailed construction procedure of this system can be found in the project's detailed schedule. Also, the equipment used for this system is shown in the superstructure phase site logistics.

SCHEDULE

The Hanza Crest apartments are scheduled to get constructed from November 2014 to June 2018.The schedule is divided into 13 phases with 7 milestones. The project started with design development for 25 days which includes initial meetings, document review and building permits. This is succeeded by the excavation phase which is one of the longest phases of the schedule. One of the critical factors which led to delay is the excavation phase. It has taken 360 days including the delay caused for excavation phases which is scheduled to finish demolition of rocks, excavation for basement and foundation. Preceding to the excavation phase comes the foundation phase. The detailed schedule of the entire project has been attached to **Appendix A**.

FOUNDATION SEQUENCING

The foundation phase is scheduled for 91 days and extra adequate time is given for foundation phase since, it creates the base for the entire construction of the project and sufficient precautions are to be taken for no errors to occur. The tasks are dependent on each other and every task in the schedule is critical path. The figure shown below shows the foundation sequencing. Most of the activities have finish to start relationship with their preceding activities.



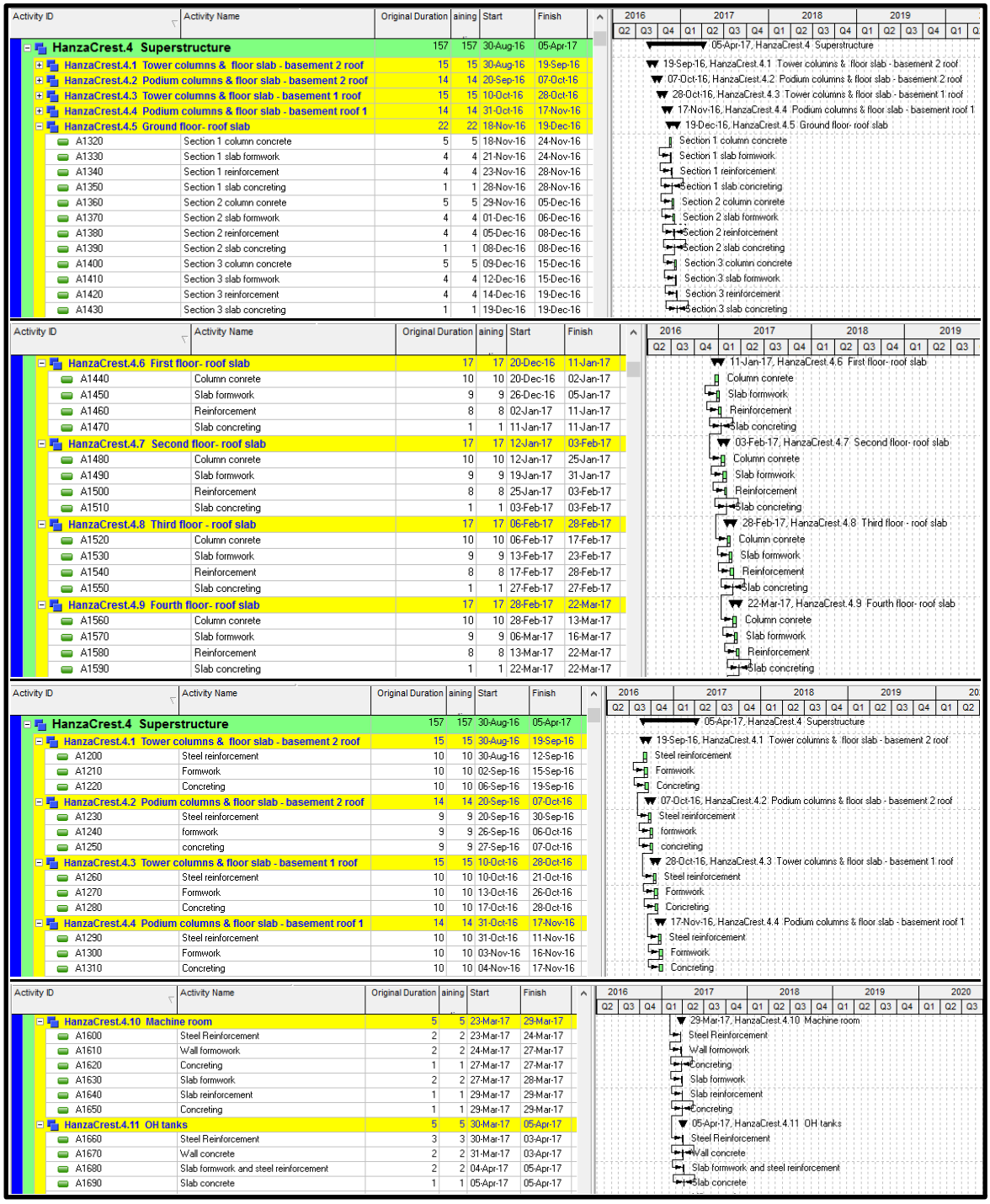
Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.1 Desgin Devlopement		25	25	03-Nov-14	05-Dec-14
A1000	Initial Meeting	3	3	03-Nov-14	05-Nov-14
A1010	Document Review	11	11	04-Nov-14	18-Nov-14
A1020	Building Permits	21	21	07-Nov-14	05-Dec-14
A2880	Milestone-1	0	0	03-Nov-14	
HanzaCrest.2 Excavation		360	360	08-Dec-14	22-Apr-16
A1030	Demolition of rocks	265	265	08-Dec-14	11-Dec-15
A1040	Excavation for basement	85	85	14-Dec-15	08-Apr-16
A1050	Excavation for foundation	5	5	18-Apr-16	22-Apr-16
A2890	Milestone-2	0	0		22-Apr-16
HanzaCrest.3 Foundation		91	91	25-Apr-16	29-Aug-16
A1060	Digital surveying	2	2	25-Apr-16	26-Apr-16
A1070	Footings marking	2	2	27-Apr-16	28-Apr-16
A1080	Soiling Work	5	5	29-Apr-16	05-May-16
A1090	FInal Dressing, Plum concrete and PCC	7	7	06-May-16	16-May-16
A1100	Footings steel reinforcement	9	9	17-May-16	27-May-16
A1110	Footings formwork	7	7	23-May-16	31-May-16
A1120	Footings concrete pouring	5	5	27-May-16	02-Jun-16
A1130	Footings column erection and stirrups	20	20	27-May-16	23-Jun-16
A1140	Soil levelling	12	12	24-Jun-16	11-Jul-16
A1150	Plinth beams placement	10	10	12-Jul-16	25-Jul-16
A1160	Backfilling	2	2	26-Jul-16	27-Jul-16
A1170	waterproofing	1	1	28-Jul-16	28-Jul-16
A1180	PCC for plinthbeams	4	4	29-Jul-16	03-Aug-16
A1190	Retaining wall	18	18	04-Aug-16	29-Aug-16

Figure1: Design development, excavation and foundation schedule summary

SUPERSTRUCTURE SEQUENCING

Followed by foundation phases, the superstructure phase starts which is scheduled to be completed in 157 days. The superstructure is the most important phase of the project, all the activities in superstructure fall under critical path activities which includes column concreting, placement of reinforced bars, slab formwork and slab concreting. The slabs are post-tensioned due to the reinforced bars.

