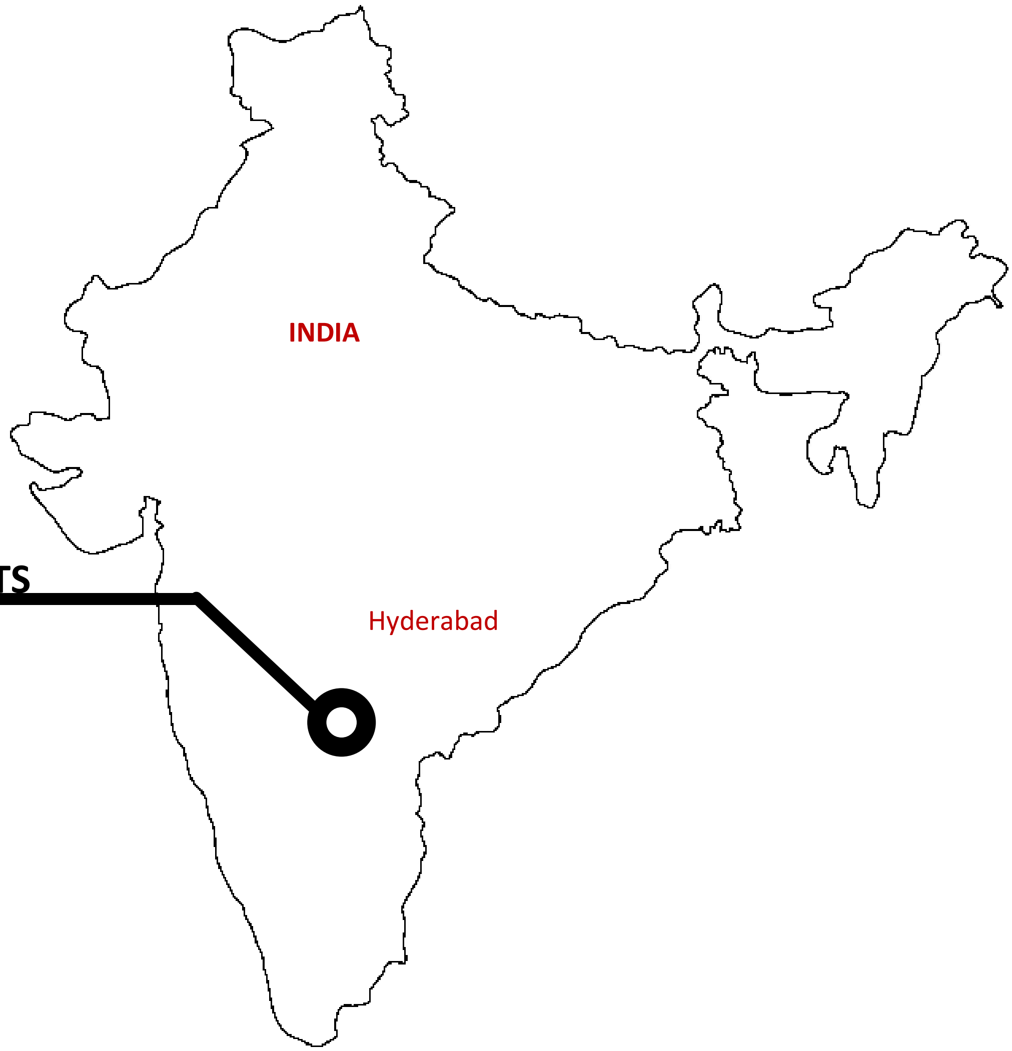
AE-482 W

SPRING 2017

FINAL THESIS REPORT



HANZA CREST APARTMENTS

Bhavana Reddy

Advisor: Dr. Robert Leicht

April 3rd, 2017

HANZA CREST APARTMENTS

GENERAL INFORMATION

Construction: November 2014- June 2018

Delivery Method: Design-Build

Project Budget: $1.05 million

No of stories: 8 Size: 56,000 Square Feet

CONSTRUCTION TEAM

Owner: Confidential

Project management: Ambience Construction firm

Architect: Finger 6

Structural and MEP: S.D Consultants

Structural and MEP Engineers: Ambience Construction firm

ARCHITECTURE

- External wooden cladding faces
- Club house for recreational facilities
- Garden around the building and center of lobby.

STRUCTURAL SYSTEM

- Made of steel and Cast in place Roller-compacted concrete (RCC)
- M35 grade concrete which has a compressive strength of 5000 psi is used
- Thermos mechanically treated (TMT) bars s which have resistance towards steel corrosion with a Fe500 grade for reinforcement
- Steel formwork used for slabs and columns.

MEP SYSTEM

- No Inbuilt mechanical system for residential buildings in India required, wall units are fixed based on requirements.
- Biometric plumbing system is used for reuse of water.
- 240 V distribution system with standard electrical points in each apartment.
- Diesel Generator for power supply during power-outrage.

East view elevation

Steel and RCC structure

Air conditioners (Wall units)

EXECUTIVE SUMMARY

This senior final thesis report will focus on four analysis and two breadths of the Hanza Crest apartments. It is a residential project located in India consisting of luxury apartments. The project is budgeted for $1.05 M and handed over in 32 months. It is constructed and represented Ambience Construction firm. Quality, safety and schedule are the top most priorities for this project. As a result, the four analysis are based upon the project's priorities.

Construction Depth 1: Prefabrication

This analysis focusses on prefabrication of the bathroom units for the Hanza Crest apartments. The prefabrication analysis is proposed due to the project possessing repetitive layout. This analysis has a scope of schedule acceleration/reduction scenario for this project. The units are prefabricated at a warehouse and transported on site with an added cost of $8319 and reducing the overall schedule by 4.2%.The analysis also includes a structural breadth to design a structural framing for the units and calculate its loads.

Construction Depth 2: Façade Change

This analysis will look at the façade change for this project. After analyzing 3 different walls, rain screen cladding has been chosen. There will be an extra 27 days added to the current schedule and added cost of $354,210 and a reduction in cost due to cooling load by $730/year for the occupants. Given the upfront cost and added schedule, there is a huge enhancement in the quality of the building and its aesthetics. There is a mechanical breadth included to calculate the envelope load for the current and new façade and there is reduction is sensible load in the building by 36,840 BTU/hr by the addition of the rain screen panels.

Construction Depth 3: SIPS for Superstructure

This analysis focusses on schedule reduction/acceleration by implementing Short Interval Production Schedule (SIPS). SIPS was utilized for superstructure phase of the project. After breaking down a typical floor into 3 sections and breaking down the trades to demonstrate magnified workflow, SIPS succeeded in reducing the schedule of superstructure by 64% with smooth workflow.

Construction Depth 4: BIM for Safety

This analysis will look at the safety concerns during construction in India. Due to the uneducated work force, it is difficult to communicate verbally and enhance their knowledge about safety. To break the language barrier, a critical industry research has been followed and using specific illustrations and OSHA guidelines, application of BIM to demonstrate safety precautions has been proposed through this analysis.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Academic:

The Pennsylvania State University

Dr. Robert Leicht – Thesis Adviser

Dr. Kevin Parfitt – Thesis In charge

Dr. Ryan Solnosky – Structural Faculty

Dr. Thomas E.Boothby– Structural Faculty

Dr. Paul Bowers- AE Faculty

Industry:

Ambience Construction Firm

Finger 6

SS Infrastructure Project Consultants

Special Thanks:

Ambience Construction Firm Project Team

Mr.Govardhan Reddy Jillela

Mr.Nithin Reddy Jillela

Mr.Prashanth

PACE Members

Family and Friends

PROJECT BACKGROUND

Ambience Construction firm was appetent about introducing their firm into residential construction market through Hanza Crest apartments project and extend the firm's reputation. The building is 56,000 SF including eight stories of residential floors with two apartments of 3500SF each and a club house for recreational purpose. The project is budgeted for $1.05M and handed-over in 32 months. The project is constructed based on the guidelines of Indian standard code (ISC).

In 2014, the land was purchased and was given to Ambience Construction firm to construct apartments. Most Indian metropolitan cities are zoned by the government. The zones can be mixed use, pure residential or pure commercial. The zone Hanza crest apartments are being built falls under the second. These apartments are designed for high-income earning demographic and to intensify the reputation of the firm, mainly in high-end residential sector. It is considered to be one of the prestigious residential projects for Ambience Construction firm due to the location of the site and for designing spacious luxury apartments, targeting on the quality.

The land acquired humongous rocks which had to be demolished and excavated to a depth of 22ft for two cellar parking floors. This created problems in schedule since it took almost 360 days for demolition and excavation causing a major delay in the project schedule. The demolition was started in December 2014 and construction began in April 2016. The goal of the project team is to accelerate the schedule to handover the building on-time and have a quality outcome for the occupants.

PROJECT SITE AND GENERAL BACKGROUND

Architecture

Hanza crest apartments are built in a hilly area. They are under construction on a rectangular site. This building is designed for residential purpose only. It is located in a complete residential zone of the suburban area. The building consists of 1 cellar and sub-cellar parking garages and 5 residential floors.

Figure 0.1: Building elevation with wooden cladding

Each residential floor consists of 2 three-bedroom apartments as per owner's requirements. The building does not consist of historical requirements. The northern and southern elevations of the building has a wooden pattern external cladding for aesthetics purpose.

Excavation

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 22 ft. (8770.6 Yd^3). as mentioned earlier, for cellar parking purpose. The entire main site underwent excavation starting from south to north. The project's site was excavated by chemical blasting with restrictions and JCB bucket equipment.

Figure 0.2: Main site after excavation

Mechanical System

Figure 0.3: Typical air conditioners (AC) used in India

Most of the buildings in India do not acquire mechanical system. Based on the occupant's requirement, wall units are fixed. The wall units are similar to ductless minisplit system or packed air terminal units approximately 6,000 BTUs. Bio-metric plumbing system is applied to Hanza crest apartments. The water acquired from and External Unit of AC (Right) bathrooms is sent to sewage treatment plant to purify it and used for gardening and bathrooms in staff rooms. This system is productive for the building and helps to reduce the water scarcity in India.

Lighting & Electrical System

The electrical system is similar in most of the residential buildings in India. Standard electrical points are fixed. Each bedroom is facilitated with electrical points, two 48" fans on ceiling which are very typically used in residential buildings in India, air conditioner, 2 sockets and two 40 W fluorescent lights. There is diesel based-run generator that supplies to the apartments in the situation of power-outrage.

Structural System

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 shuttering sheets and plywood.

Figure 0.4: Steel and RCC structure

Construction for structural system, will finish entire floor and proceed to the next floor. Each floor will be finished within 17 to 22 days. The reinforcing column bars 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.

Figure 0.5: Metal shuttering sheets for formwork

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. Based on the requirement, ready mix concrete plant, batching plant and manual concrete mix plant are utilized for concrete pouring Curing tanks and cement mortars are utilized for the superstructure. Typically, iron workers, concrete workers and foremen are the involved workforce along with a field engineer. Also, the equipment used for this system is shown in the superstructure phase site logistics.

ANALYSIS 1: PREFABRICATION

PROBLEM IDENTIFICATION

The Hanza Crest apartments is an 8 floors building comprised of residential apartments as mentioned previously. The residential units are comprised with indistinguishable floor plan as seen in *figure 1.1* in the right. The building consists of 10 similar apartments made out of steel and cast-in-place concrete structure leading to gruesome effects on the schedule of the project along with more cost consumption.

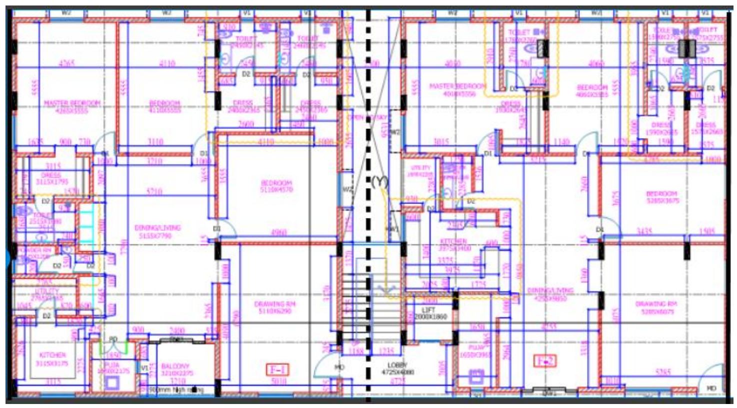


Figure 1.1: Typical floor plan with repetitive layout

Due to certain constraints such as location of the site and errors that occurred due to unskilled workforce leading to more consumption of time for rectifying the errors. All these situations lead to a certain amount of compromise in due to inconsistency in quality of the outcome of the project.

Based on the project's schedule, it is observed that each floor consumed approximately 17-22 days during the superstructure phase in which 10 days is specifically meant for column erection & column concrete for each floor. This duration is very dormant and the project's schedule might have further delays due to transportation of materials to the site and efficiency of workforce. Apart from the issues mentioned above, usage of outmoded formwork, unskilled workforce, indigent scheduling and unfulfilled duties by the project team would lead to further delay in the project's schedule. This calls for a requirement to implement different methods to accelerate/reduce schedule of this project.

The first analysis will be focusing on schedule acceleration/reduction by evaluating the process of prefabrication implementation for this project. This would ensure several work phases to be done concurrently and would reduce the cost and workforce on site leading to schedule acceleration. To make a competent impact on schedule, a typical bay that includes bathroom unit including finishes will be considered with a new structural design and compare to the current bathroom unit on certain aspects to conclude the effectiveness of this analysis on the project’s schedule.

BACKGROUND RESEARCH

Prefabrication is the practice of assembling components of a structure in a factory or some other manufacturing site. These components are then transported as a complete assembly or a sub-assembly to the construction site. This incomparably shortens the construction duration. It also is more sustainable and dismisses unnecessary costs that are associated with building a component on site. Apart from the cost and schedule benefits, prefabrication increases the productivity on site by reducing labor and materials. Quality control is another plus point of this method. As per some of the construction websites like Mortenson and Messer construction firms, "Prefabrication will reduce the overall cost and time of project delivery while increasing the quality and scope."[1]

The Mortenson construction firm has implemented prefabrication for WT Barracks building at Fort Carson project and had 30% schedule savings, along with 39% of safety enhancement and 30% improvement with field labor risk reduction when compared to the traditional methods of on-site construction for this project. The results of implementing prefabrication for the WT Barracks project are provided in *figure 1.2* on the right.

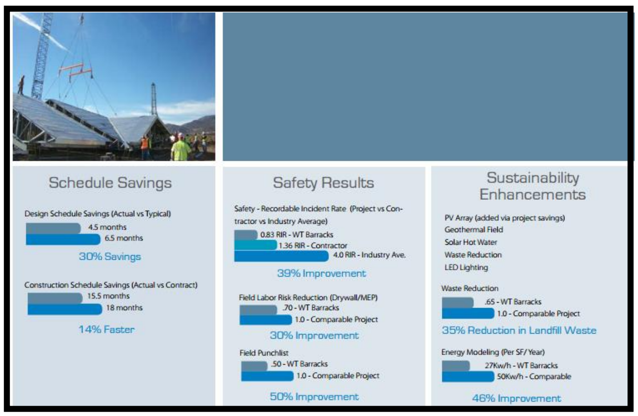


Figure1.2: Results of implementing prefabrication

Prefabrication procedure involves an immense increment in quality control and quality outcome. There is an inspection before transporting the unit to the location of site and the on-site project team ensure there are no damages before fixing the units to the structure of the building. Based upon research and after talking to the project team, it has been found that the bathroom is the most labor-intensive room, with all the different trades involved working together. This can cause delay and lack of coordination between trades might lead to errors in construction.

Bathroom units are modularized according to the desired specifications by various manufacturers and transported to the location of the site. They can be made out of light or superlight concrete, or can have a steel frame, which is easier to transport. The main variable in terms of cost is the project's location, but ultimately saves cost with positive impact on the budget of the project as per the investigation.

Prefabrication is very constructive and useful with similar layout units and requires an upfront cost which is high for setting up the whole procedure but this would yield to positive impacts with the procedure on-going. The Hanza Crest apartments with identical floor plan for 5 floors, could not have a better method to implement than prefabrication to reduce the overall project schedule. This would also highly benefit of enhancing the safety on-site.

1. https://www.mortenson.com/~/media/files/pdfs/prefabrication-building-whats-next-cost-time-quality-scope.ashx

2. http://www.messer.com/services/prefabrication/

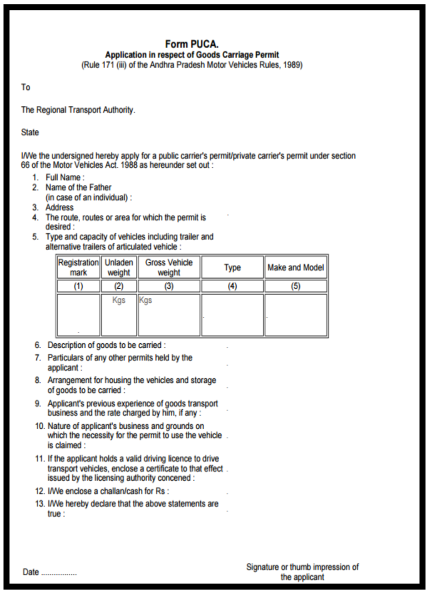
3. https://oldcastlesurepods.com/blog/4s-cost-challenge-of-prefab-bathroom-pods/

4. http://www.bathsystem.com/english/bagni-prefabbricati/bagni_prefabbricati.ht

SITE RESTRICTIONS AND TRANSPORTATION

The trucks are allowed to enter the location of site. Each apartment consists of 3 units which identical sizes for 5 apartments each and there are total 30 bathroom units to be transported to the site. Since the trucks are allowed to enter the location between 1:30pm to 7:30am and again between 11:30 am to 4pm. The site work is required to start early and ensure the modules are transported before 7 am as it would be best for the modules to be delivered in the morning and the further work can be continued during the remaining day.

There is no fee to transport goods within the state as per the government permits but one of the obstacle in the PUCA form that needs to be submitted in case there is an inspection by any authority along with $18 form fee to register. The form requires the route vehicle will be travelling, weight of the goods and description of the goods that would be carried.



Form PUCA.
Application in respect of Goods Carriage Permit
(Rule 171 (iii) of the Andhra Pradesh Motor Vehicles Rules, 1989)

To

The Regional Transport Authority.

State

I/We the undersigned hereby apply for a public carrier's permit/private carrier's permit under section 66 of the Motor Vehicles Act. 1988 as hereunder set out :

1. Full Name :
2. Name of the Father (in case of an individual) :
3. Address
4. The route, routes or area for which the permit is desired :
5. Type and capacity of vehicles including trailer and alternative trailers of articulated vehicle :

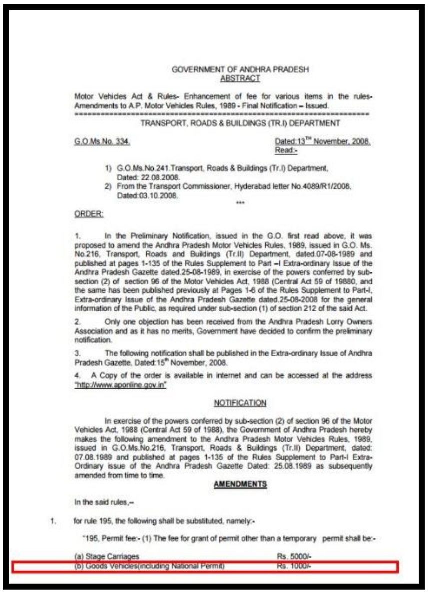
Registration mark	Unladen weight	Gross Vehicle weight	Type	Make and Model
(1)	(2)	(3)	(4)	(5)
	Kgs	Kgs		

6. Description of goods to be carried :
7. Particulars of any other permits held by the applicant :
8. Arrangement for housing the vehicles and storage of goods to be carried :
9. Applicant's previous experience of goods transport business and the rate charged by him, if any :
10. Nature of applicant's business and grounds on which the necessity for the permit to use the vehicle is claimed :
11. If the applicant holds a valid driving licence to drive transport vehicles, enclose a certificate to that effect issued by the licensing authority concened :
12. I/We enclose a challan/cash for Rs :
13. I/We hereby declare that the above statements are true :

Date ....

Signature or thumb impression of the applicant

Figure1.3: PUCA form



GOVERNMENT OF ANDHRA PRADESH
ABSTRACT

Motor Vehicles Act & Rules- Enhancement of fee for various items in the rules- Amendments to A.P. Motor Vehicles Rules, 1989 - Final Notification – Issued.

TRANSPORT, ROADS & BUILDINGS (TR.I) DEPARTMENT

G.O.Ms.No. 334. Dated:13TH November, 2008.
Read:-

1) G.O.Ms.No.241.Transport, Roads & Buildings (Tr.I) Department, Dated: 22.08.2008.
2) From the Transport Commissioner, Hyderabad letter No.4089/R1/2008, Dated:03.10.2008.

***

ORDER:

1. In the Preliminary Notification, issued in the G.O. first read above, it was proposed to amend the Andhra Pradesh Motor Vehicles Rules, 1989, issued in G.O. Ms. No.216, Transport, Roads and Buildings (Tr.II) Department, dated.07-08-1989 and published at pages 1-135 of the Rules Supplement to Part –I Extra-ordinary Issue of the Andhra Pradesh Gazette dated.25-08-1989, in exercise of the powers conferred by sub-section (2) of section 96 of the Motor Vehicles Act, 1988 (Central Act 59 of 19880, and the same has been published previously at Pages 1-6 of the Rules Supplement to Part-I, Extra-ordinary Issue of the Andhra Pradesh Gazette dated.25-08-2008 for the general information of the Public, as required under sub-section (1) of section 212 of the said Act.

2. Only one objection has been received from the Andhra Pradesh Lorry Owners Association and as it has no merits, Government have decided to confirm the preliminary notification.

3. The following notification shall be published in the Extra-ordinary Issue of Andhra Pradesh Gazette, Dated:15th November, 2008.

4. A Copy of the order is available in internet and can be accessed at the address "http://www.aponline.gov.in"

NOTIFICATION

In exercise of the powers conferred by sub-section (2) of section 96 of the Motor Vehicles Act, 1988 (Central Act 59 of 1988), the Government of Andhra Pradesh hereby makes the following amendment to the Andhra Pradesh Motor Vehicles Rules, 1989, issued in G.O.Ms.No.216, Transport, Roads & Buildings (Tr.II) Department, dated: 07.08.1989 and published at pages 1-135 of the Rules Supplement to Part-I Extra-Ordinary issue of the Andhra Pradesh Gazette Dated: 25.08.1989 as subsequently amended from time to time.

AMENDMENTS

In the said rules,–

1. for rule 195, the following shall be substituted, namely:-

"195, Permit fee:- (1) The fee for grant of permit other than a temporary permit shall be:-

(a) Stage Carriages Rs. 5000/-
(b) Goods Vehicles(including National Permit) Rs. 1000/-

Figure 1.4: Registration fee

The only site restriction is, the site has buildings on the west side and north side which is a restriction for the tower crane to place the bathroom units that are located on the edge of those side as seen in the picture below. The orange lines in *figure 1.5* around the main site shows the sides where buildings are located.

Figure 1.5: Site location

For transporting the modules, the truck chosen to transport the modules is a standard “18” wheeler truck with a dimension of 41 feet length and with a trailer length of 30 feet. The height restriction of goods not more than 14 feet taller. Since the modules are 9.5 feet tall, there is no obstacle with the height restriction. Each truck can carry 3 of units to the site. By this process, the project team would have 1 day to finish attaching the bathroom units for each apartment.

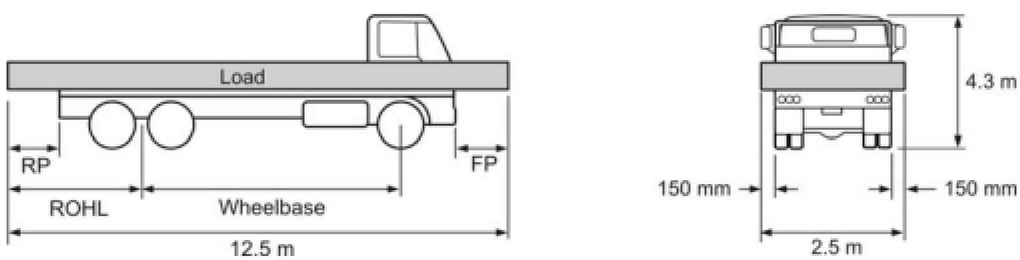


Figure 1.6: Transportation mode for modules

---

1. http://www.ctp.gov.in/Notifications_Traffic/Regulation%20%20for%20all%20HMV%20MMV%20vehicles%20in%20Cyberabad%2018.04.2015.pdf
2. http://www.tnt.com/content/dam/tnt_express_media/en_in/download_documents/services/India_Interstate_Regulatory_Requirements_Jun2014v1.pdf
3. http://www.aptransport.org/html/pdf/form_puca.pdf
4. http://www.aptransport.org/html/pdf/2008trb_ms334_permit.pdf
5. http://www.truckscales.com/trailerinfo.htm
6. https://www.thetruckersreport.com/turning-radius-info-on-eighteen-wheelers/

STRUCTURAL BREADTH

The current weight of the bathroom unit is calculated before designing a new structural frame with different materials to ensure the new design is either equal or lighter than the current design used for the current structure to bear the weight of the module. The current bathroom is made out of bricks with concrete plastering walls on RCC structure. 4" face bricks are used for this project's construction. The weight of only bricks for one bathroom unit is 8268 lbs. The density of concrete is 150 lbs/ft^3 as per research. The floor to floor height is 9.5 ft. and a typical bathroom unit volume is approximately 444 SF. The total volume of the bathroom unit is 4218 ft^3 accounting 5% for concrete and MEP framing. Considering the factors mentioned above, the total weight of the concrete is each bathroom unit is 3203 lbs. By adding weight of all the materials the total weight of each bathroom unit is approximately 11,429 lbs.

The new structural design of the bathroom unit consists of metal studs as its structural frame. The walls are attached to metal stud framing made out of prefabricated cement board. Based on the thickness of each material and area/volume (*refer to figure 1.3*) of the unit the total weight of each unit is approximately 7640 lbs accounting for MEP framing.

MATERIALS FOR NEW BATHROOM MODEL		
Type	**Materials**	**Thickness**
Wall	**Metak studs**	**2x6 24" O.C**
	Cement board	**1/2"**
Floor	**Metal studs**	**2x6 24" O.C**
	Plywood sheathing	**3/4"**
	Cement board	**1/2"**
	Epoxy Grouting	**1"**
	Ceramic tiles	**3/8"**
Roof	**Metal studs**	**2x6 24" O.C**
	Gypsum board	**1/2"**
	Cement board	**1/2"**

Figure 1.7: materials selected for the new model

The unit is attached to the existing structure of the building and the calculations above shows the current structure can bear the weight of the new module. After checking with the current structure, based on the materials selected above for the new bathroom unit, load calculations are performed to check if the weight of the walls and roof can be withstood by the floor of the bathroom unit.

The live load considered for load calculations is 40 psf based on minimum design loads. Below the calculations to find the total load of on unit is performed to select the type of metal stud that can withstand the weight. The spacing of metal is 24" O.C. This will save time during assembling the components since the lesser the number of metal studs to connect the faster the module can be constructed. This would also reduce the cost to purchase more metal studs and indirectly saving the labor costs to connect them.

	Dead Load of the floor calculations			
Dimensions:	Material type	Weight (psf)	Thickness	
	Metal studs	12	6"	
	Plywood sheathing	2.2	3/4"	
	Cement board	3	1/2"	
	Ceramic tiles	4.7	3/8"	
Dead load(DL) :	Weight *Thickness			
Total material dead load:	8 psf			
Miscellanous dead load :	10 psf			
Beam allowance :	5 psf			
Total dead load:	23 psf			
Total unfactored disrtibuted load (Wu):	1.2(DL)+1.2(LL)			
Wu:	91.6 psf*width(9')			
Wu:	**0.824 klf**			
	Dead Load of the wall calculations			
Dimensions:	Material type	Weight (psf)	Thickness	
	Metal studs	12	6"	
	Cement board	3	1/2"	
Dead load :	Weight *Thickness			
Total material dead load:	**6.14 psf**			
Total dead load of the wall:	material dead load *Spacing of metal studs(24") *height of the wall(9.5')			
Total dead load of the wall:	116.6 lbs			
Total unfactored disrtibuted load (Wu):	1.2(DL)+1.2(LL)			
Total unfactored disrtibuted load (Wu):	78.736 psf			
Point load (Pu):	0.078* length* spacing			
Point load (Pu):	**1.41 kips**			

	Dead Load of the roof calculations			
Dimensions:	Material type	Weight (psf)	Thickness	
	Metal studs	12	6"	
	Gypsum board	2.2	1/2"	
	Cement board	3	1/2"	
Dead load :	Weight *Thickness			
Total material dead load:	6.2 psf			
Beam allowance :	5 psf			
Total dead load of the floor:	11.2 psf			
Total unfactored disrtibuted load (Wu):	1.2(DL)+1.2(LL)			
Total unfactored disrtibuted load (Wu):	77.44 psf			
Point load (Pu):	0.077* length(5')* spacing(24")			
Point load (Pu):	**0.7744 kips**			
	Total Load calculations			
Total point load on each side of the floor	Pu(wall) +Pu(roof)			
Total point load on each side of the floor	2.184 kips			
Total point load	4.36 kips			
Total distributed load	Wu(floor)* length(5')			
Total distributed load	4.12 kips			
Total load	Point load+ distributed load			
Total load	**8.48 kips**			
	Moment calculations			
Moment at A (Equation)	M+ 0.824 (2.5)(1.25) = 0			
Moment (M):	**2.6 kips-ft**			

The moment calculations performed above is based on the section shown in *figure 1.7* below.

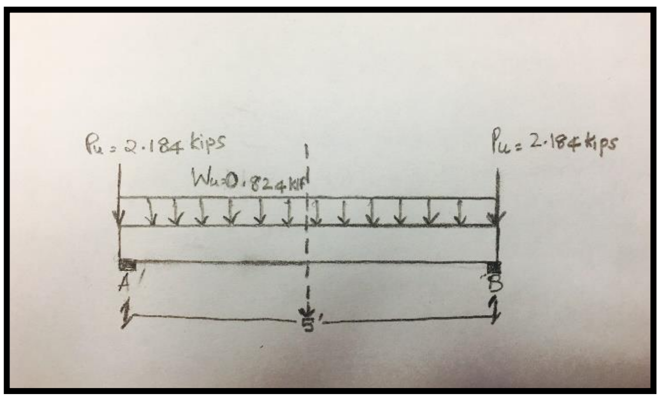


Figure 1.7: Shows the section at which moment was calculated

Based on the total load, the type of metal stud considered is S-shape, 2x6 size with 3" flange depth of 600S300-97 member with a 50 ksi F_y. This type of stud can bear 10.44 kips on a 9ft length. It can be used on walls, floor and ceiling as mentioned in the catalogue. The details of the metal stud can be seen in the catalogue attached to **Appendix-A.**

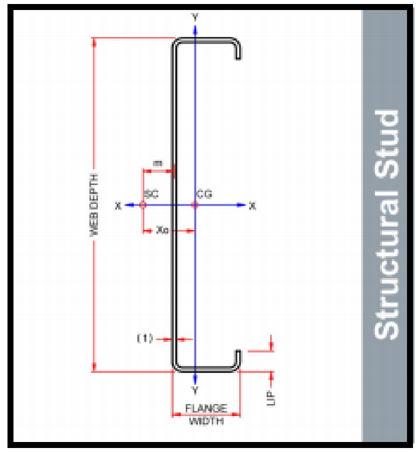


Figure 1.8: S-shaped metal stud

After analyzing the new structural framing of the bathroom units, the next step is to analyze the method to attach the prefabricated bathroom unit to the floor. Based on research and talking to the structural engineer of the project, it is understood that the simplest method to attach the units is by interlocking system which is commonly used for attaching prefabricated units. Based on the weight of the current and new bathroom units, it is evident that the current structure of the building can withstand the weight of the new bathroom unit since the new design is lighter by 3789 lbs approximately compared to the current bathroom unit. The new model design can be used for pre fabricating the bathroom units off-site and attach to the structure of the building.

1. https://www.interstatebrick.com/masonry-calculator

2. http://www.clarkdietrich.com/sites/default/files/imce/pdf/SupportTools/Catalogs/Structural/CD_Structural-UnbracedAxialLoads.pdf

PREFABRICATED MODEL

After finalizing the design, the module can be constructed and transported to the site. The model seen below demonstrates the new bathroom unit with metal stud framing. The length of the bathroom unit is 5.2ft with a width of 9ft. There is space left between the gypsum board and cement board in the ceiling for MEP purpose. The unit was chosen to be modelled in Autodesk Revit for a better understanding of the prefabricated bathroom unit design. The figures of the unit can be seen below in *figure 1.9, 1.10 and 1.11.*

Figure1.9:Model layout

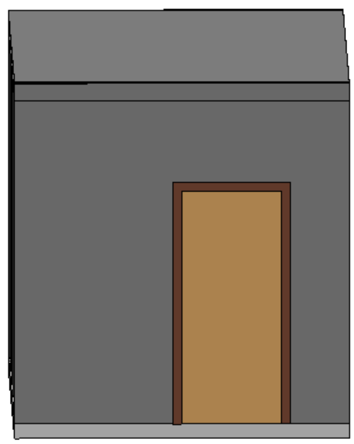
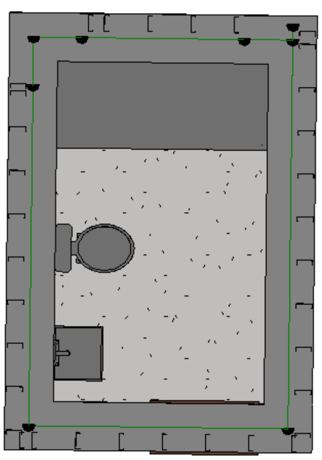


Figure1.10: Top view without roof



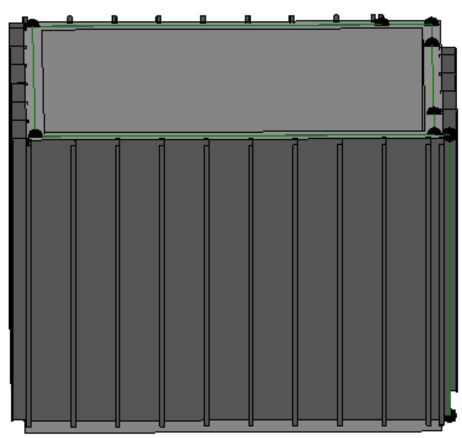


Figure 1.11: Metal studs framing layout on the wall

WAREHOUSE

After designing the new bathroom to be fabricated, there is a requirement of warehouse for the procedure and transport the modules to the site when finished. The warehouses needs to be leased by Ambience Construction firm.

The warehouse is about 20000 sq.ft in area. The exact location of the site cannot be disclosed in the report but after a brief research and coordinating with the project manager, the warehouse can be rented at approximately 40 minutes away from the location of the site. The warehouse is about 1, 00,000 sq.ft usable area and the total height of the warehouse is approximately 25 ft. with no interference of other loadings for pre fabricating the bathroom units. An example of similar warehouse used for prefabrication can be seen in *figure 1.12*. The logistics shows the sequencing of the bathroom unit in *figure 1.13*. The warehouse can be used to store the modules until they are ready to get fixed on-site.

Figure 1.13: Selected Warehouse example

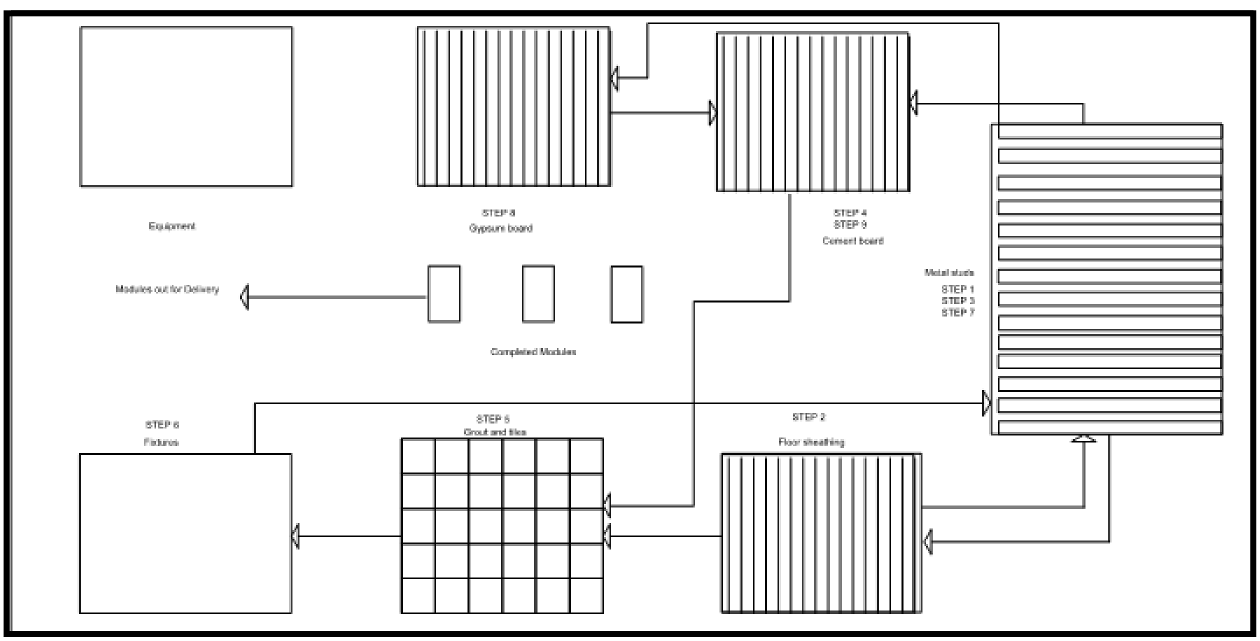


Figure 1.13: Workflow and logistics of bathroom units in the selected warehouse

SCHEDULE FOR OFF-SITE FABRICATION

Each module takes approximately 3 days get assembled in this warehouse and be ready to get transported on-site. Three modules are produced each day. The Procedure starts with assembling of metal studs and connecting them for the floor. This is followed by attaching plywood sheathing for floor. The next step is construction metal studs framing for walls and attaching cement board. Followed by this step, the floor is grouted and left for the entire night and the next step is adding tiles in the morning of the work hours. The MEP rough-in is performed while attaching tiles to the floor since MEP rough-in for this unit is only making penetrations in the wall which can be performed outside the bathroom unit. After adding tiles, the fixtures are placed and followed by forming metal stud framing for ceiling and attaching gypsum board and cement board. The last step is working on finishes and the unit will be ready for final inspection.

There is a total manpower of 12 workers in the warehouse based on the type of task. Most of the activities have a crew consisting of 2 workers except for metal stud framing which has a crew of 3 workers. for this is about A schedule has been created for a typical bathroom unit to show the sequence of assembling the bathroom unit using Microsoft office and this can be seen in *figure 1.14*.

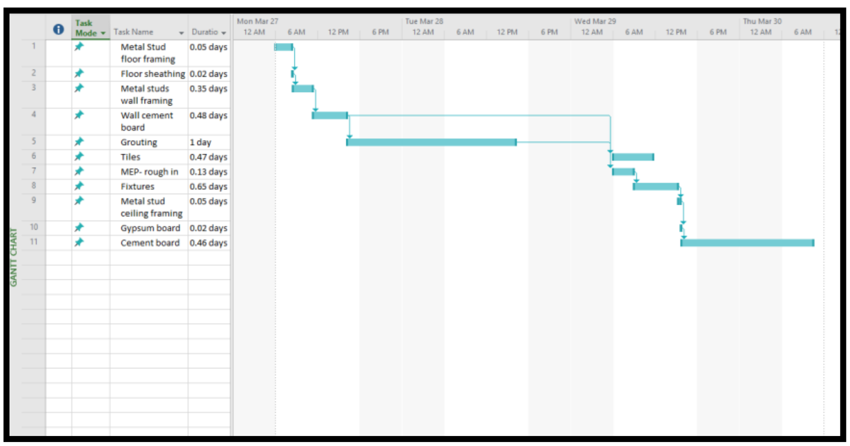


Figure 1.14: Typical schedule for bathroom unit off-site

SCHEDULE ANALYSIS

The main objective of prefabrication is to save time in the overall schedule during construction and enhance the quality of the construction. The statement can be implied to Hanza Crest apartments and this can be seen with the calculations check for the overall savings and can be seen in the figure shown below.

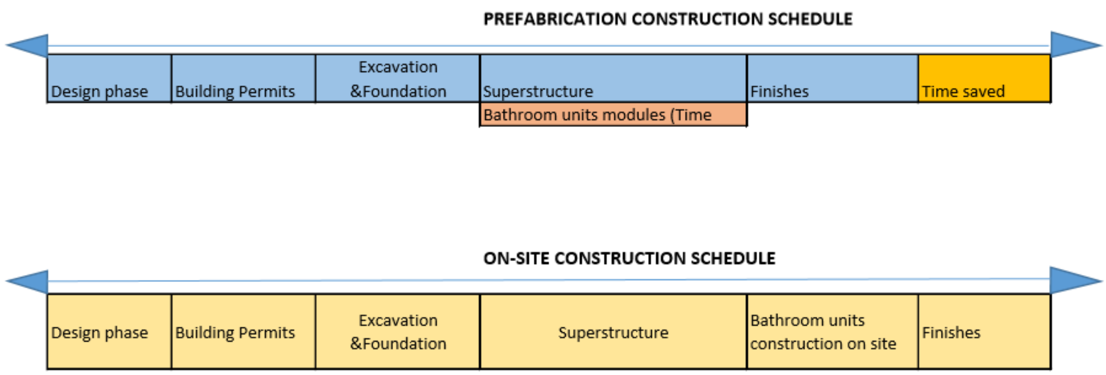


Figure 1.15: Visual representation of time savings by modular construction

Schedule Calculations:

Construction Schedule calculations

3 modules/day x 6 days/week = 18 modules / week

6 modules/ floor x 1 week/ 18 modules = 0.33 week/floor

0.4 week/floor x 5 floors = 1.65 weeks= 2 weeks = **12 days**

12 days are considered instead of 10 days since it takes 2 extra days for the last 3 modules to be completed for delivery though started on 10^{th} day, it takes 3 days for each module to get assembled simultaneously.