For superstructure phase, the entire site is divided into 3 sections due to the labor and equipment constraints. There is a standard pattern followed for the superstructure phase. Starting with the column concreting, the task is followed by slab formwork which has a finish to start and start to start relation with the column concreting which implies that after 3 days of starting column concreting task where the concrete is poured and cured. The slab formwork is also scheduled to start, but slab it will begin only after part of the column concrete is finished which takes 3 days. This is followed by steel reinforcement which is scheduled to start 2 days after starting slab formwork task leading to schedule acceleration. The slab concreting task has a finish to finish relationship with steel reinforcement since, slab concreting is scheduled to get completed on the same day on the same day of steel reinforcement completion. This continues with section 2 column concrete which has a finish to start relation with section 1 slab concreting. The same pattern is followed from section 1 to section 3 and for all the 5 floors and 2 basements. The overhead (OH) tanks and machine room structure are also included. The figure shown below is the superstructure sequencing for this project.



Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.4 Superstructure		157	157	30-Aug-16	05-Apr-17
HanzaCrest.4.1 Tower columns & floor slab - basement 2 roof		15	15	30-Aug-16	19-Sep-16
HanzaCrest.4.2 Podium columns & floor slab - basement 2 roof		14	14	20-Sep-16	07-Oct-16
HanzaCrest.4.3 Tower columns & floor slab - basement 1 roof		15	15	10-Oct-16	28-Oct-16
HanzaCrest.4.4 Podium columns & floor slab - basement roof 1		14	14	31-Oct-16	17-Nov-16
HanzaCrest.4.5 Ground floor- roof slab		22	22	18-Nov-16	19-Dec-16
A1320	Section 1 column concrete	5	5	18-Nov-16	24-Nov-16
A1330	Section 1 slab formwork	4	4	21-Nov-16	24-Nov-16
A1340	Section 1 reinforcement	4	4	23-Nov-16	28-Nov-16
A1350	Section 1 slab concreting	1	1	28-Nov-16	28-Nov-16
A1360	Section 2 column concrete	5	5	29-Nov-16	05-Dec-16
A1370	Section 2 slab formwork	4	4	01-Dec-16	06-Dec-16
A1380	Section 2 reinforcement	4	4	05-Dec-16	08-Dec-16
A1390	Section 2 slab concreting	1	1	08-Dec-16	08-Dec-16
A1400	Section 3 column concrete	5	5	09-Dec-16	15-Dec-16
A1410	Section 3 slab formwork	4	4	12-Dec-16	15-Dec-16
A1420	Section 3 reinforcement	4	4	14-Dec-16	19-Dec-16
A1430	Section 3 slab concreting	1	1	19-Dec-16	19-Dec-16

Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.4.6 First floor- roof slab		17	17	20-Dec-16	11-Jan-17
A1440	Column conrete	10	10	20-Dec-16	02-Jan-17
A1450	Slab formwork	9	9	26-Dec-16	05-Jan-17
A1460	Reinforcement	8	8	02-Jan-17	11-Jan-17
A1470	Slab concreting	1	1	11-Jan-17	11-Jan-17
HanzaCrest.4.7 Second floor- roof slab		17	17	12-Jan-17	03-Feb-17
A1480	Column conrete	10	10	12-Jan-17	25-Jan-17
A1490	Slab formwork	9	9	19-Jan-17	31-Jan-17
A1500	Reinforcement	8	8	25-Jan-17	03-Feb-17
A1510	Slab concreting	1	1	03-Feb-17	03-Feb-17
HanzaCrest.4.8 Third floor - roof slab		17	17	06-Feb-17	28-Feb-17
A1520	Column conrete	10	10	06-Feb-17	17-Feb-17
A1530	Slab formwork	9	9	13-Feb-17	23-Feb-17
A1540	Reinforcement	8	8	17-Feb-17	28-Feb-17
A1550	Slab concreting	1	1	27-Feb-17	27-Feb-17
HanzaCrest.4.9 Fourth floor- roof slab		17	17	28-Feb-17	22-Mar-17
A1560	Column conrete	10	10	28-Feb-17	13-Mar-17
A1570	Slab formwork	9	9	06-Mar-17	16-Mar-17
A1580	Reinforcement	8	8	13-Mar-17	22-Mar-17
A1590	Slab concreting	1	1	22-Mar-17	22-Mar-17

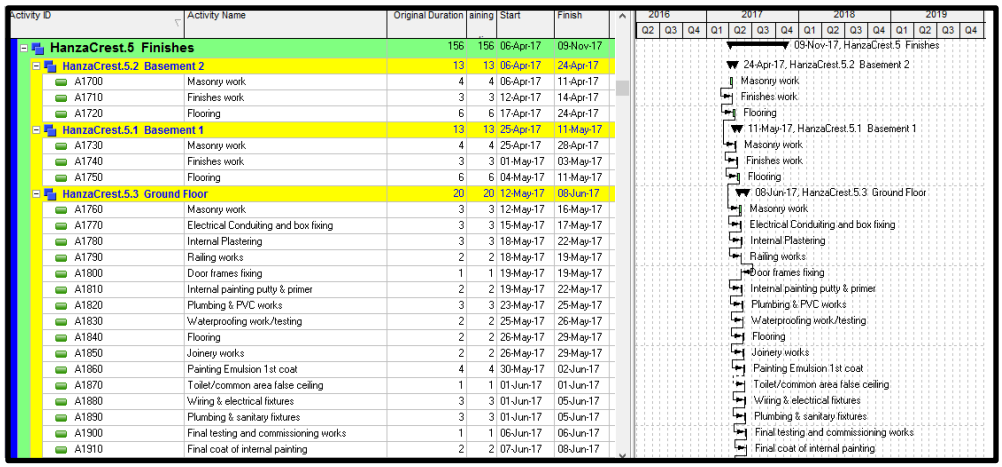
Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.4 Superstructure		157	157	30-Aug-16	05-Apr-17
HanzaCrest.4.1 Tower columns & floor slab - basement 2 roof		15	15	30-Aug-16	19-Sep-16
A1200	Steel reinforcement	10	10	30-Aug-16	12-Sep-16
A1210	Formwork	10	10	02-Sep-16	15-Sep-16
A1220	Concreting	10	10	06-Sep-16	19-Sep-16
HanzaCrest.4.2 Podium columns & floor slab - basement 2 roof		14	14	20-Sep-16	07-Oct-16
A1230	Steel reinforcement	9	9	20-Sep-16	30-Sep-16
A1240	formwork	9	9	26-Sep-16	06-Oct-16
A1250	concreting	9	9	27-Sep-16	07-Oct-16
HanzaCrest.4.3 Tower columns & floor slab - basement 1 roof		15	15	10-Oct-16	28-Oct-16
A1260	Steel reinforcement	10	10	10-Oct-16	21-Oct-16
A1270	Formwork	10	10	13-Oct-16	26-Oct-16
A1280	Concreting	10	10	17-Oct-16	28-Oct-16
HanzaCrest.4.4 Podium columns & floor slab - basement roof 1		14	14	31-Oct-16	17-Nov-16
A1290	Steel reinforcement	10	10	31-Oct-16	11-Nov-16
A1300	Formwork	10	10	03-Nov-16	16-Nov-16
A1310	Concreting	10	10	04-Nov-16	17-Nov-16

Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.4.10 Machine room		5	5	23-Mar-17	29-Mar-17
A1600	Steel Reinforcement	2	2	23-Mar-17	24-Mar-17
A1610	Wall formowork	2	2	24-Mar-17	27-Mar-17
A1620	Concreting	1	1	27-Mar-17	27-Mar-17
A1630	Slab formwork	2	2	27-Mar-17	28-Mar-17
A1640	Slab reinforcement	1	1	29-Mar-17	29-Mar-17
A1650	Concreting	1	1	29-Mar-17	29-Mar-17
HanzaCrest.4.11 OH tanks		5	5	30-Mar-17	05-Apr-17
A1660	Steel Reinforcement	3	3	30-Mar-17	03-Apr-17
A1670	Wall concrete	2	2	31-Mar-17	03-Apr-17
A1680	Slab formwork and steel reinforcement	2	2	04-Apr-17	05-Apr-17
A1690	Slab concrete	1	1	05-Apr-17	05-Apr-17

Figure2: Structure sequencing schedule summary

BUILDING FINISHES SEQUENCING

The building has of total 16 finishes activities which also includes part of the building enclosure activities such as masonry work for interiors and exterior walls. The finishes of the project is scheduled for 156 days which includes masonry work, finishes works which includes extra toilets rooms, maintenance rooms and flooring that also includes for driveways and car ramps for 2 basements. For all the 5 floors, the 16 activities are scheduled for 20 days for each floor. Most of the activities have a start-to start and finish to start relationship with the precedents.



Activity ID	Activity Name	Original Duration	aining	Start	Finish
HanzaCrest.5 Finishes		156	156	06-Apr-17	09-Nov-17
HanzaCrest.5.2 Basement 2		13	13	06-Apr-17	24-Apr-17
A1700	Masonry work	4	4	06-Apr-17	11-Apr-17
A1710	Finishes work	3	3	12-Apr-17	14-Apr-17
A1720	Flooring	6	6	17-Apr-17	24-Apr-17
HanzaCrest.5.1 Basement 1		13	13	25-Apr-17	11-May-17
A1730	Masonry work	4	4	25-Apr-17	28-Apr-17
A1740	Finishes work	3	3	01-May-17	03-May-17
A1750	Flooring	6	6	04-May-17	11-May-17
HanzaCrest.5.3 Ground Floor		20	20	12-May-17	08-Jun-17
A1760	Masonry work	3	3	12-May-17	16-May-17
A1770	Electrical Conduiting and box fixing	3	3	15-May-17	17-May-17
A1780	Internal Plastering	3	3	18-May-17	22-May-17
A1790	Railing works	2	2	18-May-17	19-May-17
A1800	Door frames fixing	1	1	19-May-17	19-May-17
A1810	Internal painting putty & primer	2	2	19-May-17	22-May-17
A1820	Plumbing & PVC works	3	3	23-May-17	25-May-17
A1830	Waterproofing work/testing	2	2	25-May-17	26-May-17
A1840	Flooring	2	2	26-May-17	29-May-17
A1850	Joinery works	2	2	26-May-17	29-May-17
A1860	Painting Emulsion 1st coat	4	4	30-May-17	02-Jun-17
A1870	Toilet/common area false ceiling	1	1	01-Jun-17	01-Jun-17
A1880	Wiring & electrical fixtures	3	3	01-Jun-17	05-Jun-17
A1890	Plumbing & sanitary fixtures	3	3	01-Jun-17	05-Jun-17
A1900	Final testing and commissioning works	1	1	06-Jun-17	06-Jun-17
A1910	Final coat of internal painting	2	2	07-Jun-17	08-Jun-17

Figure3: Building finishes schedule summary

BUILDING ENCLOSURE SEQUENCING

The building enclosure is made of nonstructural walls which includes masonry work and comes under part of finishes. Enclosure also includes a 28 days scheduled activates of touching up walls with putty which a sealing agent made of whitling and linseed oil, texture painting and final painting . Along with these activities, the building enclosure is subjected to external plaster which is scheduled for 20 days. The enclosure is subjected to start from south to north, similar to superstructure.

LABOR CURVE

The man power for any phase depends on which task is performed and number of workers required for the day. The maximum number of workers involved are between September 2016 to April 2017 as shown in figure 3. This period involves the construction of superstructure phase. Iron workers and concrete workers are the most number of workers involved during this phase of construction along with field engineers and foremen. For cost and safety purposes, it is effective if the site has minimum number of workers trained for other tasks and reduces the cost per day.