Transportation Schedule calculations

3 modules/ 4 hours x 8 hours/days= 6 modules /day

6 modules/ day x 5 days / week = 30 modules/ week

6 modules/ floor x 5 days / 30 modules = 1 day/ floor

1 day/ floor x 5 floor = 0.83 week=**5 days**

Based on the schedule with actual duration, the total time taken to construct bathroom units on-site in 40 days including finishes.

Total savings in overall schedule:

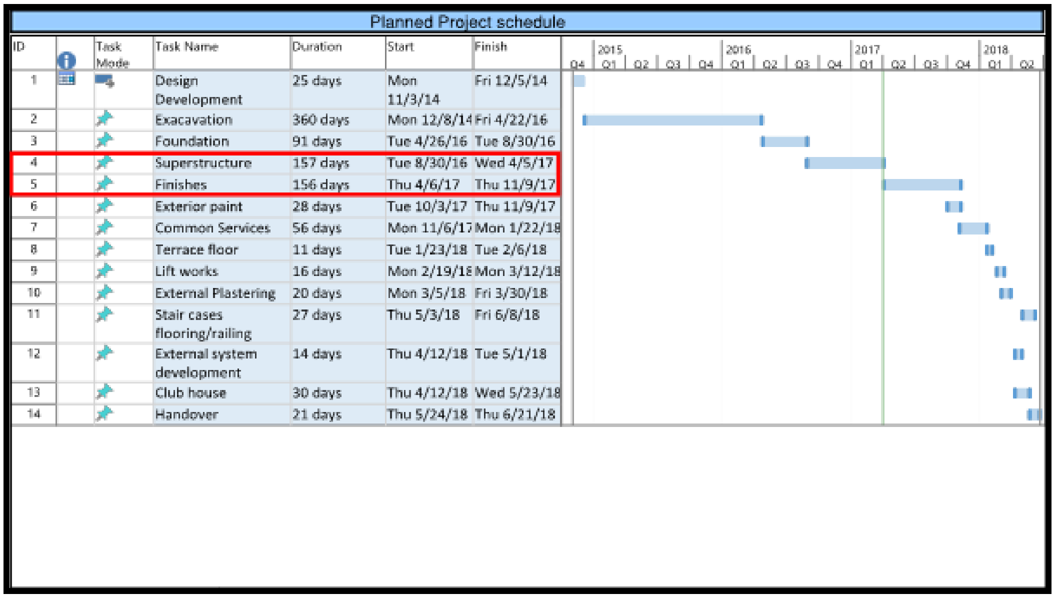
100- (939 days (Overall schedule) – 40 days (Prefabrication)/939 days (Overall schedule)) = **4.2% Reduction in schedule**

Assumptions:

- Based on the location of the site, it takes about 4 hours for the truck to deliver the modules on site and reach the warehouse back due to the traffic jams since it a city and trucks are not allowed to take some of the routes within the city which would lead to consuming more time.
- The number of days taken for bathroom units to be constructed on-site is taken from the planned project schedule which can be seen in Technical assignment 2.

1. file:///C:/Users/CBR5103/Downloads/FINAL%20TECHINCAL%20REPORT%202.pdf

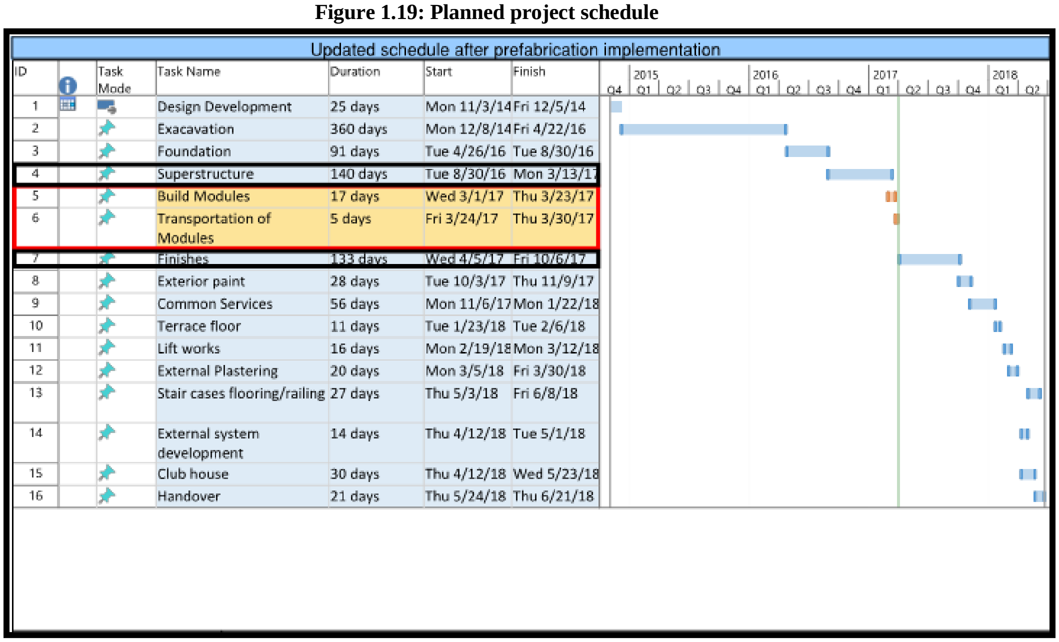
The updated schedule with implementation of prefabrication for bathroom units is displayed in figure 1.20. There is a reduction of schedule in superstructure phase from 157 days to 140 days and 156 days to 133 days in finishes phase leading to a reduction of 40 days overall. Since the modules take only 12 days to get constructed, the work force can start constructing the modules during the superstructure phase of sub-cellar (basement 2) floor which takes about 17 days to get constructed.



Planned Project schedule

ID	Task Name	Duration	Start	Finish
1	Design Development	25 days	Mon 11/3/14	Fri 12/5/14
2	Exacavation	360 days	Mon 12/8/14	Fri 4/22/16
3	Foundation	91 days	Tue 4/26/16	Tue 8/30/16
4	Superstructure	157 days	Tue 8/30/16	Wed 4/5/17
5	Finishes	156 days	Thu 4/6/17	Thu 11/9/17
6	Exterior paint	28 days	Tue 10/3/17	Thu 11/9/17
7	Common Services	56 days	Mon 11/6/17	Mon 1/22/18
8	Terrace floor	11 days	Tue 1/23/18	Tue 2/6/18
9	Lift works	16 days	Mon 2/19/18	Mon 3/12/18
10	External Plastering	20 days	Mon 3/5/18	Fri 3/30/18
11	Stair cases flooring/railing	27 days	Thu 5/3/18	Fri 6/8/18
12	External system development	14 days	Thu 4/12/18	Tue 5/1/18
13	Club house	30 days	Thu 4/12/18	Wed 5/23/18
14	Handover	21 days	Thu 5/24/18	Thu 6/21/18

Figure 1.19: Planned project schedule



Updated schedule after prefabrication implementation

ID	Task Name	Duration	Start	Finish
1	Design Development	25 days	Mon 11/3/14	Fri 12/5/14
2	Exacavation	360 days	Mon 12/8/14	Fri 4/22/16
3	Foundation	91 days	Tue 4/26/16	Tue 8/30/16
4	Superstructure	140 days	Tue 8/30/16	Mon 3/13/17
5	Build Modules	17 days	Wed 3/1/17	Thu 3/23/17
6	Transportation of Modules	5 days	Fri 3/24/17	Thu 3/30/17
7	Finishes	133 days	Wed 4/5/17	Fri 10/6/17
8	Exterior paint	28 days	Tue 10/3/17	Thu 11/9/17
9	Common Services	56 days	Mon 11/6/17	Mon 1/22/18
10	Terrace floor	11 days	Tue 1/23/18	Tue 2/6/18
11	Lift works	16 days	Mon 2/19/18	Mon 3/12/18
12	External Plastering	20 days	Mon 3/5/18	Fri 3/30/18
13	Stair cases flooring/railing	27 days	Thu 5/3/18	Fri 6/8/18
14	External system development	14 days	Thu 4/12/18	Tue 5/1/18
15	Club house	30 days	Thu 4/12/18	Wed 5/23/18
16	Handover	21 days	Thu 5/24/18	Thu 6/21/18

Figure 1.20: Updated planned project schedule with prefabrication implementation

COST ANALYSIS

The cost calculations for the off-site construction needs to be analyzed to check if the added cost for the actual budget. The total cost for prefabrication off-site is $8319. This includes the transportation cost, crane cost and warehouse cost. Since the warehouse needs to lease out at least for one month, the warehouse can be used to store the modules until they are supposed to get delivered on-site. The Ambience Construction firm will be having added cost with no reduction in costs. There will be bare minimum reduction in the workforce on site which is negligible cost reduction, since most of the construction is done on-site and most of the workforces is required to work on-site. This would lead to an increase in the labor cost. There is also an extra crane cost which is not used for the on-site construction due to the project size and warehouse cost. Overall, in cost analysis Ambience Construction firm is not benefitting through prefabrication. The cost analysis can be seen below in *figure 1.21*

Off -Site Cost Calculations		
Item	**Cost($)**	Total($)
Warehouse Rent		
$0.15 per sqft	**1543**	
1month/ Rs 1543		
Crane Cost		**8319**
$110/hourx8 hours/dayx 5 days/month	**4400**	
Transportation Cost		
$45/hourx 4 hours/3 modules x 30 modules	**1800**	
Labor Cost		
$4/dayx 12 workers X 12 days	**576**	

Figure 1.21: Added cost for prefabrication

CONCLUSION

Though prefabrication is the potential solution this project is looking for, it only saves 4.2% (40 days) of the entire project schedule and increase in the cost since there is only a small portion of the construction taking place in the ware house and the remaining 95.8% (899 days) is on-site. Due to this, there is an added cost of warehouse, transportation and labor.

Though the bathroom units have labor intensive work, Prefabrication would probably be fruitful if it has been implemented for the entire apartment unit instead of just the bathroom unit. This would save more time and reduce on-site construction cost tremendously. Though prefabrication of bathroom units could not benefit in huge reduction in schedule, the reliability of work with increased coordination and quality outcome are the major benefits for this project. Based on these positive outcomes, it would be best to analyze prefabrication for the entire apartment unit rather considering only bathroom units.

ANALYSIS 2: FAÇADE CHANGE

PROBLEM IDENTIFICATION

The construction practices in India is different compared to the construction practices in USA. There are different materials used for construction for a different outcome as per the requirements in India. The Ambience Construction firm did follow the same practices for constructing Hanza Crest apartments. The facade of Hanza Crest apartments is made out of bricks with concrete plastering which is very typical for residential construction in India. The facades are usually the weather barriers and are waterproofed with paint coated on them. The paint is typically used for aesthetics and protection for moisture content. This type of practice for the facade lacks a bit of variation for the residential construction and a typical residential building can be seen below in *figure 2.1.*

Figure 2.1: Typical apartments in Hyderabad, India

Apart from being monotonous, the issue with this type of façade is there is no reduction in absorption of heat through the wall. Though the facade is cheaper and easy to install, it requires a lot of workforce and consumes more time to get erected leading to slow workflow. Hyderabad typically has either warm weather or rainfalls, so the thermal properties are not very effective to keep the building cool without much usage of air conditioner units as most of the buildings have air conditioners to keep the building cool enough.

Bricks absorb water very easily causing fluorescence when it is not exposed to air. It also had very less tensile strength though there are highly fire resistant and low maintenance. The concrete plastering has an issue with the alkali-silica reaction (ASR) known as "concrete cancer" creating cracks and poor aesthetics. Both bricks and concrete are poor at blocking moisture and due to the moisture movement between bricks and concrete plastering, there is a chance for a weak bond to form between them. The thermal conductivity of material is the rate at which heat passes through that specified material.

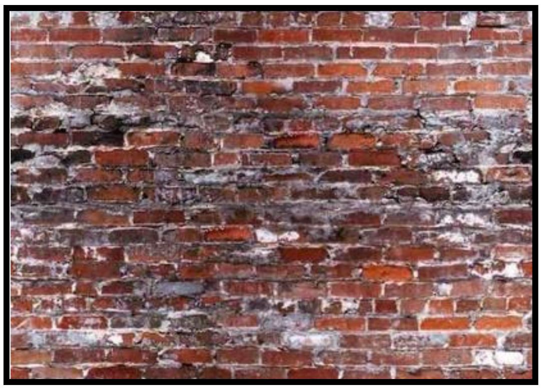


Figure 2.2: Moisture penetration in bricks

Figure 2.3: Concrete cancer (Cracks)

The thermal conductivity of brick is between 0.6-1.0 W/ (m-k) and concrete 1.0-1.8 W/ (m-k) at 25C. The R-value is the capacity of a material to lose heat at a certain amount of time. The R value of brick is 0.2 ft^2 F.h/ (BTU.in) and 0.08 ft^2 F.h/ (BTU.in) for concrete. This shows both the materials are poor at controlling heat passing through them.

It take about 11 days to erect the facade for each floor excluding the time taken for paint which takes another 28 days for the entire building and this falls on higher consumption of time to construct a facade.

These factors would direct to analyze an alternative façade with better thermal properties to be researched for, along with less consumption of time to get erected and helps for reduction/acceleration of schedule with better thermal properties, aesthetics and cost effective.

RESEARCH AND ANALYSIS

It is important to analyze and understand the mechanism of the current facade before choosing an alternative facade. As mentioned earlier, the current facade has an enclosure comprising of bricks with concrete plastering. Apart from concrete plastering, there is another plaster which is typically paint is added to the facade to even out roughness and get a smooth finish. This plaster also helps as a weather penetration blockage. The entire construction of the facade helps to avoid water penetrating into the building and acts a weather barrier.

Figure 2.4: Bricks with concrete plastering

The window on the facade is a 3-track aluminum window consisting of a 5 mm UV protection coated plain float glass with sliding shutters as seen in *figure 2.5*. These windows can be customized and selected as per the occupant's preference and requirement.

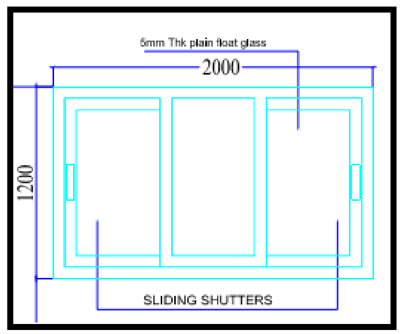


Figure2.5: Typical window used for this project

Based on the typical use of variety of facades used for residential construction, three different types of facades have been selected to understand their basic functioning and select the best option based on the categories mentioned in *figure 2.6* through research.

Type of wall	Cost/SF	R-value	Thermal Conductivity
Green Wall	\$95-165	12.9 ft^2.F.h/Btu	2 W/m^2
Glazing panel with integrated sun louvers	\$160-\$300	11.1 ft^2.F.h/Btu	1 W/m^2
Rain screen cladding	\$35-\$50	15 ft^2.F.h/Btu	0.035 W/m^2

Figure2.6: Shows the approximate values for each category mentioned above

GREEN WALL

This type of wall is best suited for urban environment since it reduces the overall temperature of the building due to the plants and absorbing solar radiation. Based on the type of weather and increment of pollution in India, the use of green wall has started to grow in an extensive pace. The heat absorbed by the vegetation of the wall from outside sources like roads, buildings and sidewalks apart from solar radiation is stored. Though the heat is stored, the temperature of the facade does not increase more than 5 degrees Celsius and sometimes cooler than expected. The green wall is a type of living wall which is very helpful for air filtration and avoids poor air quality.

The green wall also promotes natural cooling process through reduction reflected hear and shading process. Aesthetically, it a visual attractive since it enhances the visual interest and makes it distinctively noticeable as seen in *figure 2.7*. The plants on the wall go through evapotranspiration and in this process, the moisture content is converted into vapor and released back to the atmosphere**.** The green wall usually keeps the building warmer during the nights. It also improves the overall exterior and indoor air quality. It usually takes up to 6-8 weeks for installation of green wall, with an average of 26 feet of panel installation per day after finalizing the design.

Figure 2.7: Green wall for Quai Branly museum (Paris)

There are three types of green walls. The first type is loose medium which consists of soil packed well in a bag and install on the wall. The soil bag needs to get replaced yearly for the exterior walls and not best suited for areas with ground breaking and vibrational activities like earthquake and a lot of public interactions. This type of wall can get very messy and difficult to maintain. The second type of wall is Mat type made of either coir fiber or felt mats. This type of wall is very thin and cannot withhold a lot of plants even if constructed in multiple layers. It also is water inefficient and best suited for seismic prone zones and installed not more than 8 feet tall façade since it would be easy to repair as this wall is prone to require a lot of reparations leading to additional cost. The third type of wall is structural medium which is the best suited wall for Hanza Crest apartments. It is designed to have the best features of the other two types of walls incorporated. The structural medium is a strong wall and guaranteed of not getting broken down for 25 years. It is manufactured in different dimensions and shapes and knows for its high-performance in different circumstances. Though it is expensive to install structural medium, it is cost effective in terms of replacement and maintenance.

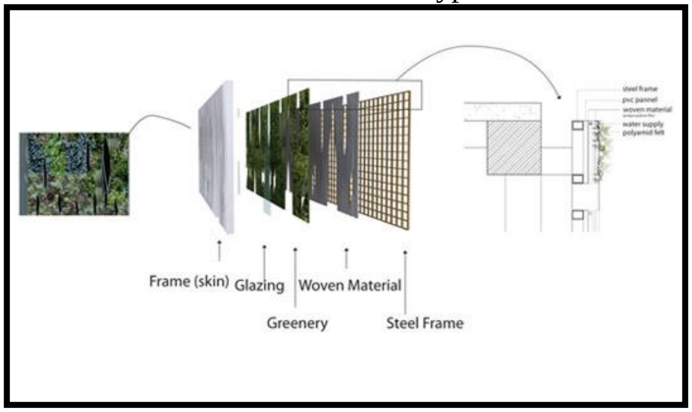


Figure 2.7: Mechanism of green wall

Some of the projects that used green wall in India are Jaaga, The Moksha Tower known for vertical cemetery and the TATA tower in Mumbai. The Pictures shown below depicts the design and mechanism of green wall.

Figure 2.8: Moksha tower in India

Figure 2.9: Tata tower in India

---

1. http://grngen.blogspot.com/2010/08/green-wall.html
2. http://www.greenroofs.org/resources/Green_Walls_Paper.pdf
3. http://www.greenroofs.org/resources/UMDGreenWallResearch(FinalReport).pdf
4. https://www.ansgroupglobal.com/about/news/how-long-does-it-take-grow-green-wall
5. http://inhabitat.com/tata-tower-has-4050-vertical-ev-parking-spots-and-powers-itself/tata-tower-10/

GLAZING PANELS WITH INTEGRATED SUN LOUVERS

The second type of facade selected for this analysis is the glazing panel with integrated sun louvers. This type of panel consists of "insulated glass units incorporated with cord-free extruded aluminum louver inside the airspace cavity"[1].

Figure 2.10: Typical glazing panel with sun louvers

The louver design plays a critical role in this facade. The louver consists of blades with inventive design that delivers the multiple light shelves in the panel. The upper louver angles maximize the daylight into the interior of the building while the lower louvers are created to reduce the glare passing into the building to give a complacent environment inside the building. Due to this design, the day light can be forecasted far into the interior before it turns out into heat.

There are three types of Retro systems for this panel. The first type consists of louvers with RetroSolar system which helps with the redirection of light. "It is a performance louver system in the interior, in-between the glass and exterior"[1]. They perform without any movement. This type of louver system is typically used for

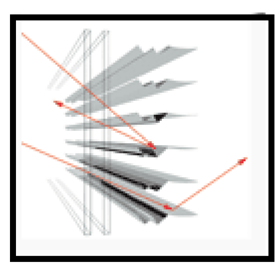


Figure 2.11: Louvers for Retrosolar system panels

shading systems, daylight control, sound and privacy purpose. There are other major benefits that include overall health of the building environment, reduced glare with more day lighting.

The second type is the RetroLux louver system. This system has a "reflector of high angle summer sunlight to heat penetration along with a light-shelf to improve day lighting deflection and for glare protection in the interior space"[1]. This type of louver system protects inside the building from low-angle winter sunlight and high angle summer light leading to prevention of glare and overheat in the building. It also plays a major role in reduction in cooling and electrical loads.

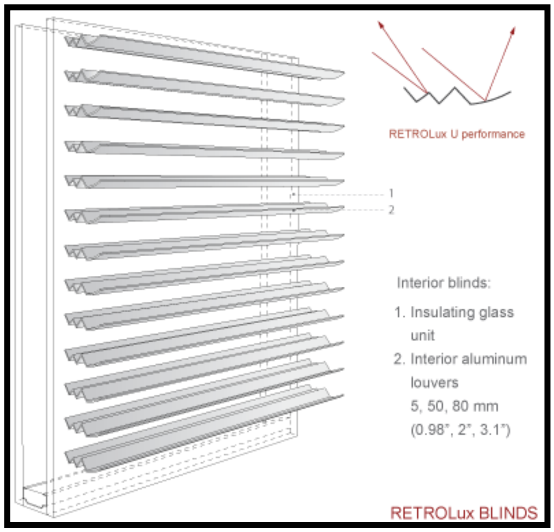


Figure 2.11: Louvers for Retrolux system panels

The louvers are made with extruded aluminum bent in the form of convex or concave shapes with mirrored top surfaces, usually with "50mm width and customized length"[2] as per the building's requirement and installed to the glazing panel. The louvers get adjusted based on the sun angle and weather conditions. They can be simultaneously or in groups adjusted and multiple times in a day. This system can be operated automatically or manually and the switch time for the louvers is 4 seconds. Some of the other apart from mentioned above are reduction in cooling and electrical loads.

The third type of system is the Retroflex louver system. The motive of this system is to allow a controlled daylight distribution and reduce glare and overheating problems by creating concave toothed blinds in a horizontal position. This system has two components: the vertically curved used for sun control function and the horizontally curved for daylight functioning.

The Retroflex is very similar to Retrolux system in terms of using aluminum for louvers and the method they are shaped and sizing in 50 mm and 80 mm with spacing 56 mm except the louvers s have "micro-prismatic structure rolled on the top surface"[1] instead of mirror top surface. This provides a visual transmission and even distribution of light throughout the interior space.

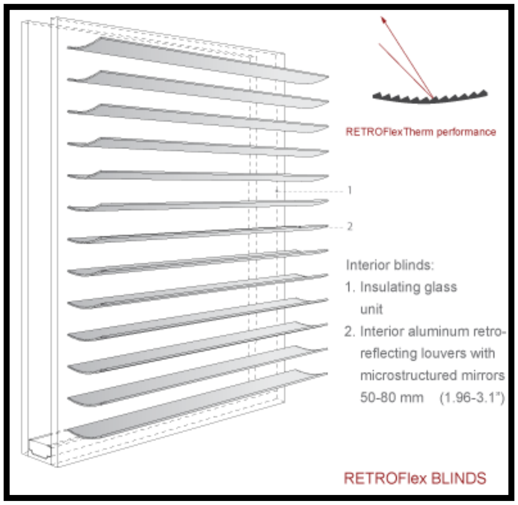


Figure 2.11: Louvers for Retroflex system panels

The Retrolux system is the potential suited type for Hanza Crest apartments since it gives some of the benefits like reduction in cooling load, improved day lighting and avoid overheat the building. These benefits bring very critical change to the environment in the building with an overall positive impact. But this type of panel is still not augmented for residential construction and it is mostly used for commercial or office buildings, due to its high cost as the louvers come on higher side of price ranging between $160-$300 for 2x2 louver and not yet familiarized in residential construction especially in India.

---

1. http://www.skycoshade.com/retro-solar-louvers.html

2. http://www.d-lite.org/page/micro_sun_shield_louvers_p166.php

3. http://www.wfm.co.in/facade-designs-materials-are-constantly-changing-evolving/

4. http://www.archlouvers.com/How_Louvers_Work.htm

5. http://www.constructionweekonline.in/changing-face-of-facades/http://grihaindia.org/grihasummit/presentations/16feb/Sameer_Maithel.pdf

6. http://www.centriaperformance.com/products/wall/architectural_insulated_metal_panel_systems/integrated_solutions/products/cs_louvers.aspx

RAINSCREEN CLADDING

The third type of facade chosen is the rain screen cladding. This type of wall has a good potential to be the best-fit for Hanza Crest apartments since the rainfall rate is 32.6" in Hyderabad. Not only it gives protection from rainwater penetrating into the building but its main goal is to prevent moisture content penetrate and energy transfer through wall assembly. Rain screen is a long-lasting façade and has high-performance system which is visually attractive. It is a form of double wall that utilizes outer layer to prevent rainwater seeping into the building and the inner layer manages air leakage and thermal insulation like heat transfer into and out of the building. It prevents interstitial condensation which is one of the major problems faced in construction especially in India.

The motive of the rain screen cladding is to "control and manage the elements of nature that act upon wall assembly."[1] Some of the benefits of rain screen cladding to be mentioned are reduction of passing ultraviolet radiation into the building, control of negative wind pressure, air infiltration, vapor transmission and heat transfer into and out of the building.

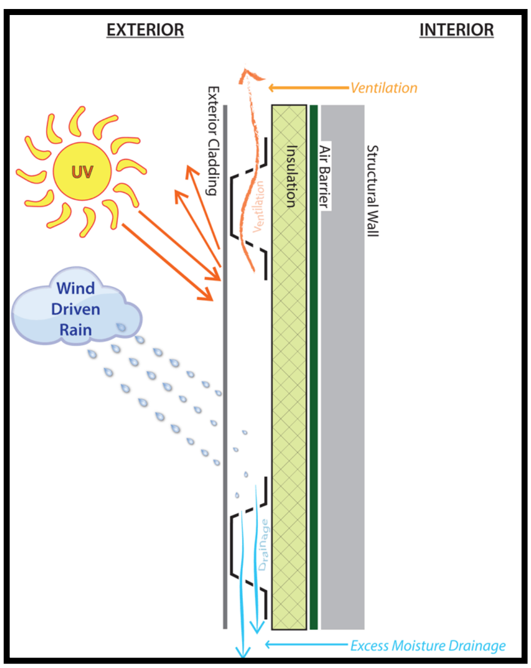


Figure 2.12: Components in a typical rain screen wall

There are 4 components in a rain screen wall assembly as seen in *figure 2.12*. The exterior cladding which is made out of metal is a high quality wall panel protecting the wall assembly from rain, negative wind pressures and ultra-violet radiation. The next component is ventilation/drainage and framing system. This is a very crucial part of the rain screen facade and must be built into the system through the framing system. It is designed for ventilating behind the cladding and supports airflow and residual water behind the panel. As per garlando website, the ventilation cavity can be fixed by anchoring hat channel to metal panel and this reduces thermal bridging to a great extent.

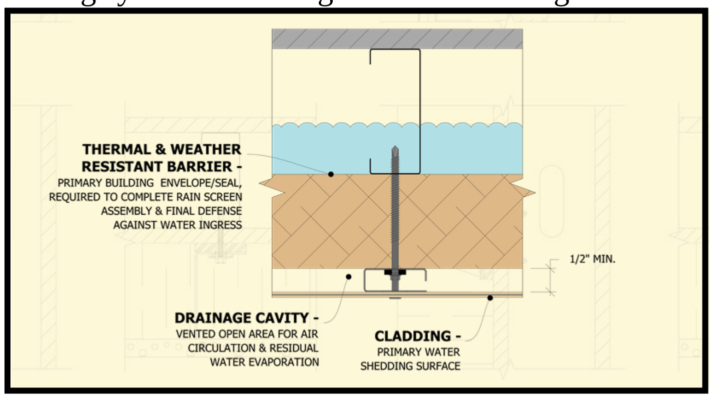


Figure 2.13: Impact of each component in the wall

Followed by ventilation cavity is the insulation that reduces the heat flow into and outside of the building. For more effective results, it is best if the insulation is a continuous layer to the exterior of the air barrier. The last component in the wall assembly is the air barrier which is used as water barrier also.

Any residual that escapes the layers before air barrier is ultimately stopped and drained out. In some buildings, the vapor is allowed through the air barrier for good results but for this project, it will be best if the vapor transmission is not allowed to pass through the air barrier. The back ventilated system has an opening at the top and at the base which is a continuous cavity that runs through the panel width or several feet of the height of the building.

Some of the examples for rain screen cladding is the ALCOA building in Pittsburgh that consisted of open-jointed aluminum baffle panels and Etalbond rain screen cladding is another type which is used for the below seen in the picture on the right. It is made out of an ACM panel which consists of two corrosion-resistant aluminum sheets that are pre-painted aluminum and "thermally bonded to polymeric core by a continuous procedure" [2]. Etalbond can also be used for curved surfaces but is mostly preferred in the form of large flat panels.

Figure 2.13: ALCOA building facade in Pittsburgh

Figure 2.14: Building etalbond rain screen panel

1. http://www.garlandco.com/educational/ytr/understanding-rainscreen-design.html
2. http://www.brooklineconnection.com/history/Facts/AlcoaBuilding.html
3. http://www.nvelope.com/rainscreen-thermal-calculations.html
4. http://www.nvelope.com/rainscreen-thermal-calculations.html
5. http://www.nvelope.com/rainscreen-thermal-calculations.html
6. http://www.nvelope.com/rainscreen-thermal-calculations.html
7. http://northclad.com/products/acm/
8. http://www.americanfibercement.com/information/rainscreen-cladding

ALTERNATIVE FACADE

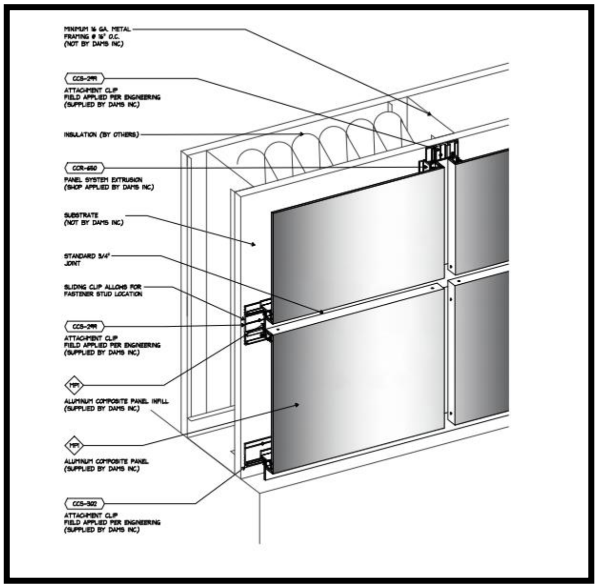
Out of the three facades that were analyzed, rain screen cladding implies to be the best potential alternate facade based on the R-value, cost, thermal conductivity and maintenance compared to green wall and glazing panels with integrated sun control louver. Though green wall would be an ideal choice based on its features of heat reduction and promotes shading through natural cooling process along with enhancing aesthetics and reduce the cracks problem for the current façade. Though the green wall demonstrates benefits like quality air and reduction in cooling load, the maintenance of green wall is the biggest issue to be faced if it is installed to the existing facade. This can get very expensive and a lot of work will be involved to maintain the facade especially added water irrigation system to maintain the plants on the facade.

The glazing panels integrated with integrated sun louvers is also a suitable type of facade for this project. Having advantages of reduction in cooling load, enhanced day lighting and avoiding overheat of the building if the Retrolux system panel is used. The change in structural system of the building and the panel falling in the higher cost would compel to choose an alternative facade.

The third option of this analysis which is the rain screen cladding system can be added to the existing facade. It is easy to maintain with a replacement of once in 25 years. The cost for installing the panel is cheaper compared to the other options analyzed. Since the rain screen panel is not very prominent in India currently, the product chosen is manufactured in a United States company since it was difficult to find a company from India that gives complete information about the rain screen panel. The product

Figure 2.14: ACM rain screen panel

is rain screen (Aluminum composite metal) ACM panels-CCRS series manufactured by DAMS incorporated located in Illinois.



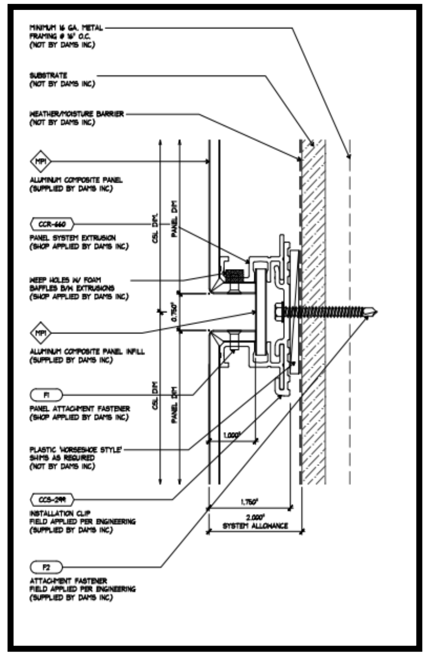


Figure 2.14 and 2.15: CCRS- ACM rain screen panel Mechanism

The ACM rain screen panel will be added to the existing façade consisting of bricks and replacing concrete plastering with water proofer leading to reduction in cost. The panel will be anchored to the existed façade

The description of the product can be seen in *figure 2.16* that is taken from DAMS Inc. website. The finish selected is Composite aluminum panel which is typically non-corrosive, durable and mostly used for facades and also fulfills the aesthetics purpose. The brochure and panel system details of this product is attached to **Appendix- B.**

Figure 2.16: ACM rain screen panel product description

1. http://www.damsinc.com/acm-panels/

MECHANICAL BREADTH

Hanza Crest apartments has a bricks with concrete plastering facade as mentioned earlier. This type of facade though typical in residential construction has a numerous problems to be dealt with. To avoid the category of problems mentioned earlier, an alternative facade has been chosen for long and high-level performance, easier maintenance and cost effective. Prior to analyzing the envelope load of the new façade, the envelope load of the current façade has been analyzed below using TRACE 700 software.

CURRENT FAÇADE (Bricks with concrete plastering)

Internal Loads

The heat gained from people is 250 BTU/hr of sensible heat and latent heat of 200 BTU/hr used for the internal load calculations. The airflow calculations for this project has been performed as per ASHRAE guidelines for ventilation. Since, the building is newly getting constructed, there would be less air changes per hour due to tighter atmosphere for the building.

Each apartment is divided into 5 sections to calculate internal loads. The following sections are:

1. Bedrooms
2. Living room
3. Toilets
4. Kitchen
5. Drawing room

Bedroom

Starting with the Bedrooms. Each apartment has 3 bedrooms with a total area of 854 SF. The average area of each bedroom is 285 SF A family of 4 to 6 members was assumed to be living in each apartment. It is assumed that only parents and 2 kids will be living in the apartment typically. So for each person 142 SF would be a fair estimate. The area also includes the dress room given to each bedroom.

Based on the lighting/electrical plans for approved for this project, each bedroom has 3 1x40 W fluorescent tube light hung on the ceiling with imposes 100% load in the space, 1 48" fan attached to the ceiling , 1 20A socket for air conditioner and 1 television socket. The total wattage of tube light comes to 120 W, air conditioner of 175 W in each bedroom, a notebook computer of 45W and 2 desktop computers of 100 W each bedroom giving a heat gain of **1.26 W/SF.**

Living room

The living room occupies 451 SF of each apartment. It consists of 2 48" fan on the ceiling, 2 1x40 W fluorescent tube lights attached to the ceiling separately. Since it is also used as dining room, this space is used most of the time to only eat. As mentioned earlier, assuming to have 4 people occupying this space in the apartment, the area is divided into 112.8 SF/person. The total heat load is 80 W in this space and the heat gain is **0.18 W/SF.**

Toilets

There are 3 toilets that occupy 147 SF in each apartment. Each toilet consists of with 15W CFL, 2 6A sockets and a HD exhaust fan. There is also a point left for ceiling fan but typically not used. The total head load is 45 W in the toilets with a heat gain of **0.31 W/SF**.

Kitchen

The kitchen occupies a total area of 146 SF in each apartment. It consists of 1 1x40 W fluorescent tube lights attached to the ceiling. Along with the heat gain from the tube light, there are other miscellaneous loads to be considered for this space that add up to give heat gain. The other equipment including refrigerator, stove, microwave, oven, dishwasher and stove together give a heat load of 700W. The total heat load in the kitchen is 740 W with a heat gain of **5 W/SF.**

Drawing room

The drawing room has a total area of 345 SF. It can assumed that the whole family would spend time in the drawing room, the space is occupied by 4 people. So, the area is divided as 86 SF/person**.** There are 2 1x40 W fluorescent tube lights attached to the ceiling, a television socket, 2 48" fan on the ceiling, telephone socket and 2 switch boards. Apart from the light heat load, there is heat load given by a television of 100 W and an air conditioner which is typically used in the drawing room of 175 W. The total heat load spaced out in this room is 180 W. This leads to giving a heat gain of **1.02 W/SF.**

Construction:

The construction template for the project summarizes the details about wall, roof, slab and window. The information provided in this template has been extracted from the project's plan and project team. The slab and roof are constructed with 6" light weight concrete. The wall/facade is constructed with 4" face brick covered with concrete plastering. The floor to floor height is 9.5' As mentioned above, the window is a is a 3-track aluminum window consisting of a 5 mm UV protection coated plain float glass with sliding shutters.

---

1. https://www.thefreelibrary.com/Revised+heat+gain+rates+from+typical+commercial+cooking+appliances...-a0217848196
2. https://sustainabilityworkshop.autodesk.com/buildings/equipment-and-lighting-loads
3. https://sustainabilityworkshop.autodesk.com/buildings/equipment-and-lighting-loads
4. https://www.bijlibachao.com/water-heaters/gas-water-heatersgeyser-better-than-electric-geysers-in-saving-energy.html

Construction:

The construction template for the project summarizes the details about wall, roof, slab and window. The information provided in this template has been extracted from the project's plan and project team. The slab and roof are constructed with 6" light weight concrete. The wall/facade is constructed with 4" face brick covered with concrete plastering. The floor to floor height is 9.5' As mentioned above, the window is a is a 3-track aluminum window consisting of a 5 mm UV protection coated plain float glass with sliding shutters. The *figure 2.17* demonstrates the construction of the existing façade used to calculate the envelope load.

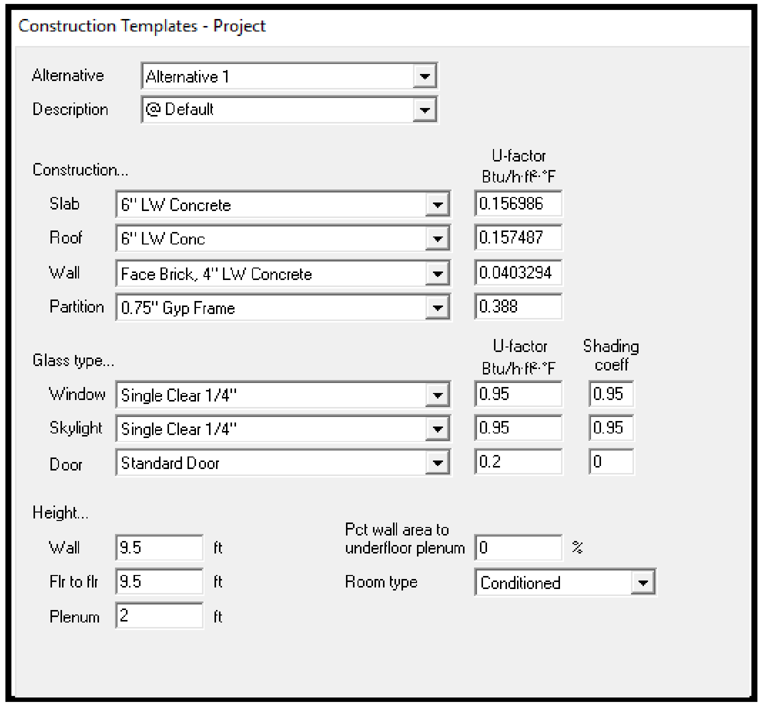


Figure 2.17: Existing façade construction template

Systems:

As mentioned earlier, most of the residential buildings in India do not acquire mechanical system. The occupants typically use wall units like air conditioners, ceiling fans and exhaust fans which are similar to terminal air conditioners and fan coil systems. The entire apartment is divided into 3 zones:

Zone1: Master Bedroom, bedroom 2, bedroom 3, living room and drawing room

Zone 2: Kitchen

Zone 3: Toilet 1, Toilet 2 and Toilet 3

Checksum calculations:

Based on the internal loads calculated above, the values are entered in Trace 700 to each room. Since, this is a mechanical breadth for the facade change analysis, only the envelope load is considered. The sensible heat column is to be focused since the building is typically designed based on the sensible heat. *Figure 2.18* shows the sensible heat calculation for zone 1 which acquires a total load of 31,002 BTU/hr that includes master Bedroom, bedroom 2, bedroom 3, living room and drawing room of one apartment is 31,002 BTU/hr:

Zone Checksums
By ACADEMIC

Zone - 001

COOLING COIL PEAK — Peaked at Time: Mo/Hr: 9 / 16; Outside Air: OADB/WB/HR: 89 / 72 / 89
CLG SPACE PEAK — Mo/Hr: 9 / 11; OADB: 82

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	6,280	6,280	2	0	0
Glass Solar	24,955	0	24,955	7	29,092	15
Glass/Door Cond	1,065	0	1,065	0	770	0
Wall Cond	1,105	353	1,458	0	787	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	-291		-291	0	354	0
Sub Total ==>	26,834	6,632	33,466	10	31,002	16
Internal Loads						
Lights	765	191	956	0	765	0
People	313,250	0	313,250	89	156,625	81