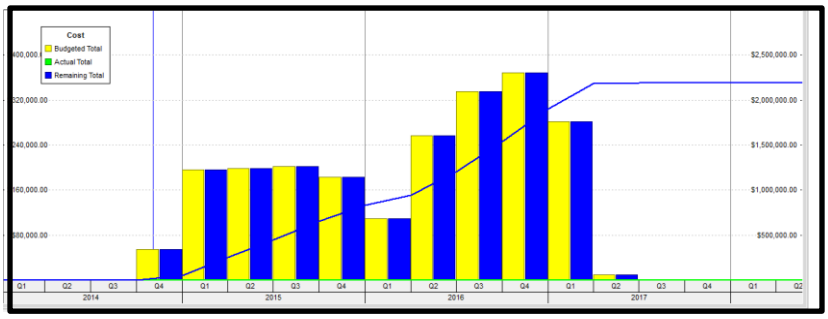


Figure4: Building finishes schedule summary

DETAILED COSTS

DETAILED FOUNDATION AND STRUCTURAL ESTIMATE

Hanza Crest apartments consists of 2 basement floors and 5 floors with two apartments per floor. The building has a repetitive floor layouts. The 2 basements floors a similar floor layout and the 5 residential floors has the same floor plan. The project is made of raft foundation. This type of foundation which consists of PCC (Portland cement and concrete), reinforcement, sand and concrete.

The structural system of the building is steel with Roller-compacted concrete (RCC). A typical floor is made of concrete beams, columns and slabs. Most of the structural system uses metal sheets which are prefabricated for formwork. Plywood is cut and used as formwork only when there are irregular sizes

The project uses reinforced bars which range between 225mm X 150mm to 225mm X 750 for the columns, 900mm X 900mm to 2450mm X 1900 mm for footings and 225mm X 450mm to 225mm X 600mm for beams. The Overhangs which are called Sunshades in India are included in structural system.

The detailed estimate is calculated based on the construction prices in Los Angeles due to the similarities in size and population with Hyderabad. The total cost for foundation and structural system is $ 2,071,718. There were assumptions made for the detailed estimate due to the usage of different materials which are not included in the detailed report.

For the formwork, there are different sizes of metal sheets which range from 9inch X 9inch to 24inch X 24inch. For footings, beams and plinth beams metal sheets of different sizes are used for formwork but encased steel frame is considered.

There are different reinforced bar sizes used for footings, columns and slabs. The footings and columns schedule has provided the different reinforced bar sizes in Metric

sizes. To convert the reinforced bar sizes to Imperial sizes, the table shown table has been utilized.

Imperial Bar Size	"Soft" Metric Size	Weight per unit length (lb/ft)	Mass per unit length (kg/m)	Nominal Diameter (in)	Nominal Diameter (mm)	Nominal Area(in^2)	Nominal Area (mm^2)
#3	#10	0.376	0.561	0.375	9.525	0.11	71
#4	#13	0.668	0.996	0.500	12.7	0.2	129
#5	#16	1.043	1.556	0.625	15.875	0.31	200
#6	#19	1.502	2.24	0.750	19.05	0.44	284
#7	#22	2.044	3.049	0.875	22.225	0.6	387
#8	#25	2.67	3.982	1.000	25.4	0.79	509
#9	#29	3.4	5.071	1.128	28.65	1	645
#10	#32	4.303	6.418	1.27	32.26	1.27	819
#11	#36	5.313	7.924	1.41	35.81	1.56	1006
#14	#43	7.65	11.41	1.693	43	2.25	1452
#18	#57	13.6	20.284	2.257	57.33	4	2581

Table1: Conversion table of reinforced bars from Metric to Imperial Size (other sources)

Based on the conversion from the Metric to Imperial size, the footing and columns consist a range of #3 to #7 sizes of reinforced bar that are used for the structural system. The roof slabs have reinforced bars of #7 throughout the slabs.

The beams and girders are assumed to be W10x33, W 8x10 and W 10x22 which are the closest to the beam sizes that are being used for the structural system. The retaining wall is 10’ high with 2’ thickness for the first 6’ and 1.5’thickness for the remaining 5 feet. The thickness of concrete slabs has 3 different size of 5”, 6” and 7”. The 7” slabs are typically used for area which consists of more loads. Table 2 depicts the materials utilized for Hanza crest apartments and the materials utilized for detailed estimate report.

Group	Materials utilized in detailed estimate report	Materials utilized in the project
Concrete Forming		
03-11-13.20	Forms in Place beams, and girders	Metal sheets formwork for beam and girders
03-11-13.25	Forms in Place, Columns	Metal sheets formwork for columns
03-11-13.45	Forms in Place, Footings	Metal sheets formwork for foortings
Reinforcement		
03-21-05.75	Splicing Reinforcing Bars	#4 and #5 reinforced bars for footings, #7 Reinforced bars for roof slabs
03-21-11.60	Reinforcing in Place	#3 to #7 reinforced bars for columns
Concrete		
03-31-13.35	Heavyweight Concrete, Ready Mix	Portland cement and concrete (PCC) of 4 different ratios
03-31-13.70	Place in Concrete	Concrete for the entire structural system and foundation
Structural Steel		
05-12-23.75	Structural Steel Members	Steel beams, plinth beams and girders for 8 floors with 3 different sizes
Overhangs		
13-34-19.50	Pre-Engineered Steel Buildings	Overhangs with 2' thickness
	Common Work for Results for earth	
31-05-13.10	Borrow	Earthwork for MEP
	Retaining Wall	
32-32-13.10	Retaining Wall, Cast Concrete	10' high retaining wall with a thickness varying from 5" to 7"

Table2: Depicts the materials utilized in the detailed estimate and materials utilized in the project

The detailed estimate of foundation and superstructure is attached to **Appendix B**.

SITE PLAN AND LOGISTICS

EXCAVATION PHASE

Excavation is one of the longest and critical phases for this project. Located in a residential zone, the project had constraints with the usage of blasting. Since the zone Hanza crest apartments located had a height restriction, the land had to be excavated to a depth of 22ft (8770 Yd^3) for basements purpose.

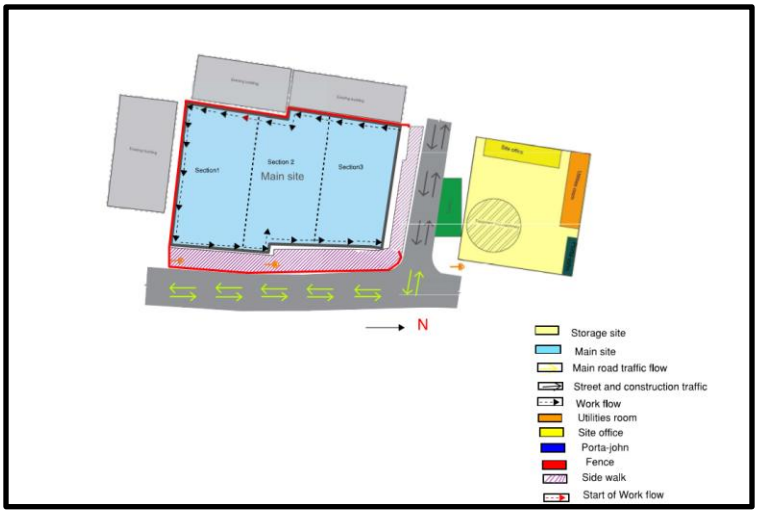


Figure5: Site plan during excavation phase

The project's site was excavated by chemical blasting with restrictions and JCB bucket equipment. The entire site is divided into 3 sections to show from which part the excavation is started. The main site is shown in blue color, the red color line depicts the fence throughout the site and the light yellow color indicates the site used for storage and temporary utilities purpose. The entire main site underwent excavation. The excavation phase started from south to north from section1 and continued excavating section 2 and lastly section 3.

The red color arrow indicates the point excavation was started. Section 3, was excavated after section 1 and 2 since section 3 was considered the path for the labor and equipment to access section 1 and 2. This pattern was set up for creating access to the equipment and machinery. Ambience Construction firm utilized the land opposite to the main site for different purposes at different phases. For excavation phase, the site was utilized for temporary site office, utilities room, porta-john that was set up at that site only for excavation phase and mainly for storing equipment and machinery. The parking area is utilized for equipment to be parked for a short period of time during the working hours since they are big in size, it is an obstacle for the residents in that street to enter the street.

The site office, utilities room and porta-john are shifted closer to the site and the storage site is utilized for materials, equipment and machinery. There a huge amount of space in storage site utilized for storing metal sheets and reinforced bars since they are utilized on a wide scale in this phase. The entire site plan is attached to **Appendix C**.

SUPERSTRUCTURE PHASE

The superstructure phase is the important phase for the project as the remaining phases of the schedule depend on the completion of this phase. Succeeding after excavation and foundation, the construction is continued with superstructure. The superstructure of this project is made up of steel and Roller-compacted concrete (RCC) and this phase starts from foundation with the column erection from footings.

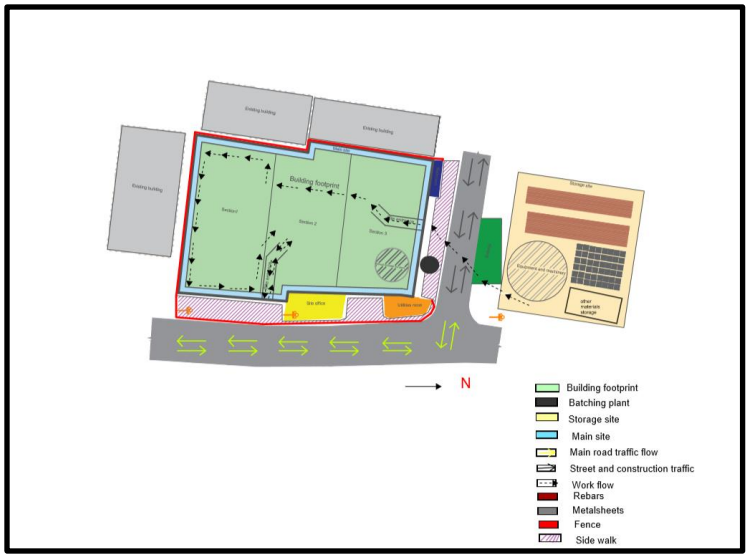


Figure6: Site plan during superstructure phase

The site layout has a few changes here. The light green color is the building footprint which the constructed part of the site. There are two site entrances created after excavation phase that are similar to a ramp, and the site entrance from the street road is typically used for delivering material and to access section 3.

The site entrance facing towards the main road is not utilized for delivering materials but only for entering sections 1 and 2 since it is located near the main road and it is easier to transfer materials from site entrance facing the street road since the storage site is opposite to it and faster to deliver materials with easy movement. The superstructure phase is constructed by following the division of 3 sections. Section 1 superstructure is constructed first due to the fact that it is the corner most section from the site entrance and it wouldn't affect the access to site and materials under construction. Section 2 is

followed by section 1 and finally section 3 superstructure is constructed with minor changes in the site layout due to the utilizing section 3 for other purposes as mentioned.

The site office, utilities room and porta-john are shifted closer to the site and the storage site is utilized for materials, equipment and machinery. There a huge amount of space in storage site utilized for storing metal sheets and reinforced bars since they are utilized on a wide scale in this phase. There is also enough space for storing other materials like sand, cement and aggregates for concrete mixing. Based on the requirement, ready mix concrete plant, batching plant and manual concrete mix plant are utilized for concrete pouring. The manual concrete plant is located in section 3 and transferred near the site entrance when section 3 is scheduled for construction. The grey color circle is where concrete plant truck is placed adjacent to the site entrance to avoid unnecessary movement around the site. The concrete is sent with the help of labor through the site entrance ramp and is transferred to the required location manually. Along with the concrete trucks, curing tanks and cement mortars are also utilized in this phase.

BUILDING FINISHES AND ENCLOSURE

The finishing phase is another most important phase for this project. The finishes phase is started after superstructure phase and has similar site layout of superstructure with minor changes.

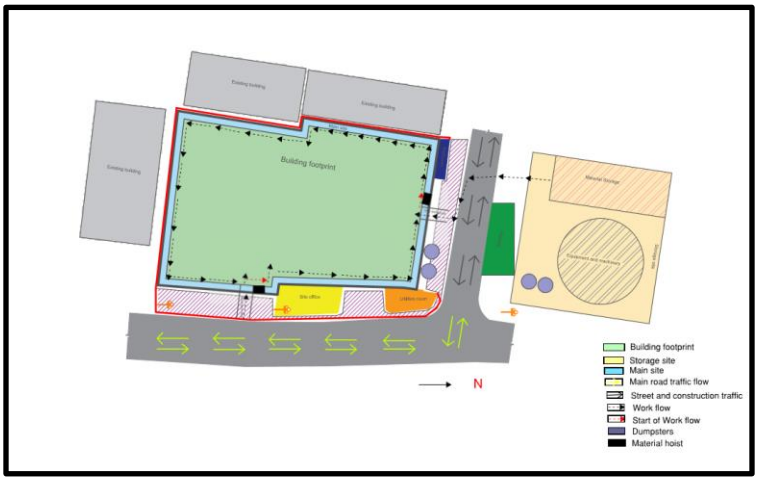


Figure7: Site plan for Building finishes

There is more space in the site storage for materials since the finishing phase involves a lot of different activities which requires different material and equipment. So there is a temporary completely closed storage area with 2 dumpsters in site storage and 2 dumpsters near the street site entrance due to the space constraint near the building. There

are two material hoist placed closer to the site entrances for easy delivery of material to the hoist. The finishing sequence is floor wise. Only after completion of one floor, the work is shifted to the next floor and it starts from basement 2. The concrete truck spot is utilized for dumpsters and for other equipment based on the activity that is scheduled to be done. The red color arrows depicts the starting point of materials getting delivered to the required floor.