HEATING COIL PEAK — Mo/Hr: Heating Design; OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-6,317	30.30
Glass Solar	0	0	0.00
Glass/Door Cond	-5,437	-5,437	26.08
Wall Cond	-662	-872	4.18
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-1,876	-1,876	9.00
Sub Total ==>	-7,976	-14,502	69.55
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	71.3
Ra Plenum	75.8	69.4
Return	75.8	69.4
Ret/OA	75.9	69.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	8,759	8,759
Terminal	8,759	8,759
Main Fan	8,759	8,759
Sec Fan	0	0
Nom Vent	77	77
AHU Vent	77	77
Infil	57	57
MinStop/Rh	0	0
Return	8,815	8,815

Figure 2.17: Zone 1 checksum calculations

Figure 2.18 shows the sensible heat calculation for zone 2 which acquires a total load of 3600 BTU/hr that includes only kitchen of one apartment:

Zone Checksums
By ACADEMIC

Zone - 002

COOLING COIL PEAK — Peaked at Time: Mo/Hr: 9 / 15; Outside Air: OADB/WB/HR: 90 / 71 / 83
CLG SPACE PEAK — Mo/Hr: 12 / 14; OADB: 73

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	867	867	3	0	0
Glass Solar	2,216	0	2,216	7	3,507	19
Glass/Door Cond	231	0	231	1	-43	0
Wall Cond	185	57	242	1	147	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	94		94	0	-10	0
Sub Total ==>	2,727	924	3,650	12	3,600	20

HEATING COIL PEAK — Mo/Hr: Heating Design; OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-673	29.63
Glass Solar	0	0	0.00
Glass/Door Cond	-520	-520	22.88
Wall Cond	-75	-97	4.29
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-179	-179	7.89
Sub Total ==>	-774	-1,470	64.69

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.9
Ra Plenum	76.0	69.3
Return	76.0	69.3
Ret/OA	76.4	68.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	828	828
Terminal	828	828
Main Fan	828	828
Sec Fan	0	0
Nom Vent	25	25
AHU Vent	25	25

Figure 2.18: Zone 2 checksum calculations

Figure 2.19 shows the sensible heat calculations for zone 3 which acquires a total load of 2592 BTU/hr that includes all the 3 toilets of one apartment:

Zone Checksums
By ACADEMIC

Zone - 003

	COOLING COIL PEAK				CLG SPACE PEAK			HEATING COIL PEAK		
Peaked at Time: / Outside Air:	Mo/Hr: 7 / 17	OADB/WB/HR: 87 / 70 / 87			Mo/Hr: 7 / 18	OADB: 85		Mo/Hr: Heating Design	OADB: 40	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)		Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	1,309	1,309	2	0	0	Roof Cond	0	-658	10.43
Glass Solar	1,836	0	1,836	2	1,957	5	Glass Solar	0	0	0.00
Glass/Door Cond	140	0	140	0	125	0	Glass/Door Cond	-356	-356	5.65
Wall Cond	358	93	451	1	468	1	Wall Cond	-216	-273	4.32
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0.00
Infiltration	39		39	0	41	0	Infiltration	-123	-123	1.95
Sub Total ==>	2,373	1,402	3,775	5	2,592	7	*Sub Total ==>*	-696	-1,410	22.36
							Internal Loads			

Figure 2.19: Zone 2 checksum calculations

The total sensible load for one apartment in this project is **37,192 BTU/h**r based on the existing facade. The total checksum calculation charts is attached to **Appendix – C.**

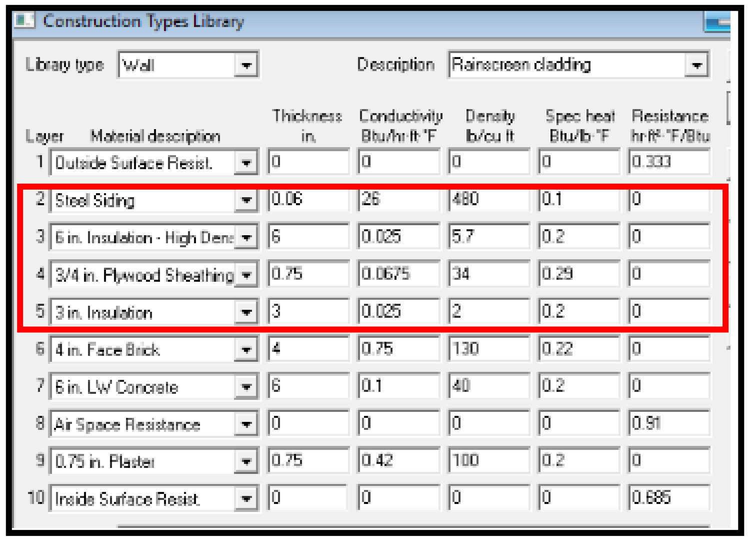
1. file:///C:/Users/CBR5103/Downloads/200583084452_886%20(4).pdf
2. file:///C:/Users/CBR5103/Downloads/200418145036_347%20(3).pdf

ALTERNATE FAÇADE (Rain screen cladding)

To calculate the envelope load with the new façade, the systems, zones, air flow, internal loads of the apartment are the same ones used for the current façade except for the construction template in TRACE 700, which would comprise of materials used for the new façade.

Construction:

As mentioned earlier, the rain screen cladding facade consists of 4 components attached to the current facade. Based on the mechanism of the rain screen panel assisted by research, the materials /elements have been added to the existing facade to create a rain screen cladding panel best fit for this project. The new materials included are steel siding/metal panels, plywood sheathing and insulation. The materials selected are closest to the materials utilized to construct rain screen panel.



Layer	Material description	Thickness in.	Conductivity Btu/hr·ft·°F	Density lb/cu ft	Spec heat Btu/lb·°F	Resistance hr·ft²·°F/Btu
1	Outside Surface Resist.	0	0	0	0	0.333
2	Steel Siding	0.06	26	480	0.1	0
3	6 in. Insulation - High Dens	6	0.025	5.7	0.2	0
4	3/4 in. Plywood Sheathing	0.75	0.0675	34	0.29	0
5	3 in. Insulation	3	0.025	2	0.2	0
6	4 in. Face Brick	4	0.75	130	0.22	0
7	6 in. LW Concrete	6	0.1	40	0.2	0
8	Air Space Resistance	0	0	0	0	0.91
9	0.75 in. Plaster	0.75	0.42	100	0.2	0
10	Inside Surface Resist.	0	0	0	0	0.685

Figure 2.20 shows the new façade construction template.

Checksum calculations:

The checksum calculations can be run after creating the new facade in TRACE 700. Similar to the existing facade checksum calculations, the new facade calculations will also focus only the envelope load. The sensible heat column is to be focused since the building is usually designed based on the sensible heat. *Figure 2.21* shows the sensible heat calculation for zone 1 which acquires a total load of 28,612 BTU/hr that includes master Bedroom, bedroom 2, bedroom 3, living room and drawing room of one apartment:

Zone Checksums
By ACADEMIC

Zone - 001

	COOLING COIL PEAK				CLG SPACE PEAK			HEATING COIL PEAK		
Peaked at Time: / Outside Air:	Mo/Hr: 7 / 17	OADB/WB/HR: 87 / 70 / 87			Mo/Hr: 9 / 12	OADB: 85		Mo/Hr: Heating Design	OADB: 40	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)		Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	6,251	6,251	2	0	0	Roof Cond	0	-6,316	30.54
Glass Solar	23,590	0	23,590	7	27,436	14	Glass Solar	0	0	0.00
Glass/Door Cond	1,084	0	1,084	0	614	0	Glass/Door Cond	-5,437	-5,437	26.29
Wall Cond	248	75	323	0	230	0	Wall Cond	-488	-642	3.10
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0.00
Infiltration	-266		-266	0	333	0	Infiltration	-1,876	-1,876	9.07
Sub Total ==>	24,656	6,326	30,981	9	28,612	15	*Sub Total ==>*	-7,801	-14,272	69.01
Internal Loads							**Internal Loads**			

Figure 2.21: Zone 1 checksum calculations (New façade)

Figure 2.22 shows the sensible heat calculation for zone 2 which acquires a total load of 3327 BTU/hr that includes only kitchen of one apartment:

Zone Checksums
By ACADEMIC

Zone - 002

	COOLING COIL PEAK				CLG SPACE PEAK			HEATING COIL PEAK		
Peaked at Time: / Outside Air:	Mo/Hr: 9 / 16	OADB/WB/HR: 89 / 72 / 89			Mo/Hr: 11 / 14	OADB: 77		Mo/Hr: Heating Design	OADB: 40	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)		Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	921	921	3	0	0	Roof Cond	0	-673	29.96
Glass Solar	2,081	0	2,081	7	3,299	18	Glass Solar	0	0	0.00
Glass/Door Cond	221	0	221	1	-3	0	Glass/Door Cond	-520	-520	23.14
Wall Cond	32	10	42	0	18	0	Wall Cond	-55	-72	3.19
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0.00
Infiltration	113		113	0	14	0	Infiltration	-179	-179	7.99
Sub Total ==>	2,447	930	3,377	11	3,327	19	*Sub Total ==>*	-754	-1,444	64.28

Figure 2.22: Zone 2 checksum calculations (New façade)

Figure 2.23 shows the sensible heat calculation for zone 3 which acquires a total load of 1569 BTU/hr that includes all the 3 toilets of one apartment:

Zone Checksums
By ACADEMIC

Zone - 003

COOLING COIL PEAK	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	CLG SPACE PEAK: Space Sensible Btu/h	Percent Of Total (%)
Peaked at Time: Mo/Hr: 9 / 16; Outside Air: OADB/WB/HR: 89 / 72 / 89					Mo/Hr: 7 / 18; OADB: 85	
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	724	724	1	0	0
Glass Solar	927	0	927	1	1,319	4
Glass/Door Cond	128	0	128	0	119	0
Wall Cond	76	19	95	0	89	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	52		52	0	41	0
Sub Total ==>	1,183	743	1,926	3	1,569	4

HEATING COIL PEAK	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Mo/Hr: Heating Design; OADB: 40			
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-658	10.54
Glass Solar	0	0	0.00
Glass/Door Cond	-356	-356	5.71
Wall Cond	-165	-209	3.34
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-123	-123	1.97
Sub Total ==>	-645	-1,346	21.56

Figure 2.23: Zone 1 checksum calculations (New façade)

The total sensible load for one apartment in this project is **33,508 BTU/h**r based on the existing facade. The total checksum calculation charts is attached to **Appendix – D.**

ENVELOPE LOAD COMPARISON

After using performing calculations to determine total load obtaining from current facade and new facade, the loads have been compared. It can be seen that rain screen cladding panel saves a total load of 3684 BTU/hr for each apartment in the building. If rain screen panel is attached to the existing facade, then a total load of 36,840 BTU/hr will be saved for entire building. *Table 2.1* shows the comparison.

MECHANICAL LOAD COMPARISON					
Facade Type	**Zone 1 (BTU/hr)**	**Zone 2 (BTU/hr)**	**Zone 3 (BTU/hr)**	**Total load/ apartment(BTU/hr)**	**Total load for the building(BTU/hr)**
Bricks with concrete plastering (Current facade)	31,002	3600	2592	37192	371920
Rainscreen cladding panel(New facade)	28612	3327	1569	33508	335080

Table 2.1: Compares the envelope load between the two facades

COST ANALYSIS

The cost of rain screen cladding calculated above is a rough estimate based on the price given by damsinc.com and greenhomeguide.com.The square foot of each wall has been calculated by deducting the area occupied by windows. The cost of rain screen panel is approximately $20. Since it was difficult to get a detailed cost, the price per SF is was broken down approximately for a detailed calculation with the RS means guidelines. The installation charges are quoted between $23- $30. Since the project is located in India and the installation price is cheaper comparatively to United States, the price for installation is calculated based upon the price in India. The detail cost calculation can be seen in *table 2.2 and 2.3.*

Material Type	Unit	Quantity	Cost($)	Total($)
Aluminium panels	SF	11807	12	141684
Insulation 6"	SF	11807	2	23614
Insulation 3"- wool	SF	11807	3	35421
Plywood sheathing	SF	11807	3	35421
			20	236140

Table 2.2: Cost calculations for the new façade (Material)

Material Type	Unit	Quantity	Cost($)	Total($)
Aluminium panels	SF	11807	4	47228
Insulation 6"	SF	11807	2	23614
Insulation 3"- wool	SF	11807	2	23614
Plywood sheathing 3/4"	SF	11807	2	23614
				118070

Table 2.3: Cost calculations for the new façade (Installation)

The total added cost for the new façade = **$ 3, 54,210**

There is a possibility for the cost to get reduced if the concrete plastering is replaced with another waterproof material on the brick, then the price would reduce from $23.50/SF to $12/SF leading to a reduction is cost by **$135,780**. But this can be done only if the water proofing can substitute the concrete appropriately without a compromise in the quality of the façade.

Based on the internal load calculations with the rain screen panel, there is a reduction in cooling load which would save money for the project. The cooling cost has been determined based on the formula:

$$kWh = Operating\ hours * BTU\ hr * 0.293\ /\ 1000$$

Cost of cooling load of brick with concrete plastering:

KWh= (8hrs *37,192*0.293)/1000= 87.18 kWh

Cost per unit = 2cents/kWh*87.18= $ 1.74/unit

Total cost= $1.74/unit*2 units/floor*5 floors=**$17.4**

Cost of cooling load of rain screen panel:

KWh= (8hrs *33508*0.293)/1000= 78.54kWh

Cost per unit = 2cents/kWh*78.54= $ 1.57/unit

Total cost= $1.54/unit*2 units/floor*5 floors=**$15.4**

The cost difference for the two facades is $2/day. This would save the cooling cost by **$730/year.**

1. http://www.damsinc.com/acm-panels/

2 .http://www.greenhomeguide.com/

SCHEDULE ANALYSIS

Since all the elements in the rain screen cladding system are prefabricated and ready to be installed, there will be a minor change in the schedule. *Table 2.4* shows the detailed calculation of duration for installing the panel. Since, it was difficult to get an approximate time to install the panel from the manufacturers. The total number of hours have been calculated by breaking down the time taken to install each wall component with the guidelines from RS means 2017 and research.

Material Type	Unit	Quantity	Men/Crew	Daily Output in 8	Crew	Total Manpower	Hourly Production	Duration(hours)
Aluminium panels	SF	11807	3	775	1	3	96.875	41
Insulation 6"	SF	11807	2	1600	1	2	200	30
Insulation 3"- wool	SF	11807	2	600	1	2	75	77
Plywood sheathing 3/4"	SF	11807	2	1209	1	2	151.125	40
Miscellaneous material	SF	11807	2	1700	1	2	212.5	27
							Total no of hours	215
							Total no of days	27

Table 2.4: schedule calculations for the new facade

The total duration for installing rain screen panel is approximately 27 days added to the building enclosure phase as seen above. The new schedule for the finishes phase is total 183 days. This would be an additional time for the planned schedule increasing it by approximately 3% overall. But this increment is only due to the assumptions made for breaking down time for a detailed schedule.

SITE LOGISTICS

The site logistics will remain almost unchanged after changing the existing façade except for Creating a storage area for the rain screen panels at the storage site. Since there is ample amount of empty space at the storage site, there is more space allocated for the materials since it is the phase and the rain screen panels are also allocated storage space next to the materials storage with similar workflow as seen in *figure 2.24.* The storage area are temporary closed areas in order to protect the materials from weather. There are two material hoist placed closer to the site entrances for easy access of the materials. The attachment of the existing façade is completed floor wise. The red color arrows depicts the starting point of materials getting delivered to the required floor. The entire site plan is attached to **Appendix E.**

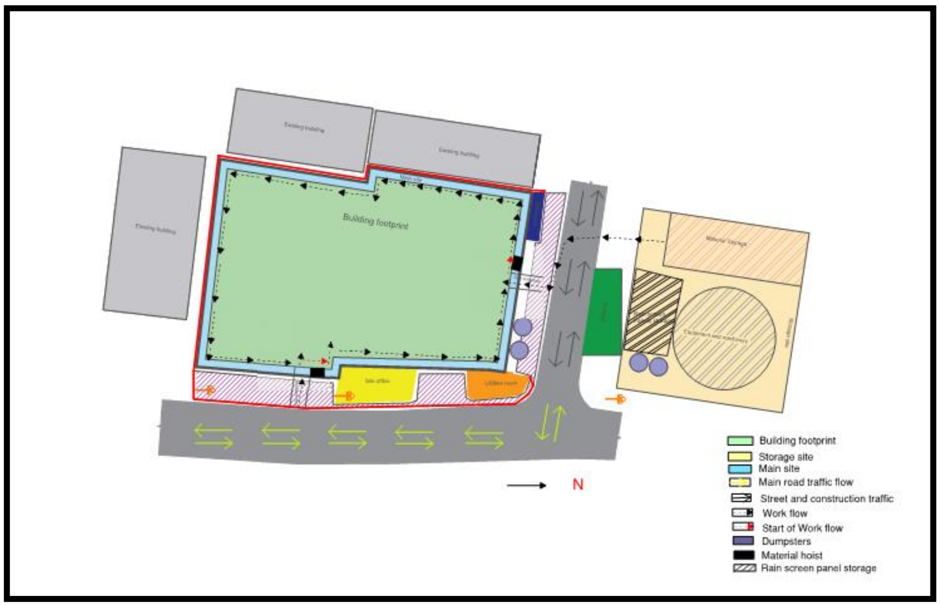


Figure 2.24: Snip of Updated site logistics for the new façade

1. http://media.wix.com/ugd/110bc4_2881fcf5f1b343bd8499f58221b0b6e7.pdf

The Rain Screen cladding provides an exceptional solution for the problems faced due to the current façade like moisture penetration, concrete cancer (cracks) and poor aesthetics. The panels are also visually attractive with an enhanced polished look for the building. This would successfully enhance the quality of the project and making it more luxurious space for the occupants to live. There is a reduction is cost for the occupants by $730/year and possible reduction of $135,780 if concrete plastering is replaced with water proofing material like cementitious waterproofing and needs to be analyzed to check if it works. Though one of the goals, enhanced quality for the project is accomplished through this analysis, the major drawbacks are its upfront cost of $354,210 and 27 days of added schedule.

Since the panels are prefabricated there is a potential of consuming less time than shown above with bare minimum addition of time to the planned schedule. Since the labor costs is very cheap in India, by doubling the workforce, the panels can be attached in less than 14 days. If the owner is looking for an enhanced quality outcome for this project, then an argument can be made that addition of rain screen panels is the best option with 25 years of guaranteed maintenance. But if the owner is looking for cost savings then the current façade remains to be the practical, feasible and economical option for a residential building in India.

ANALYSIS 3: SIPS FOR SUPERSTRUCTURE

PROBLEM IDENTIFICATION

As mentioned earlier, being located in a residential zone, the Hanza Crest apartments had a number of restrictions during demolition and excavation phase. The entire duration for this phase took 360 days to finish, leading to almost 150 days delay from the actual schedule of the project. Even with superlative effort invested to maintain the schedule on track after the delayed caused by demolition and excavation phase, there are other obstacles that were encountered due to site congestion, unskilled work force, lack of coordination between workers and delay in transportation of materials as per the schedule. These obstacles have a huge impact on the schedule since they crunch the flow of other trades along with the current phase.

Most of the site congestion is occurred during the superstructure phase due to the amount of material and work force required to finish the superstructure tasks. The materials used for reinforcement, formwork and concrete pouring occupies a lot of space leading to site congestion along with debris lying around on site making a negative impact on work. This also creates a crunch in the flow of other trades along with the superstructure phase.

Figure 3.1 & 3.2: Debris lying around on site

The total duration consumed for the superstructure phase is 157 days. This phase falls on the critical path and there are high chances of further delay due to the obstacles mentioned above.

Since the superstructure phase is a very critical phase of the construction process ,it is very important to see alternative approaches to avoid further delays as Ambience Construction firm cannot afford anymore delay in handing over the project to the client. For schedule reduction/acceleration an alternative approach needs to be analyzed for the project's schedule and increase the productivity.

BACKGROUND RESEARCH

SIPS known as Short Interval Production Schedule is specifically used for projects that consists of repetitive layout like hotels, apartments, schools and offices. This schedule is developed to portray day-to-day production for repetitive layout in a magnified appearance. SIPS involves higher level of details for the schedule to understand the breakdown of tasks in a easier manner and enhance the efficiency of workflow. SIPS demands personal commitment and involvement in a way the workforce is committed to ensure the schedule is executed as planned and maintain high level coordination. Some of the projects the implemented SIPS are bukharat and pentagon renovation project which consisted of repetitive layouts.

Some of the common concerns in construction is the delay due to various reasons mentioned above and goes over budget due to poor scheduling, workforce and ineffective coordination. For such problems, SIPS would be effective if the project has repetitive layout and implemented on the tasks involved in the critical path and consuming a major part of time and giving other issues such as site congestion and inconvenience for the workflow of other trades.

SOLUTION

This analysis will be focusing on implementing Short Interval production schedule to the superstructure phase which is the most important phase of the project since all the activities involved fall under critical path. Implementation of SIPS will ensure schedule acceleration/reduction and enhanced coordination between workers to finish the tasks on time smoothly. The first step of the analysis is to determine the sequence of activities. As mentioned earlier, the SIPS is utilized for project with repetitive layout and based on the current schedule of the project, each floor is divided into 3 sections with equal work based on the floor layout. Time required for each section to finish the tasks is the next step to be determined.

The simplest method is to divide each floor into segments. As mentioned above, each floor is divided into 3 segments/sections. 2 sections are comprised with apartments and 1 section comprising corridor. This forms a typical sandwich structure. The division of the floor can be seen in *figure 3.3*

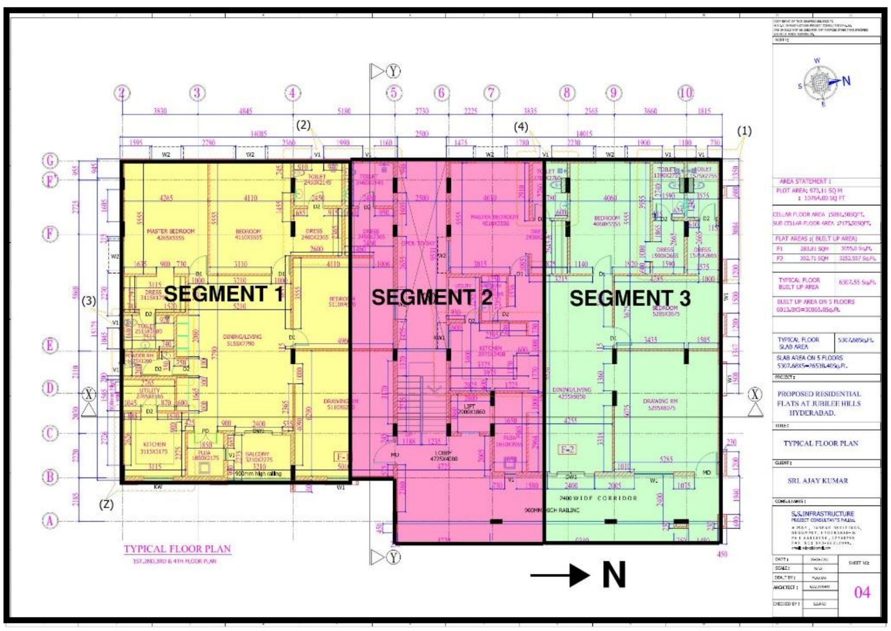


Figure 3.3: Division of a typical floor into segments

After the floors have been broken down into subsections/segments, workflow needs to be determined. The segments are divided vertically and the workflow will start from south to north as seen in the plan above. Since there is a lot of materials flow from north side of the building, it is a good option to start from south side, from bottom to top. This could not be the shortest path for the flow of materials, since the north side of the building is closer to access the materials and equipment.

The next critical step is recognizing the work involved in the superstructure phase. There are 4 major activities involved in the current schedule and carried to SIPS in the same order. They are mentioned orderly below:

- Reinforcement
- Formwork
- Concrete Pouring
- Stripping

Figure 3.4 below shows the breakdown of the floor into segments with equal area and equal amount of work distributed between the 3 segments. The figure also shows the workflow and sequence of activities from one segment to another.

Followed by the sequence of activities, production rate is to be determined. This is analyzed using the current project information since is it difficult to calculate these production rates with a specific formula as it varies by each project and location. Production rates were calculated based on the input from project team about the work hours per floor. The obtained quantity has been divided into 3 segments for each segment of the floor. Based on the production rate, manpower has been estimated assuming 8 hours of work per day with 5 working days in a week. *Table 3.1* shows the SIPS duration calculations

Lower level

Segment 1: Empty **Segment 2:** Empty **Segment 3:** Empty

Lower level

Segment 1: Reinforcement **Segment 2:** Empty **Segment 3:** Empty

Lower level

Segment 1: Formwork **Segment 2:** Reinforcement **Segment 3:** Empty

Lower level

Segment 1: Concrete Pouring **Segment 2:**Formwork **Segment 3:** Reinforcement

Lower level

Segment 1: Stripping **Segment 2:**Concrete pouring **Segment 3:** Formwork

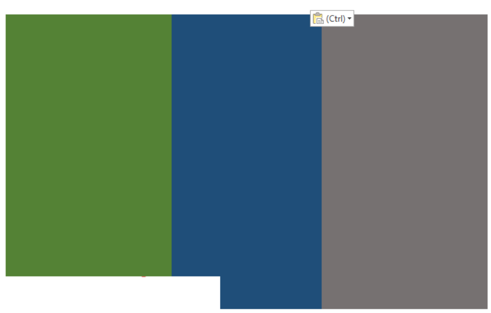
Upper level

Segment 1: Reinforcement **Segment 2:** Empty **Segment 3:** Empty

Lower level

Segment 1: Formwork **Segment 2:** Reinforcement **Segment 3:** Empty

Lower level



Segment 1: Completed **Segment 2:**Stripping **Segment 3:** Concrete pouring

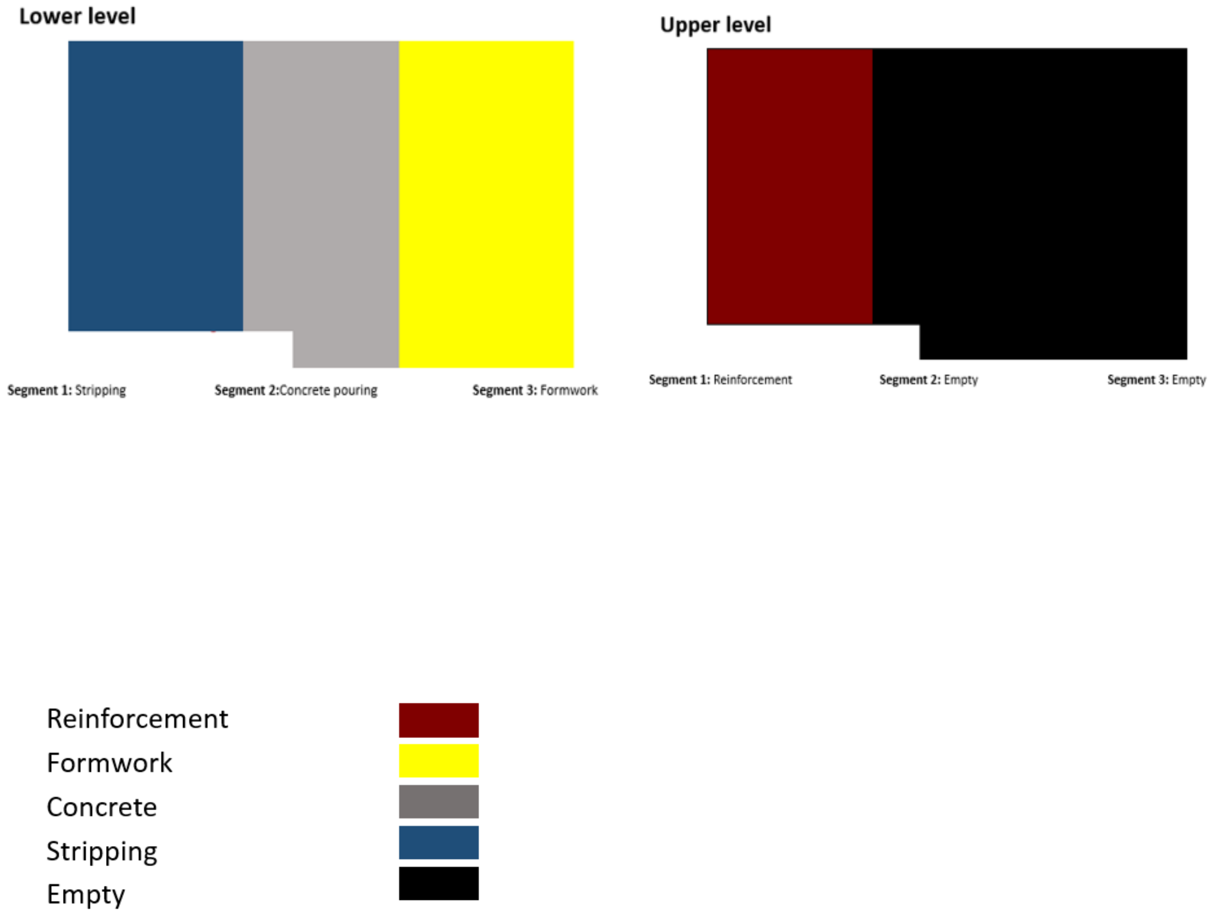


Figure 3.3: Demonstrates workflow through segments and workflow from lower level floor to upper level floor

PRODUCTION RATES FOR SIPS										
Activity	Floor Type	No. of Floors	Actual Duration (Days/Floor)	Total Duration (Days)	Average Manpower	Total Manpower	Total Production (Work Hours)	SIPS Production (Wk Hrs./Section)	SIPS Duration (Days/Section)	SIPS Manpower
Reinforcement	Residential	5	8	40	10	50	16000	3094	4	16
	Parking	2	8	16	10	20	2560			
	Average						**9280**			
Formwork	Residential	5	9	45	15	75	27000	5220	4	24
	Parking	2	9	18	15	30	4320			
	Average						**15660**			
Concrete	Residential	5	10	50	5	25	10000	1934	4	10
	Parking	2	10	20	5	10	1600			
	Average						**5800**			
Stripping	Residential	5	1	5	5	25	1000	194	4	6
	Parking	2	1	2	5	10	160			
	Average						**580**			

Table 3.1: Calculations of SIPS durations for superstructure phase

The final step for SIPS is to produce a matrix schedule to the project team to execute during the superstructure phase. The matrix schedule can be a very productive tool for the project to check the progress of the schedule and helps to manage the schedule in an enhanced form. This would bring a positive impact on a large scale for overall project's schedule since it would helpful for an effective workflow for other trades also. The figure below is a snip of the matrix schedule which shows the workflow of the entire superstructure phase moving from one floor to another floor as per the segment. As seen below, the schedule is divided by 4 activities and division of work between columns as one part, beams and slabs as the another part of the sequence since, only after finishing columns, the slabs can be raised. This matrix schedule is created based on the durations calculations and a snip of it can be seen figure *3.4.* The entire matrix schedule is attached in **Appendix-F**.

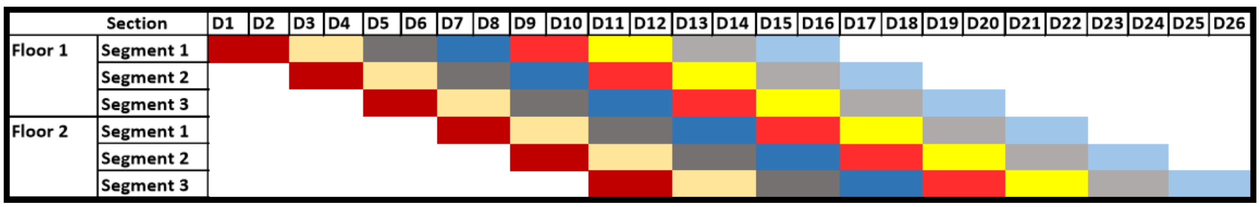
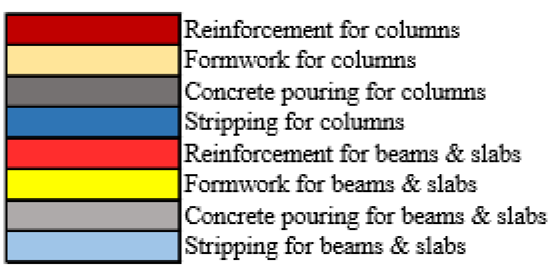


Figure 3.4: Matrix schedule snip

Key:



BREAKDOWN OF TRADES

Based on the information acquired, it is seen that formwork consumes more manpower and time due to the kind of work it takes to form molds for concrete pouring. As a result, formwork activity has been picked for in-depth SIPS analysis and this will help to apprehend an enhanced understanding and manageable plan of the movement of workforce through each segment. To obtain appropriate and effective results, segment 1 in *figure 3.5* has been chosen to perform this analysis.

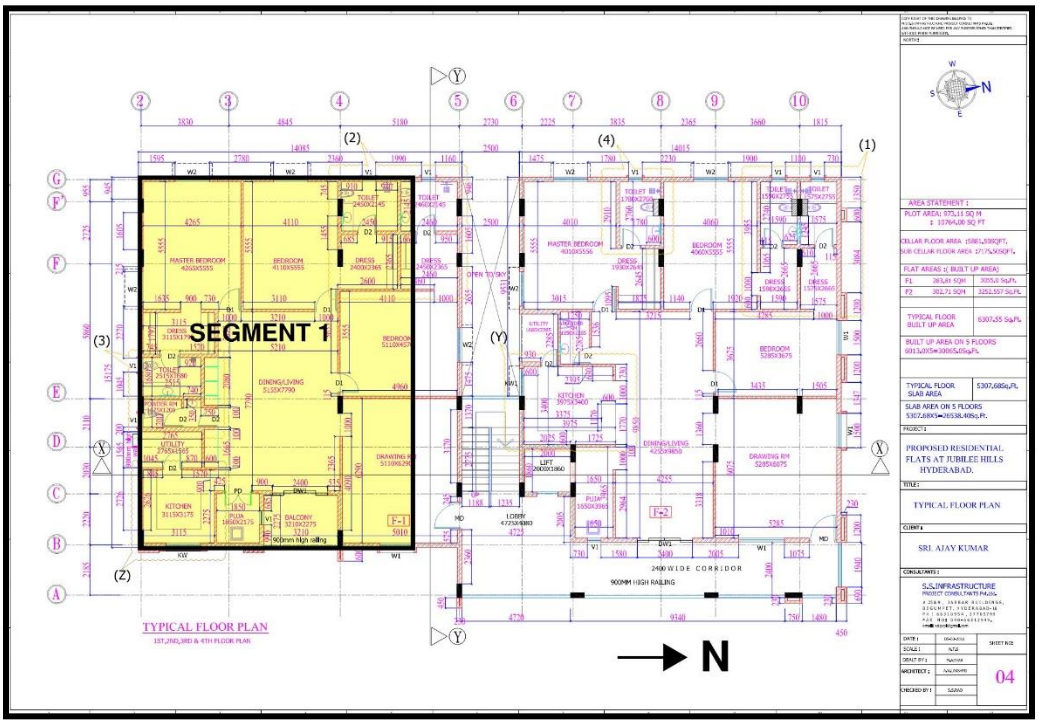


Figure 3.5: Segment 1 for detailed analysis

The next step is to analyze the sequence of activities and determine production rates. The sequence of activities is based on sequence followed for this project as mentioned below:

- Reinforcement of columns
- Formwork of columns
- Concrete pouring of columns
- Stripping of columns
- Reinforcement of beams and slabs

- Formwork of slabs and beams
- Concrete pouring for slab and beams
- Stripping for slabs

The sequence mentioned above is a mirror image of what was done on this project along with some research about steel shuttering and plywood formwork. The production rates were determined by the input from the project team and RS Means 2017. The following data is shown in *table 3.2.*

Production Rates for Formwork						
Section	RS means code	Type	Unit	Crew	Daily Output in 8 hrs	Labor Hours
Columns	03 11 13.25 6100	Columns (16"x16", 3 use)	SFCA	C-1	700	0.139
	03 11 13.25 6600	Columns (24"x24", 3 use)	SFCA	C-1	540	0.139
	03 11 13.25 7100	Columns (36"x36", 3 use)	SFCA	C-1	900	0.131
Beams	03 11 13.20 0600	Beams (12"x12", 3 use)	SFCA	C-2	900	0.163
Slabs	03 11 13.35 2100	Flat slab (3 use)	SF	C-2	1500	0.9

Table 3.2: Production rates calculation

A detailed quantity take off has been performed to calculate the quantities of each element required/involved in the superstructure phase. These calculations are used to determine the durations with the estimated production rates. In the *table 3.3* the take-off quantities and provided. As you can see, the take offs are calculated for formwork.

Quantity take-offs for formwork								
Section	RS means code	Type	Unit	Quantity	Men/Crew	Crew	Daily Output in 8 hrs	Labor Hours
Columns	03 11 13.25 6100	Columns (16"x16", 3 use)	SFCA	910	2	C-1	700	0.139
	03 11 13.25 6600	Columns (24"x24", 3 use)	SFCA	315	2	C-1	540	0.139
	03 11 13.25 7100	Columns (36"x36", 3 use)	SFCA	369	2	C-1	900	0.131
Beams	03 11 13.20 0600	Beams (12"x12", 3 use)	SFCA	2080	2	C-2	900	0.163
Slabs	03 11 13.35 2100	Flat slab (3 use)	SF	8040	4	C-2	1500	0.9

Table 3.3: Depicts the takeoff quantity calculations for segment 1 based on assumptions mentioned in the next page

Assumptions:

- The type of beams, columns and slabs have been extracted from RS Means 2017. Most of them are same type or the closest type have been selected for take-off quantities.

- The number of use of formwork have been extracted based on the input given by the project team based on what was done on the project.

- Some of the daily outputs and crew numbers had to be envisioned due to the difference in quantity takeoffs compared to RS means and the actually daily output of the project based on the information given by the project team.

After determining the production rates and quantities for each element, total duration and manpower are determined for formwork of segment 1 shown in *table 3.4.*

Durations for formwork											
Section	RS means code	Type	Unit	Quantity	Men/Crew	Crew	Daily Output	Crew	Total Manpower	Hourly Production	Duration(hours)
Columns	03 11 13.25 6100	Columns (16"x16", 3 use)	SFCA	910	2	C-1	700	1	4	87.5	6
	03 11 13.25 6600	Columns (24"x24", 3 use)	SFCA	315	2	C-1	540	1	4	67.5	2
	03 11 13.25 7100	Columns (36"x36", 3 use)	SFCA	369	2	C-1	900	1	4	112.5	3
Beams	03 11 13.20 0600	Beams (12"x12", 3 use)	SFCA	2080	2	C-2	900	2	4	112.5	6
Slabs	03 11 13.35 2100	Flat slab (3 use)	SF	8040	4	C-2	1500	2	8	187.5	13

Table 3.4: Durations for formwork

Below, in *figure 3.6* detailed breakdown of activities that takes place for the formwork of columns is shown. The schedule is broken down with a 20 minutes interval each and shows the workflow of the crew. The columns formwork process has 7 tasks typically as seen on site. Based on the site visit, it has been observed that the rebar cage consumes more time with 2 to 3 workers usually performing the task. This type of schedule demands workers who are multi-skilled since they would be shifted to work on another task after once the previous task is finished and the succeeding task could be different from the preceding one to keep the schedule on track. The formwork for each column consists of 7 activities which include area preparation, transportation of the rebar, setting the layout to set the rebar cage followed by setting the formwork and pinning them together. The final step is setting the braces for the formwork to be held in right position.

	Mangified workflow of column formwork in 20 minutes interval																											
Area	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Column 1	1	2	2	3	3	3	2	2	2	2	2	2																
Column 2		1	2	2	3	3	3	2	2	2	2	2	2															
Column 3			1	2	2	3	3	3	2	2	2	2	2	2														
Column 4				1	2	2	3	3	3	2	2	2	2	2	2													
Column 5					1	2	2	3	3	3	2	2	2	2	2	2												
Column 6						1	2	2	3	3	3	2	2	2	2	2	2											
Column 7							1	2	2	3	3	3	2	2	2	2	2	2										
Column 8								1	2	2	3	3	3	2	2	2	2	2	2									
Column 9									1	2	2	3	3	3	2	2	2	2	2	2								
Column 10										1	2	2	3	3	3	2	2	2	2	2	2							
Column 11											1	2	2	3	3	3	2	2	2	2	2	2						
Column 12												1	2	2	3	3	3	2	2	2	2	2	2					
Column 13													1	2	2	3	3	3	2	2	2	2	2	2				
Column 14														1	2	2	3	3	3	2	2	2	2	2	2			
Column 15															1	2	2	3	3	3	2	2	2	2	2	2		
Column 16																1	2	2	3	3	3	2	2	2	2	2	2	
Column 17																	1	2	2	3	3	3	2	2	2	2	2	2
Manpower	1	3	5	8	11	14	16	18	20	22	24	26	26	26	26	26	26	25	23	21	18	15	12	10	8	6	4	2

Figure 3.6: Magnified workflow for column formwork

Key:

	1	Area Preparation
	2	Transportation
	2	Layout
3	3	Set Rebar
2	2	Set column forms
2	2	Pin forms together
2	2	Set braces

MANPOWER

There is a significance difference between the manpower acquired for SIPS and actual project schedule. This can be seen in the curve that was plotted. The Manpower has been increased compared to the Actual manpower for the superstructure phase due to the intense workflow planned with a 20 minutes of interval. Every activity from reinforcement to formwork has a decreasing order of manpower. You can see the difference in manpower required for the actual schedule versus SIPS in *figure 3.7*.