PRODUCTION ANALYSIS

PRODUCTION

The superstructure schedule is very efficient given the crew, resources and site constraints. The 14 to 22 days period allotted for constructing each floor's structure section wise, will be required to follow without any change or delay. 1 day is the maximum of days that can be reduced for each floor if the work flow is faster but this will not make any huge difference to the remaining schedule. But there is no necessity to reduce the time period and go fast with the work, since the project team's goal is to show quality in work rather than making any error with pressurizing the workers to finish the task before time.

The division of floors section wise, number of days assigned for each activity and a clear perceive of time period given to start, gives an understanding and time to prepare the materials and coordinate with workforce required for the succeeding activity to stay on schedule and avoid any delay. As shown in the schedule, there is a 6 days' time period before starting slab formwork and 5 days times period before starting reinforcement. The concrete pouring is finished on the same the day of reinforcement completion. So this requires ironworkers and concrete workers coordinating with each other.

One of the concerns is labor not attending the work as per the schedule. This could cause shortage of workers and the only option to follow to avoid delay is having the workers already present work for extra time and pay them for the extra hours. The other concern is shortage of materials. This definitely needs to take charge by the field engineer. There are two concerns that could possibly be encountered.

The overall production schedule of the project specifically the structural system's schedule is effective and accomplishes the project's team goal which is to have high standards of quality in work and stay on-time.

COST ANALYSIS

There is a wide difference between the abstract estimate from Ambience Construction firm and detailed estimate report. According to the detailed estimate report the total cost is $ 2,071,718 for foundation and structural system estimate, which is much higher than compare to the total cost from Ambience Construction firm estimate calculated is $315,166.88. Both the estimates have Labor, material and equipment costs included. This is mainly due to the fact that the material, labor and equipment costs are very low in India compared to the prices in USA. To construct a similar structural system of Hanza Crest apartments in USA, it would cost 6.6 times higher than cost in India.

The detailed estimate report had a high number of assumptions to be considered, and some of the Items in the estimate had materials included that were not required for this project's structural system. The estimate provided by Ambience Construction firm has the materials measured in Metric units and the detailed estimate report has the materials measured in Imperial units. The detailed estimate report is attached in **appendix 2** and table 3 shows the abstract estimate provided by Ambience Construction firm.

Description of work	Quantity	Unit	Rates(₹)	Total amount (₹)
Earthwork for MEP	2092	cum	86	179912
Earthwork for MEP	1220	cum	103	125660
Footings	98.1	cum	6078	596251.8
Plinth Beams	25	cum	8284	207100
Columns	135	cum	9580	1293300
230 mm thick retainin	552	sqm	2928	1616256
231mm thick retaining	50	sqm	2626	131300
Roof beam	50	sqm	8981	449050
Roof slab(150mm)	3671	sqm	1207	4430897
Roof slab(175mm)	105	sqm	1363	143115
TMT bars	162.2	MT	50054	8118758.8
Mild steel bars	4.9	MT	51156	250664.4
Sunshades	165	RM	452	74580
PCC(1:4:8)	27	cum	3637	98199
PCC(1:5:10)	85	cum	3447	292995
PCC(1:5:10)	849	cum	3447	2926503
PCC(1:3:6)	4	cum	5177	20708
PCC(1:1.5:3)	11	cum	6403	70433
			Total(₹)	**21025683**
			Total($)	**315,166.88**

Table3: Abstract estimate provided by Ambience Construction firm

SITE LOGISTICAL ANALYSIS

There is a very huge space restriction around the main site. The 2 sides of the main site is surrounding with neighboring buildings, 1 side has main road with side walk, site office and utilities room in-between the road and main site and 1 side is the street road side which can be used for site logistics purpose. So there not a huge scope for making alternative arrangements for this project's logistics. The materials and equipment storage is in the storage site which is considerably close to the main site.

An alternative option is switching the utilities room to the storage site and have that space utilize for storing materials since a lot of time is consumed for delivering the materials from storage site to main site due to traffic interference sometimes. But there is not much time saved with this option since the utilities room is very compact and not all materials can be stored. So only limited amount of materials can be stored.

One area of concern is open storage of materials in section 3 and part of the site storage. The materials are only partially and covered and a temporary storage area is set up in the site storage only for the building finishes stage. Though the materials are semi-closed with sheets over them. There needs to a temporary closed storage area for the structural system phase also. Though the phase is scheduled to take place during the period with most appropriate weather, it is always for the best not to expose materials

Typically there is traffic on the street road only for few hours of the day and the rest of time it is mostly risk-free to use the road with minimal traffic though it is time taking to deliver materials which are heavy. But the materials are delivered even during the traffic hours and this needs to be taken charge and a safety precaution needs to be initiated to avoid life safety issues.

FIELD SUPERVISION INTERVIEW

SCHEDULE ACCELERATION SCENERIOS

The foundation and superstructure schedules are directly and always related to the critical path of the project's schedule. Therefore, it is very important to finish the superstructure on time since Ambience construction firm cannot afford any major delays due to the time taken for excavation. To make sure there are no major delays in superstructure phase, the project's schedule is formed in a way that the superstructure schedule falls between September to April and during this period the weather is very appropriate for construction.

In order to follow this step, Ambience construction firm had to accelerate the foundation phase by changing the method of concrete pouring from manual concrete plant mix to ready mix concrete plant and usage of small scale batching plant. This was done because mixing concrete manually would take longer and is not very efficient. This could be the biggest risk for the superstructure schedule causing delay since errors are very likely to occur in concrete mixing and this will lead to redoing the task. To avoid this risk, concrete trucks were brought to the site on a daily basis to fasten the procedure, though the manual concrete plant mix was still used but minimal.

This step had an increment in the cost. The manual concrete mixing plant had a very low cost since the concrete was manually mixed. The labor charges which is $4/day was inclusive of this procedure apart from the materials, transportation of materials and equipment cost required for mixing which is $600/day. With an increase in usage of ready mix concrete plant and batching plant usage, the cost had an increment of $1300/ day including materials and transportation.

CONSTRUCTABILITY AND LOGISTICAL CHALLENGES

In India, labor is one of the largest constructability challenges faced in almost all the projects. Most of the delays occur due to the inefficiency of labor and their lack of skills. Site logistics and labor are the largest constructability challenges for Ambience Constructions project team.