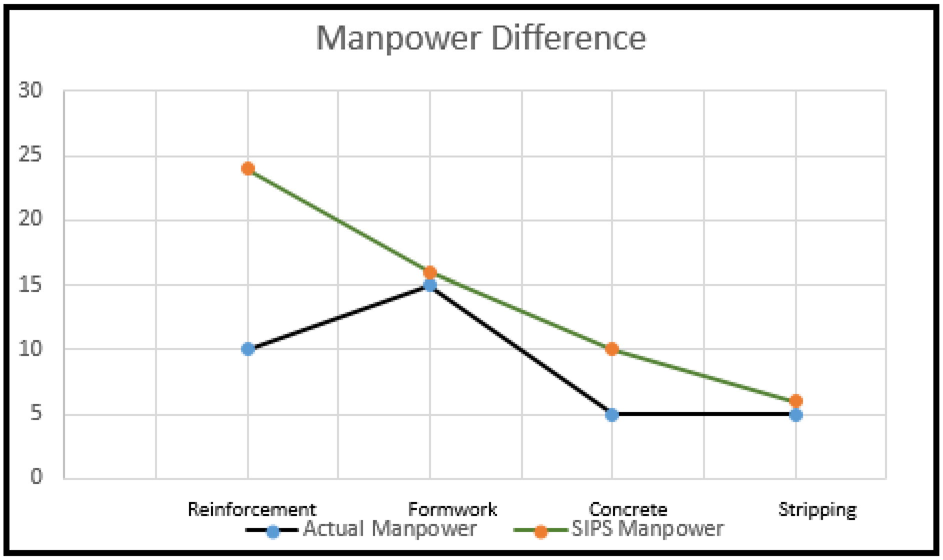


Figure 3.7: Manpower comparison

OUTCOME

Implementation of SIPS for this project has reduced the schedule of superstructure phase by 64%. The project team will have to face the delays due to the workforce and delay in receiving materials on time at the site. By implementing SIPS, the project team will have a predictable and scheduled plan to finish the superstructure phase since the progress of each day can be tracked. SIPS will also make the work flow smoother, faster and easier to check the coordination between the workers and what each worker is working upon instead of letting the workers wasting time during work hours. An another added advantage is saving costs in general estimate and hiring workers for less number of days to work.

Planned time for superstructure -100 days

Actual time taken for superstructure- 157 days

After implementation of SIPS for superstructure - 56 days

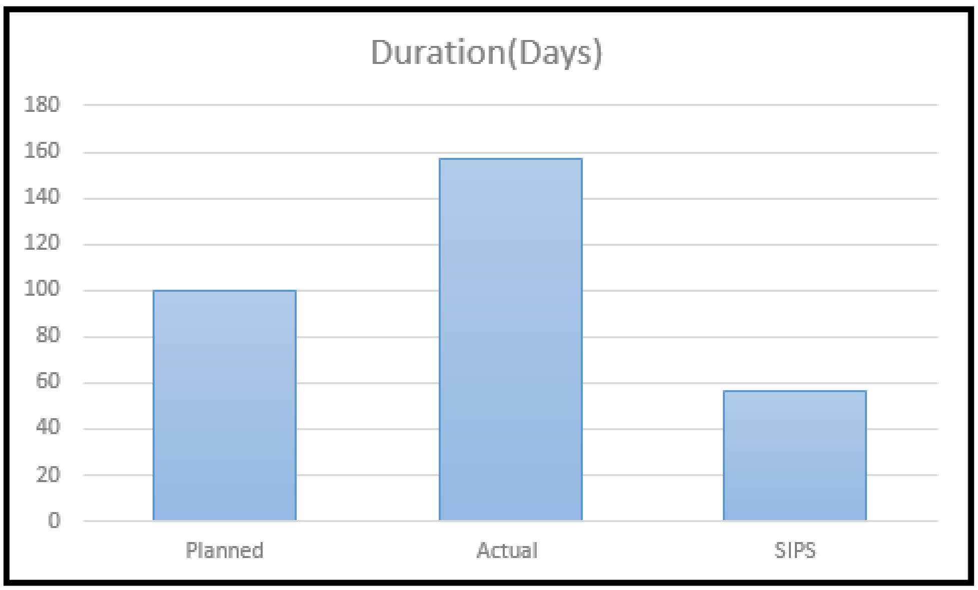


Figure 3.8: Shows the difference in schedule after implementing SIPS

CONCLUSION

Schedule acceleration/reduction has been a major aspect for Hanza crest apartments and the analysis of SIPS has shown a potential scope of reduction in schedule which would leave the project team save humongous amount of time and money with a better quality of work due to enhanced coordination and understanding the planned workflow.

The conclusion states SIPS has high-caliber to give better outcomes in terms of schedule compared to the Gantt chart for this project. After implementation of SIPS, the schedule of superstructure phase has been reduced by 101 days leading to saving money and time on a very high scale.

As mentioned above SIPS will help to have a smooth workflow and the progress of each day can be tracked which would help to plan in a better manner if a delay or change is occurred due to workforce, materials transportation or other external reasons. The only issue with SIPS is it consumes a lot of manpower compared to the actual workforce on site**.** So the project team will have intense work to maintain a smooth coordination between the workers.

ANALYSIS 4: BIM FOR SAFETY

PROBLEM IDENTIFICATION

Safety is one of the biggest concerns in the construction industry. It is faced worldwide and India has been facing number of issues due to lack of site safety. Workers do not do not follow the rules and ethics for safety purposes. One of major reasons is due to being untrained and not enough exposure of safe work zones. There has not been enough and very effective steps taken to train and educate the workers about the importance of safety and the consequences for not understanding the potential risks involved. This projects has a site superintendent but he can manage the safety of the site and workers to a bare minimum. This is due to the time involving to make the untrained and uneducated workforce understand safety importance.

Since the workers are not educated enough to follow safety on site, it is the responsibility of the construction firms to enhance the safety on site with better guidelines and rules applied to the workers. In India, construction industry acquires a "labor force of 7.5% of the total world labor force"[1]. But it also contributes to 16.4% of total world occupational accidents. The common accidents in India are similar to the ones in USA as mentioned by Occupational safety & Health administration such as falls (36%), struck by objects(10%) , electrocutions(10%) and caught in-between (2%).

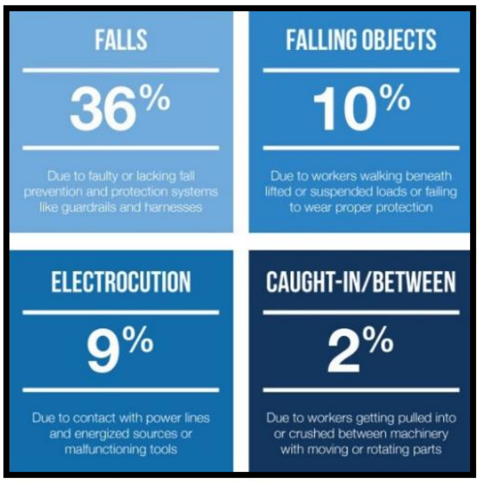


Figure 4.1: Fatal four accidents in construction

There are violations occurred by multiple workers at the same time and such circumstances is difficult to handle on site. Some of the instances occurred in site are workers without shoes while nails, debris and sharp equipment lying on the site. The hard hats are not worn and high chance of free fall while erecting columns at 22 feet high due to not being tied back. This kind of practice of not following safety rules needs to be discouraged. Everyone on site is responsible for their own safety and make a safe-working site.

A better approach should be considered for enhancing the safety and educate the workers in a way they can grasp the important information required to maintain safety on site and for their personal protection since a huge amount of money is consumed for the owner to cover a worker's medical expenses if injured.

1. https://www.hindawi.com/journals/tswj/2015/590810/
2. http://work.chron.com/safety-precautions-scaffoldings-11101.html
3. https://www.tfharper.com/4-safety-tips-every-construction-worker-know
4. https://www.osha.gov/Publications/construction_ppe.html

CURRENT SAFETY METHODS FOR THIS PROJECT

Apart from the superintendent inspecting rarely regarding safety concerns as mentioned above, there are no big steps taken to ensure there is a safe working environment. Though there has been efforts taken to communicate with the workers verbally to give instructions about mandatory and job specified PPE's and basic guidelines while performing tasks such as working carefully with heavy equipment and materials, that did not seem effective enough for the uneducated workforce to understand specific precautions to be taken for tasks prone to be more risky. For instance, it is important for a worker to understand the guidelines of fall protection safety equipment such as "safety harness or a belt attached to a stable structure" versus a worker who is working on carpentry , who is prone to less accidents and mostly falls under personal safety protection.

Most of the workers working with scaffolding are not aware of the extra precaution of using safety harness and instead work without hard hat sometimes due to the lack of knowledge about consequences for not following safety rules. These problems lead to accidents and injuries. There is only one visual about personal protective equipment (PPE) on site which shows a worker must wear hard hats, shoes, located in the office room which of mostly no use since the workers are mostly on-site and cannot understand well what the picture is trying to communicate them as per the workers interviewed on site.

Figure 4.3: Picture of PPE used on site

It is very evident that the workers are not educated enough and this indicated that the methods used to train them for safety purpose are not any effect to enhance the safety. Giving only basic knowledge will not be helpful to have zero accidents prone site. The guidelines and methods to educate the workers should be more specific and research for better means to communicate the safety knowledge is very critical.

RESEARCH AND ANALYSIS

The highest percentage of fatal falls and injuries can be seen in *figure 4.2*.According to Capterra construction management, the highest injury rates is in the ironwork job. Ironwork falls under superstructure which includes work like erecting the steel structure of a building based on the plans. According to the Perceman firm, the ten most common causes of accidents are scaffolding, ladders, stairways, trenching, cranes, chemicals, forklifts, failure to use personal protective equipment and repetitive motion injuries which are very common in construction industry in India with a higher chance of serious injuries due to bare minimum safety precautions.

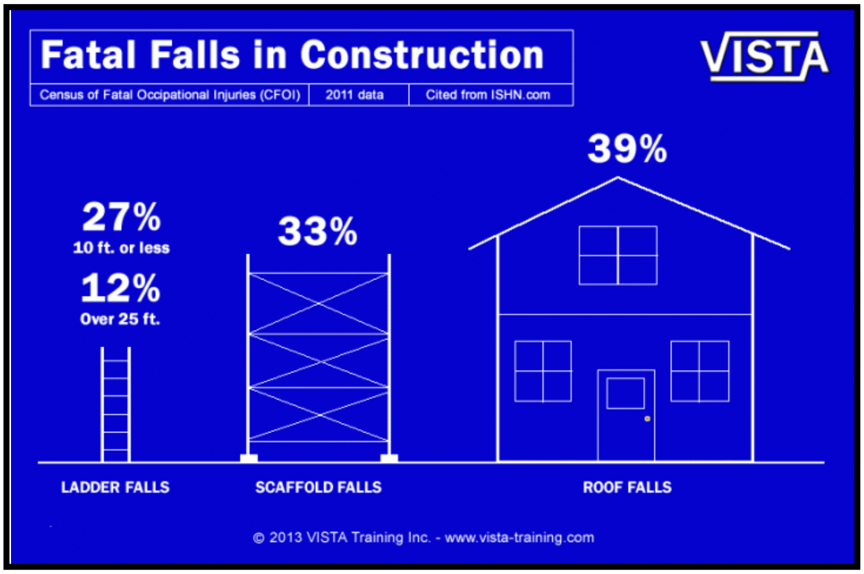


Figure 4.2: Most common fatal falls during construction

As mention earlier, Scaffolding is also another major cause for injuries in workplace, which i**s** typically used for superstructure phase for the workers and materials to aid in the construction during formwork and erection of the steel structure. The placement of the scaffolding and ensuring the weight placed on its base jack/ floor does not overboard its capacity which would lead to fall and major injuries. Similar injuries can occur while using a hoist. After talking to the project team and visits on site, It has been found that a lot of debris have been lying around on site due to the formwork and rebar used for structural erection creating unsafe environment for workers to walk around and do the tasks and also leading to site congestion. Workers working at slab edges without any guard rails or safety nets is another problem seen during superstructure phase leading to a higher risk of fall accidents.

Safety is one of important aspects that construction firms strive to keep a clean record of zero injuries/accidents on a construction site. As mentioned time and again, every construction firm strives to reach the zero accidents site zone and have a safe working environment. The Occupational Safety & Health Administration (OSHA) is held responsible for the safety of many fields including construction. They have specific rules and guidelines for different activities performed on site and methods to operate the equipment safely. Having a safe working zone on site not only ensures the workers of safety but also shows positive impacts in other sectors like schedule and budget of the project. It can also have negative impact if there are serious accidents or injuries occurred on site on a regular basis.

Based on the Smart Market report created by McGraw Hill Construction firm5, the contractors have been experiencing positive outcome due to adoption of safety programs. Additionally, this led to reduction in schedule and budget, with increased project quality. Based on statistics collected by surveying about the "impact of safety programs on project" [5]:

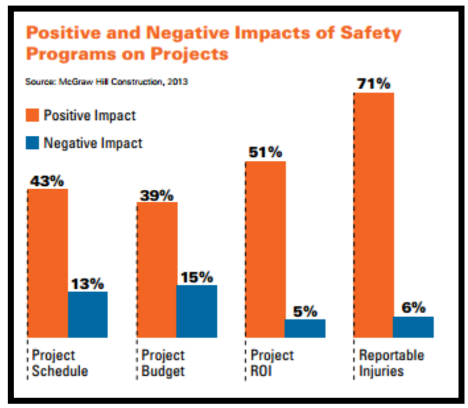


Figure 4.3: Impacts of safety on projects

- 50% report a decrease in project schedule by 1 week or more
- 73% report decrease of project budget by 1% or more, with 24% noting a decrease of greater than 5%
- 73% also report an increase in project ROI by 1% or more, with 20% reporting an increase of greater than 5%
- Improved Project quality by 66%

The survey statistics shows a clear indication of having more positive outcomes through safety programs not only reducing injuries but also on schedule and cost of the project as mentioned earlier.

Due to the low cost investment of implementing safety programs, this type of practice will be very beneficial for smaller firms yet, large firms are adopting such safety programs more than smaller firms. The Ambience Construction firm falls under the medium firms range *(*green color category*)*. It is very critical for Ambience Construction firm to implement safety programs in order to have a safer working environment with reduced schedule and budget. *Figure 4.4* shows the level of adoption of safety as per smart report market by McGraw hill. They conducted a survey in 2013 to show the approach towards safety practices by different ranges of construction firms.

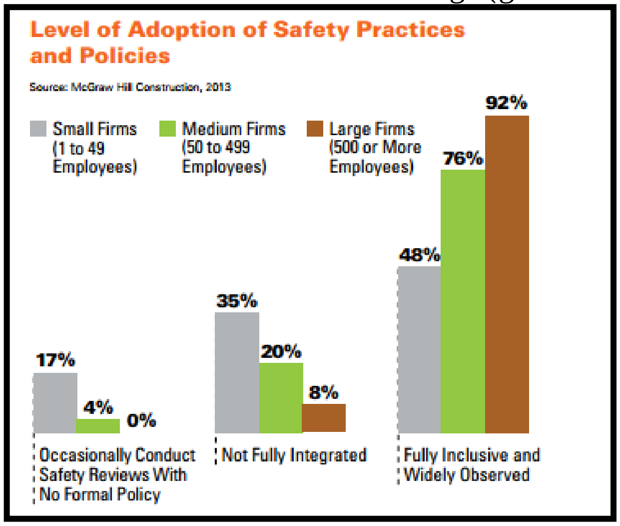


Figure 4.4: Adoption of safety in different firm sizes

Though there is satisfying results with implementing these safety programs, the construction firms average approximately 10 employees and also for better results, there is a need for enhanced methods to be follow for a safer working environment in a way, even smaller firms can adapt the methods without much cost. The top "three practices for a safer working zone as mentioned by MC Graw Hill are" [5]:

- Develop site-specific health and safety plan (HASP)
- Analyze potential site hazards in pre-construction phase
- Appoint/Assign/Authorize project safety personal

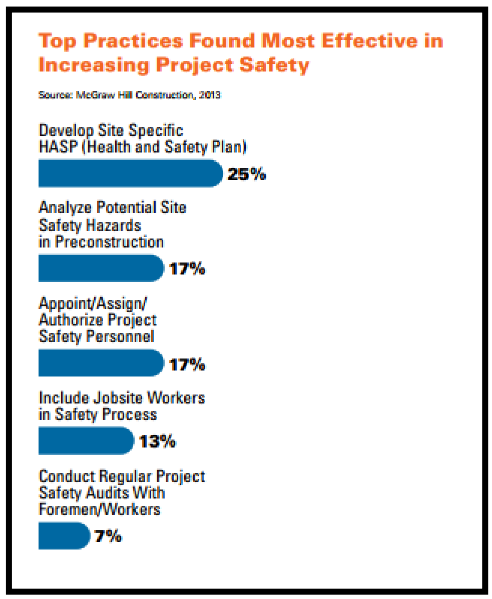


Figure 4.5: Top safety Practices

The online safety training and education is considered most impactful method for jobsite workers to educate them about safety, according to 82% firms who used this method. BIM would enhance the safety on site especially for workers who cannot understand and grasp the information verbally. Since most of the Indian workers are untrained and uneducated, it would be effective to communicate virtually rather verbally. Virtual communication would not require to understand any verbal communication and visual demonstration would be more effective than the superintendent instructing the workers about safety. Such visual communication is possible through Building information modeling (BIM) which a procedure of creating digital representations of project before, during and after construction.

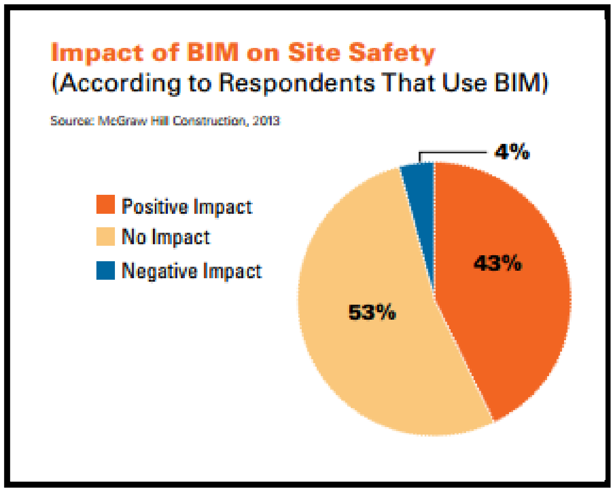
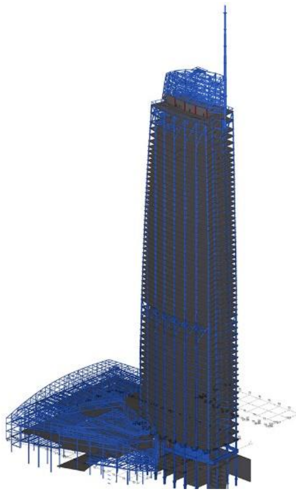


Figure 4.6: Statistics about the positive impacts of BIM on safety

BIM is utilized for various purposes in the construction industry. The creation of 2D into 3D models with data and information installed for the entire project team to share it. This leads to enhanced coordination, reduced errors on site and mostly importantly, enhanced safety on site through virtual demonstrations. According to Dodge data & analytics article, there are some terrific impacts of implementation of BIM on labor and material waste through incorporation of safety into planning.

The main concept is conducting safety planning with BIM though developing safety models and using BIM as tool for "automated safety logistics"[9] which helps to set rules to analyze the geometric connections in models in order to cover OSHA requirements for performing tasks and other local requirements. One of the most effective ways to prevent accidents is through pre-plan processing by inputting all the details into a 3D model. Realizing the impact of BIM, turner construction firm used BIM to preplan "the pour process and equipment sequencing for the Wilshire Grand hotel in Los angeles"[9].

During the construction of Wilshire Grand hotel, the RFI's and supplemental instructions were tracked in the 3D for better assessment and decision making process. This had helped in terms of safety, since this project is known for the "largest continuous mat slab pour"[9] which required intensive labor work and had reduced risks due to coordination through BIM.



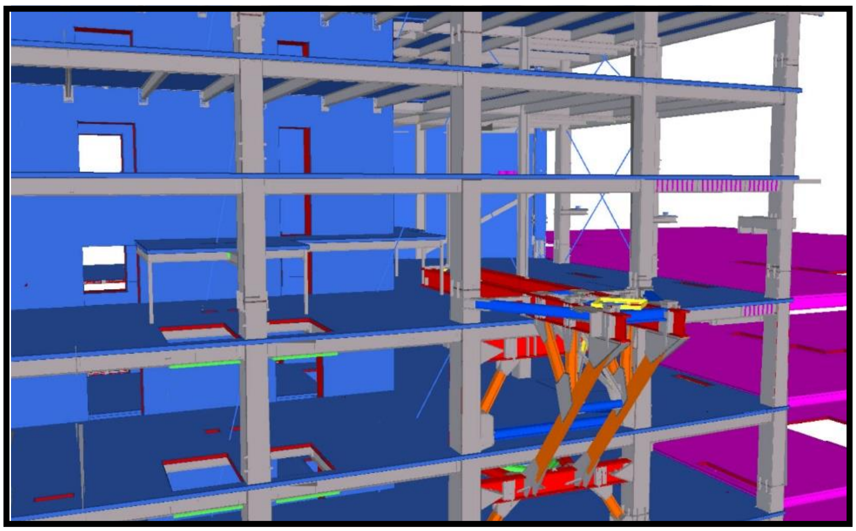


Figure 4.6 &4.7: BIM model of Wilshire Grand hotel

Another effective way of using BIM for safety is through visualization technology to enhance safety planning. An instance provided by Skanska is BIM will let you see the view behind the walls and this would help to "identify potential hazards and take action preventing accidents."[9] An advanced version of BIM is creating virtual reality games that would test the superintendent to identify potential hazards and educate the workers about the possible hazards. The virtual technology with BIM is the potential solution for Hanza Crest apartments project to enhance the safety by training the workers through visualization to make them understand better about the potential hazards they would come across in specific tasks.