Figure8: Section 3 used for manual plant mix

Since, there is no contract between labor and the project's firm, many works do not attend their work in the site as per their schedule and quit their jobs without informing. For the superstructure phase, trained workers were required to understand the placement of reinforced bars, concrete pouring and making sure the structure is well connected.

Due to the limited number of trained workers for specific tasks and space constraint around the main site, the site opposite to the main site is used for storage of materials and equipment. This had created a challenge for transporting the materials from the storage site to the main site since there is a street road between the two sites which has traffic during working hours sometimes. Another challenge due to site logistics is the usage of section 3 for storing materials and setting up manual concrete mixing plant, since it was easier to have the concrete mixing plant and materials delivered to section 3 from storage site and have them closer to section 1 and 2. Though constructing section wise would take longer than usual, it is easier to construct section 1 and 2. While constructing section 3 superstructure, the manual concrete mixing plant would shift to the site storage leading to consuming more time compared to section 1 and 2 since the materials are not in close proximity. The interview questions are attached in **Appendix D**.

APPENDIX A

PROJECT SCHEDULE

APPENDIX B

DETAILED COST

Group	Phase	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Pri
03-11-13.0		**Structural Cast-In-Place Concrete Forming**					
	03-11-13.20	Forms In Place, Beams And Girders					
		C.I.P. concrete forms, beams and girders, interior, plywood, 12" wide, 3 use, includes shoring, erecting, bracing,	231.00 cy	6.05 /cy	6.05 /cy	1,398	1.47 /cy
	03-11-13.25	Forms In Place, Columns					
		Cip concret forms,col,square,steel framed plywd,24"x24",based 50 us purchsd forms,4 us bracing lumber,includ	177.00 cy	3.24 /cy	3.24 /cy	573	0.79 /cy
	03-11-13.45	Forms In Place, Footings					
		C.I.P. concrete forms, footing, spread, plywood, 3 use, includes erecting, bracing, stripping and cleaning	129.00 cy	3.56 /cy	3.56 /cy	459	0.91 /cy
03-21-05.0		**Reinforcing Steel Accessories**					
	03-21-05.75	Splicing Reinforcing Bars					
		Splice rebar, standard, self-aligning type, taper threaded, #4 bars, includes holding rebar in place while splicing	204.00 ea	6.95 /ea	6.95 /ea	1,418	5.95 /ea
		Splice rebar, standard, self-aligning type, taper threaded, #4 bars, includes holding rebar in place while splicing	1,000.00 ea	6.95 /ea	6.95 /ea	6,950	5.95 /ea
		Splice rebar, standard, self-aligning type, taper threaded, #5 bars, includes holding rebar in place while splicing	2,086.00 ea	7.75 /ea	7.75 /ea	16,167	7.30 /ea
		Splice rebar, standard, self-aligning type, taper threaded, #7 bars, includes holding rebar in place while splicing	1,130.00 sf	10.15 /sf	10.15 /sf	11,470	9.80 /sf
		Splice rebar, standard, self-aligning type, taper threaded, #8 bars, includes holding rebar in place while splicing	39,514.32 sf	11.50 /sf	11.50 /sf	454,415	16.60 /sf
03-21-11.0		**Plain Steel Reinforcement Bars**					
	03-21-11.60	Reinforcing In Place					
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for acces	89,398.00 lb	0.56 /lb	0.56 /lb	50,063	0.50 /lb
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for acces	89,398.00 lb	0.56 /lb	0.56 /lb	50,063	0.50 /lb
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for acces	89,398.00 lb	0.56 /lb	0.56 /lb	50,063	0.50 /lb
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for acces	89,398.00 lb	0.56 /lb	0.56 /lb	50,063	0.50 /lb
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for acces	10,802.00 lb	0.56 /lb	0.56 /lb	6,049	0.50 /lb
03-30-00.0		**Cast-In-Place Concrete**					
	03-30-53.40	Concrete In Place					
		Strt concrt,place,col (4000 psi),square,2% - 3% rnfrcn,12"12",inclds frms(4 us),grade 60 rebar,concrete (portlan	1,277.00 cy	935.00 /cy	935.00 /cy	1,193,995	565.00 /cy
05-12-23.0		**Structural Steel For Buildings**					
	05-12-23.75	Structural Steel Members					
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl sh	33.00 lf	4.83 /lf	4.83 /lf	159	14.60 /lf
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl s	3,507.00 lf	4.83 /lf	4.83 /lf	16,939	32.00 /lf
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl s	663.00 lf	4.83 /lf	4.83 /lf	3,202	32.00 /lf
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x33, A992 steel, shop fabricated, incl s	1,624.00 lf	5.25 /lf	5.25 /lf	8,526	48.00 /lf
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x33, A992 steel, shop fabricated, incl s	16.00 lf	5.25 /lf	5.25 /lf	84	48.00 /lf
32-32-00.0		**Retaining Walls**					
	32-32-13.10	Retaining Walls, Cast Concrete					
		Cast-in place retaining walls, reinforced concrete cantilever, 33 degree slope embankment, 10' high, includes exc	6,480.00 sf	204.00 /sf	204.00 /sf	1,321,920	102.00 /sf

Estimate Totals

Description	Amount	Totals	Hours	Rate	Cost Basis	Cost per Unit	Percent of Total	
Labor	797,688						38.51%	
Material	1,200,558						57.96%	
Subcontract								
Equipment	73,254						3.54%	
Other								
	2,071,500	2,071,500					100.00	100.00%
Total		*2,071,500*						

Group	Phase	Description
03-11-13.0		`
	03-11-13.20	Forms In Place, Beams And Girders
		C.I.P. concrete forms, beams and girders, encasing steel frame, plywood, hung, 3 use, includes shoring, erecting, bracing, stripping and cleaning
	03-11-13.25	Forms In Place, Columns
		Cip concret forms,col,square,steel framed plywd,24"x24",based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning
	03-11-13.45	Forms In Place, Footings
		C.I.P. concrete forms, footing, spread, plywood, 3 use, includes erecting, bracing, stripping and cleaning
03-21-05.0		**Reinforcing Steel Accessories**
	03-21-05.75	Splicing Reinforcing Bars
		Splice rebar, standard, self-aligning type, taper threaded, #4 bars, includes holding rebar in place while splicing
		Splice rebar, standard, self-aligning type, taper threaded, #4 bars, includes holding rebar in place while splicing
		Splice rebar, standard, self-aligning type, taper threaded, #5 bars, includes holding rebar in place while splicing
		Splice rebar, standard, self-aligning type, taper threaded, #7 bars, includes holding rebar in place while splicing
		Splice rebar, standard, self-aligning type, taper threaded, #7 bars, includes holding rebar in place while splicing
03-21-11.0		**Plain Steel Reinforcement Bars**
	03-21-11.60	Reinforcing In Place
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories
		Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories
03-31-13.0		**Heavyweight Structural Concrete**
	03-31-13.35	Heavyweight Concrete, Ready Mix
		Struct concrete,ready mix,flowable fill,40 - 80 psi,includes ash,portland cement type i,sand and water,delivered,excludes all additives and treatments
	03-31-13.70	Placing Concrete
		Structural concrete, placing, column, square or round, pumped, 24" thick, includes leveling (strike off) & consolidation, excludes material
05-12-23.0		**Structural Steel For Buildings**
	05-12-23.75	Structural Steel Members
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl shop primer, bolted connections
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x33, A992 steel, shop fabricated, incl shop primer, bolted connections
		Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x33, A992 steel, shop fabricated, incl shop primer, bolted connections
13-34-19.0		**Metal Building Systems**
	13-34-19.50	Pre-Engineered Steel Buildings
		Pre-engineered steel building accessory items, eave overhang, with soffit, 26 gauge, 2' W
31-05-00.0		**Common Work Results For Earthwork**
	31-05-13.10	Borrow
		Soils for earthwork, common borrow, spread with 200 H.P. dozer, includes load at pit and haul, 2 miles round trip, excludes compaction
32-32-00.0		**Retaining Walls**
	32-32-13.10	Retaining Walls, Cast Concrete
		Cast-in place retaining walls, concrete cribbing, open face, 12' high, includes excavation, backfill, and reinforcement

steel									
columns									
Type	no of them	inches	no of Reinforcement ba	Sizemm- change to feet	inches	Sizemm			
C1	18	225x450	8.85x17.7	8	16	0.629			
C2	6	225x600	8.85x23.6	8	20(4)	0.787			
C3	6	225x600	8.85x23.6	10	20	0.787			
C4	8	225x750	8.85x29.5	10	20	0.787			
C5	3	225x750	8.85x29.5	14	20	0.787			
C6	8	225x750	8.85x29.5	14	25(8)	0.984			
	49								
Footings		Size	in	Depth					
F1A	16	900x900	35.5	300	11.811		5.088		70.86
F1	1	1500x1500	59.05	450	17.7165				132.825
F2	5	1800x1800	70.86	500	19.6851				394.488
F3	2	2100x2100	82.6	575	22.6378				604.882
F4	2	2400x2400	95	650	25.5906				854.111
F5	2	2700x2700	107	750	29.5276				1231.89
CF-1	1	2150x4350	84.6x171.26	650	25.5906				1067.64
RF-1	3	2450x1900	96.4x74.8	600	23.6221				985.512
Plinth beam	m	**ft**							
PB1/RWI	98610.1	324							
PB2	202115.9	663							
PB3	4760.3	16							
Beams	sub cellar								
Type	no	length	**ft**						
225x600	3	45203	148.3038058						
225x450	light blue	68221.8	223.8248031						
	light orange	66570	218.4055118						
	light pink	67698	222.1062992						
Beams	sub cellar								
Type	no	length	**ft**						
225x600	3	41686	136.7650919						
225x450	light blue	32028.8	105.0813648						
	light orange	80124	262.8740157						
	light pink	67698	222.1062992						
ground to 4th floor									
Type	no	length	5 floors	**ft**					
225x600	light green	147495	73975	242.7001312					
	light grey	26655	133275	437.253937					
	light blue	40151	200755	658.6450131					
				0					
225x450	light green	7361	36805	120.7513123					
	light grey	54052	270260	886.67979					
	light blue	70290	351450	1153.051181					
225x150	light green	1960	9800	32.15223097					
sd-14									
225x450		27807		91.23031496					

Calculations for the estimate

APPENDIX C

SITE PLANS AND LOGISTICS

APPENDIX D

FIELD SUPERVISIOR

INTERVIEW QUESTIONS

SUPERINTENDENT INTERVIEW

SCHEDULE ACCELERATION SCENERIOS QUESTIONS

What are the biggest risks to the project completion date?

Monsoon weather. It causes a lot of issues especially due to the fact there is poor drainage system and water flow is not very smooth. This leads to accumulation of water on site and materials getting damaged in water. Most importantly, Labor is not prepared to work on heavy tasks during monsoon like activities during the superstructure phase and this causes a heavy impact on the schedule.

What are the potential ways to accelerate foundation and superstructure phases apart from increasing manpower and shifts?

The planning department wanted to make sure the schedule for superstructure falls between September to April since the weather is very apt for this phase construction. One of the measures taken to fasten process is different procedure for concrete pouring. Initially, manual concrete mix was used but this lead to errors in mixing the concrete with right ratios and took a lot of time than usual. To avoid this there has been an increase in the usage of ready mix concrete plant and batching plant. But this is helping to quicken the process. The manual concrete plant mix is still used but very minimum. Though the manual concrete plant is very cost friendly, it has taken longer time to mix and there were few errors in mixing the ratios for concrete which led to re-doing the task. Apart from the change concrete pouring process, there is no other scope to accelerate the superstructure schedule.

What would be essential as in resources, techniques or costs required to accomplish these alternative options?

The cost has been increased from $600/day to $1300/day including materials and transportation. The labor charges remain the same for mixing the concrete which is $4/day. But this is helping to fasten the process of concrete pouring.

CONSTRUCTABILITY AND LOGISTICAL CHALLENGES QUESTIONS

Can you describe any unique challenging constructability issues for foundation and especially superstructure phase?

Site logistics and labor. These factors would slow down the work pace. Also, there are not many trained workers and some of them lack skills but are sent by the concerned perform to perform tasks which are meant to be done by trained workers. Site logistics is another issue which could cause delay, since there is space constraint around the site, the firm had to take permission for the usage of site opposite to the main site. But this has a toll on delivering the materials to the site due to the traffic that interrupts from workers crossing the road sometimes and time taken to carry and deliver the materials from storage to main site.

How did your team overcome these challenges?

labor is one of the factors that is very hard to have a grip since the workers leave without informing and do not show up for work due to any reason. So there is nothing that can be done in this issue unless there is a contract issued. Coming to the site logistics, due to the space restriction, there hasn't been much scope for improvement and also led to the usage of section 3 of main site to set up manual concrete plant mix and store some of materials which are required for constructing section 1 and 2. Though this made the task little easier, there is still a delay cause because until section 1 and 2 are finished, section 3 cannot be constructed since it is equipped. Also, it takes longer period to construct section 3 since the materials are not in close proximity to the section like the way it is for section 1and 2.