In 2012, another project Turner construction received approval for BIM based site safety plans is the New York City department of buildings. This created an access of virtual tours of the project and review the 3D/BIM safety plans on site. This was one of the first projects to take initiative to enhance safety plans in this process. The BIM model showed the location of "site fencing, crane, hoists, perimeter protection, materials and other equipment"[11] and most importantly the virtual model and walkthroughs helped to identify the potential hazards involved before the construction started. These aspects led to requirement of less office visits and better coordination along with faster mobilization on site. All these aspects can be seen in *figure 4.8* which shows the approved BIM safety plan of NYCDOB.

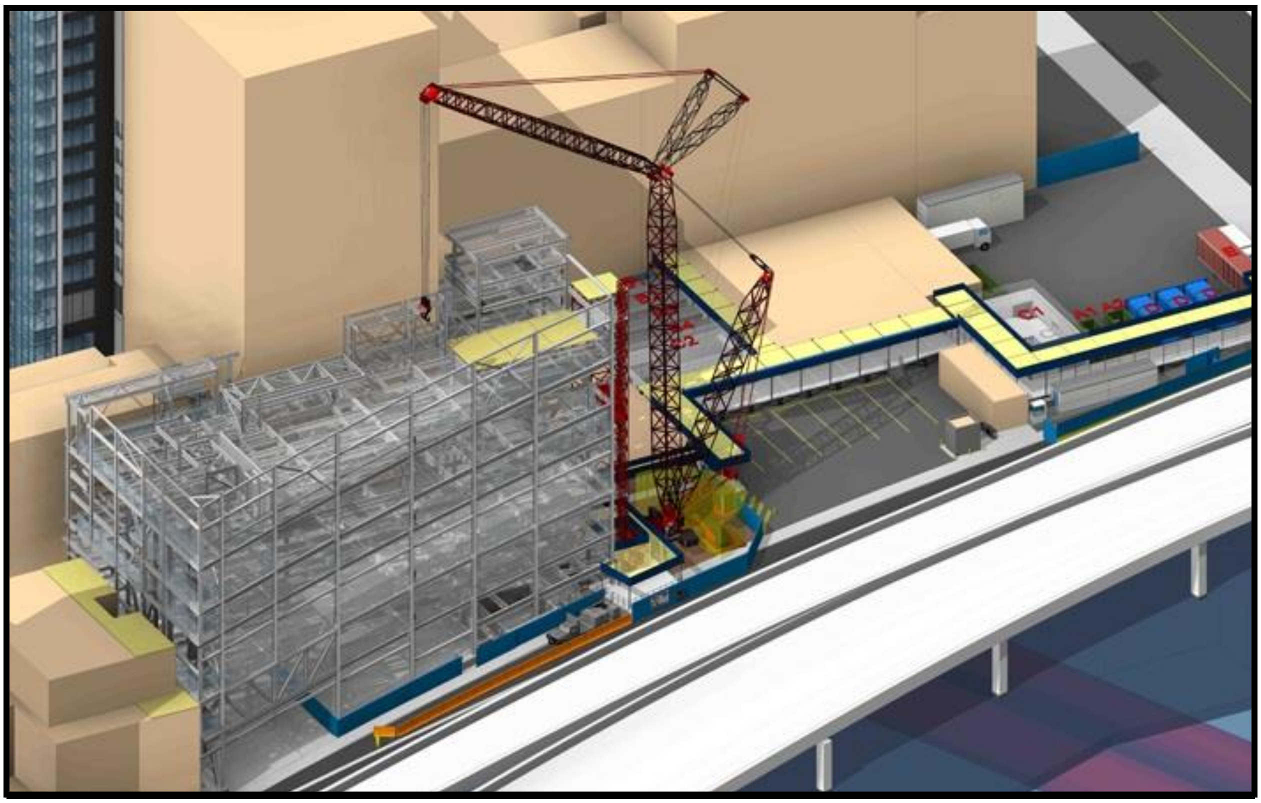


Figure 4.8: Approved BIM safety plan of NYCDOB

Based on the positive impacts mentioned above, this kind of BIM technology is very critical and required for the workers in India to get educated and understand the kind of risks involved in each phase to improvise safety. This would also help in decrease of project's schedule and budget as mentioned earlier. The Wilshire Grand hotel and NYCDOB projects had set an example that each and every construction firm irrespective of the type and size, would consider implementation of BIM for a better outcome in building a safer environment on site.

Some of the major benefits through BIM according to McGraw Hill construction firm are:

- Increased profits increased more than any other BIM benefit.
- Maintaining repeat business with past clients, which requires completed projects, outpaced marketing new business to new clients, a benefit that can be done right after adopting.
- The most engaged users enjoyed far larger increases in BIM benefits

As per the information gathered above through research and input from the project team, the superstructure phase has the most potential risks and injuries involved. So creating virtual tours for the superstructure phase for this project would be the potential scope to give a major positive impacts on site safety.

---

5. http://www.cpwr.com/sites/default/files/publications/SafetyManagementinConstructionSMR-2013_0.pdf6. 6. https://www.perecman.com/blog/2014/may/what-is-the-most-common-accident-in-construction/
7.http://www.cpwr.com/sites/default/files/publications/SafetyManagementinConstructionSMR-2013_0.pdf
8. https://www.healthandsafetyatwork.com/construction/bim-spells-safety-site
9.http://www.usa.skanska.com/Global/BIM%20New/Measuring-the-Impact-of-BIM-on-Complex-Buildings-2015f.pdf
10.https://www.tekla.com/bim-awards/wilshire-grand-hotel
11.http://www.turnerconstruction.com/news/item/2dc5/New-York-City-Department-of-Buildings-Approves-First-Three-Dimensional-BIM-Site-Safety-Plans
12.http://blog.capterra.com/the-top-3-safety-management-systems-for-construction/
13.https://www.perecman.com/blog/2014/may/what-is-the-most-common-accident-in-construction/

SOLUTION

This analysis will look at the process to implement building information modelling (BIM) for safety guidelines and information virtually to the workers who are performing tasks. As mentioned above, most of the accidents have occurred during the superstructure phase of the project, BIM will be utilized to create videos to train workers about safety on site including basic guidelines such as PPE and also focusing on specific tasks that involve the most potential risks. This new method is not meant to replace the old methods of following safety, but it will enhance the safety of the workers providing them and the entire project team a safer working zone though there are not many methods followed currently for safety purpose.

As mentioned time and again, one of the main problems after investigation is the workers not being educated enough to understand and identify the potential risks on site and the directions given verbally by site superintendent. Another problem identified is most of the workers can understand English only to a bare minimum level. So there is a huge language barrier since it is very hard for the site superintendent to guide and educate each and every worker about the safety rules to be followed in their respective languages.

Another important factor determined is the workers on site are mostly men on whom an entirely family depends on his income. So it is very critical for these workers to work safe and get back home safely. But there is least bit of concern about their safety since the workers recklessly work without taking any precautions. As seen in *figure 4.9*, the worker is standing at the edge of the site while holding rebars for column erection. There was a very high chance for him to fall down and he was neither wearing any personal protection equipment though that is the only safety guideline mentioned on site by superintendent and barely followed by the workers.

Figure 4.9: Workers without PPE at the edge

It is very important to prioritize these problems before facing any fatal accidents and educate and train the workers virtually with implementing BIM specifically representing Hanza Crest apartments virtually for a safe working site.

A simple layout of the building during superstructure phase has been developed to demonstrate some of the potential risks involved during this phase and possible precautions to be taken with OSHA guidelines. This can be given to the project team to see the impact of the sample visuals and apply BIM to show more details and demonstrate the safety precautions to be taken for general and specific tasks.

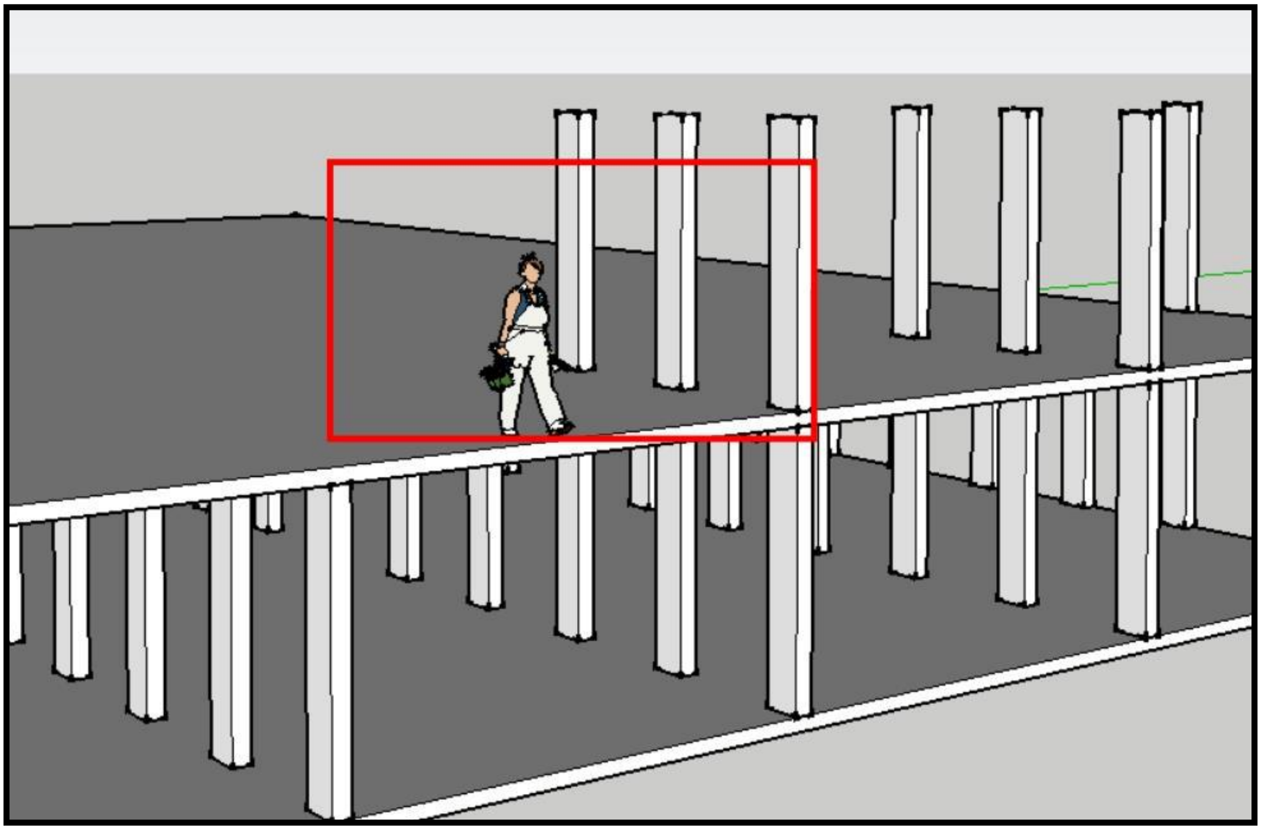


Figure 4.10: worker at edge of the slab

Figure 4.10 shows a worker at the edge of the slab. As seen, the worker does not have any PPE equipment and has a major risk of falling down and getting injured. This can be avoided if appropriate PPE equipment is worn as seen in *figure 4.11*. The worker on the left is taking appropriate precautions by wearing hard hats, gloves and shoes which would lead to less injuries if he falls while working. Demonstrating to have safety nets is also another safety precaution that could be demonstrated.

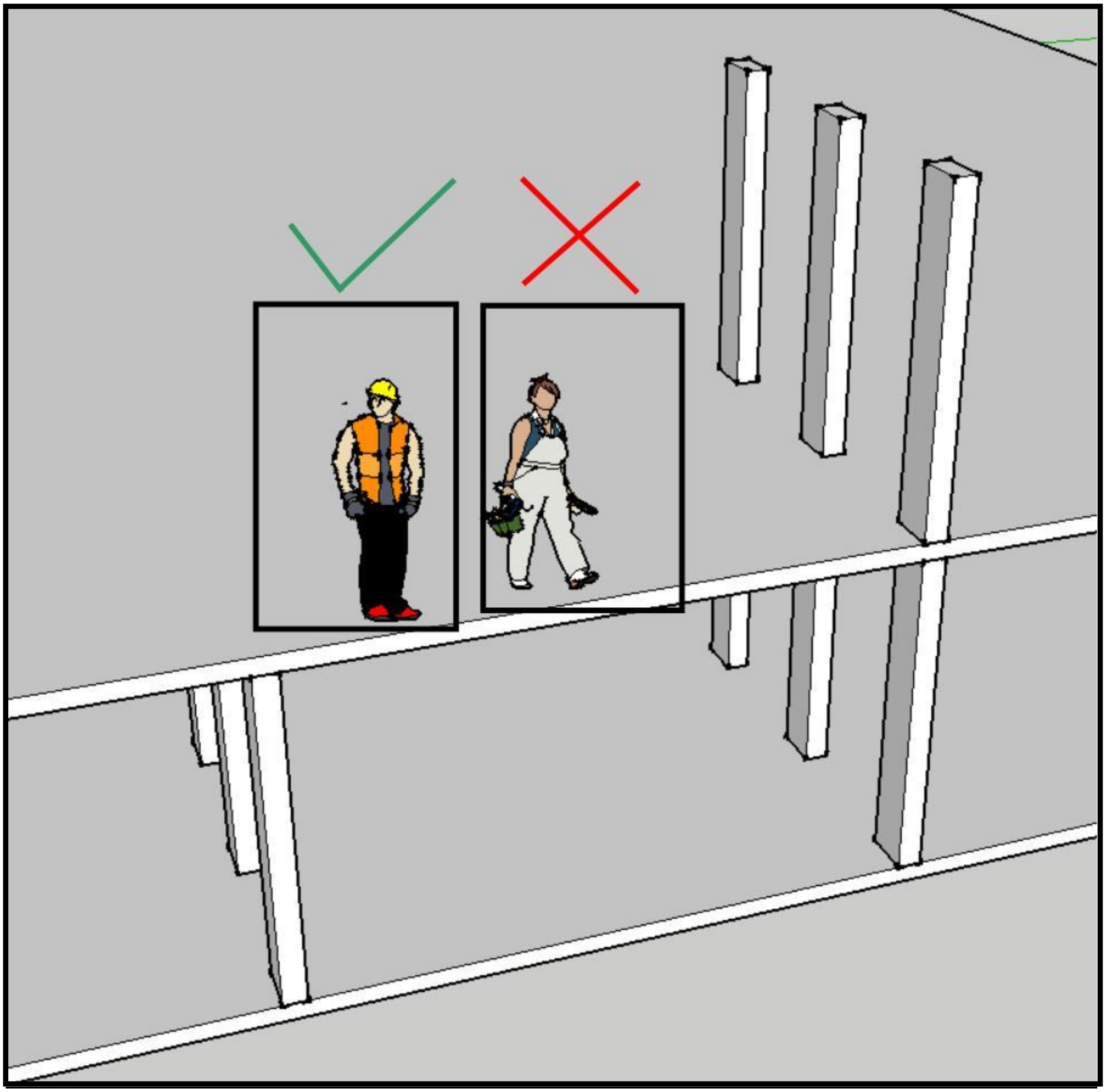


Figure 4.11: Shows the right way for worker to work at edge of the slab with PPE equipment

Another task chosen to show the potential risk is scaffolding. Since there is a 33% fatal falls during scaffolding, it is very important to maintain the weight on its base floor and not overload it which would lead to the flooring down. Another potential hazard while scaffolding is the fall. Apart from PPE, other equipment is required to be worn by the worker is to get tied back in case the worker slips or the floor breaks down and lack of guard rails leading to falls. *Figures 4.11-4.14* demonstrates the consequences for not following safety rules and some of the precautions to be taken during scaffolding.

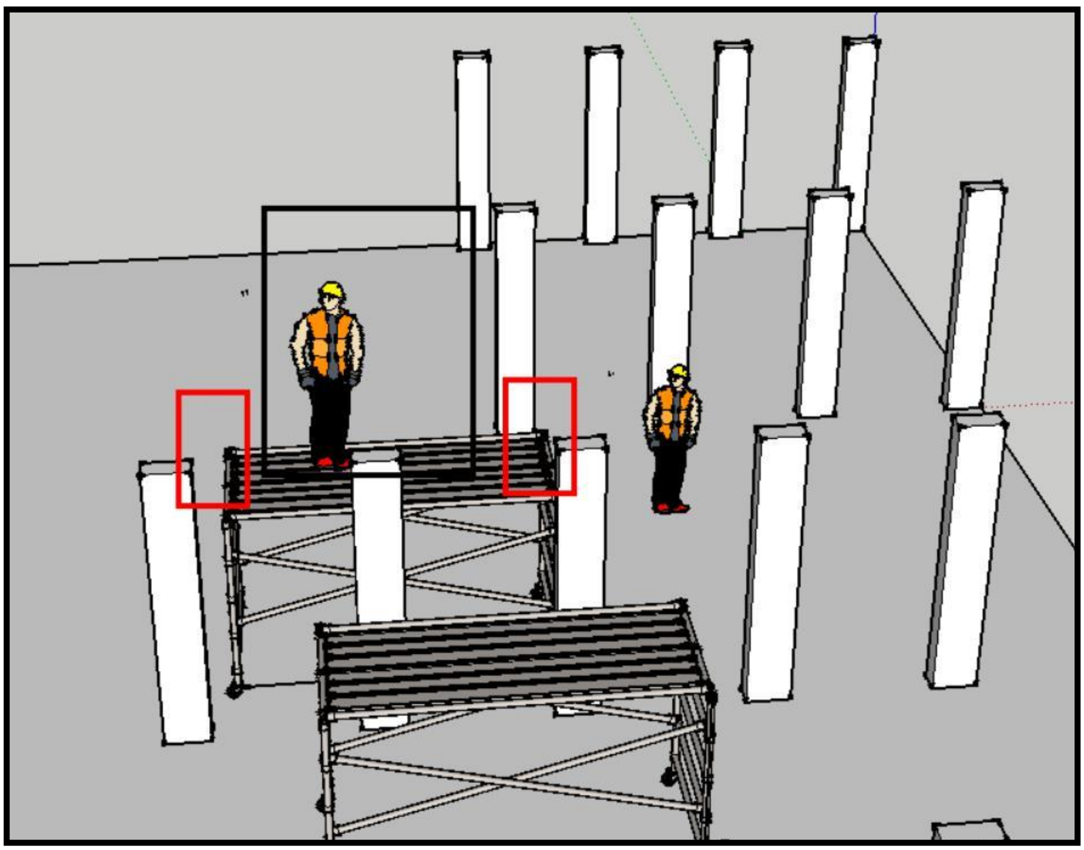


Figure 4.11: Shows the worker working without guardrails on the scaffold and also not tied back.

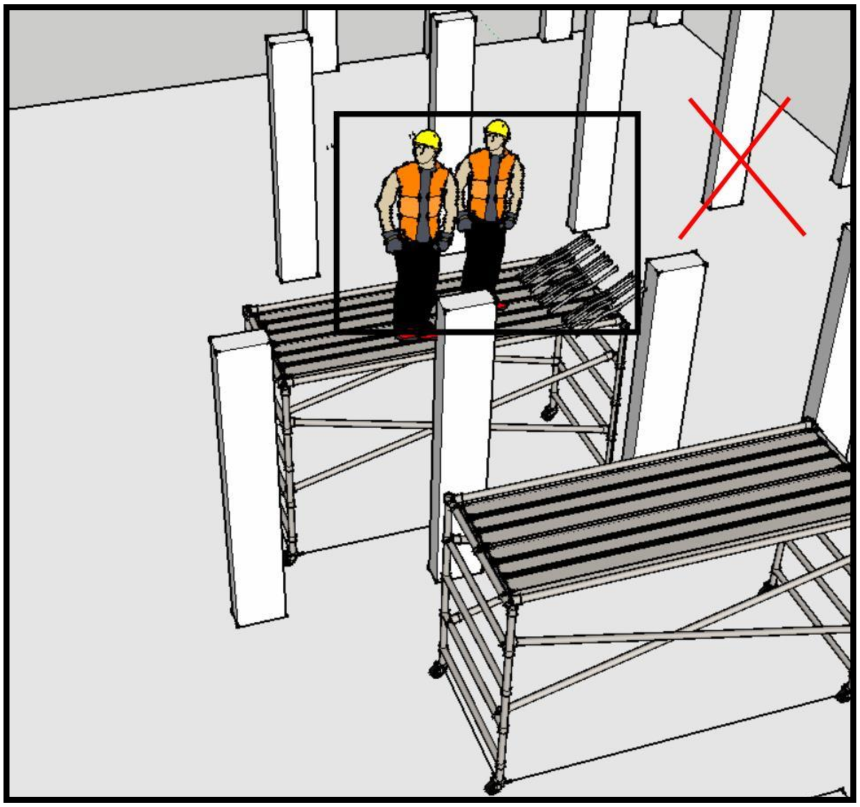


Figure 4.12: Shows two workers on the scaffold along with heavy equipment where the floor base is over loaded

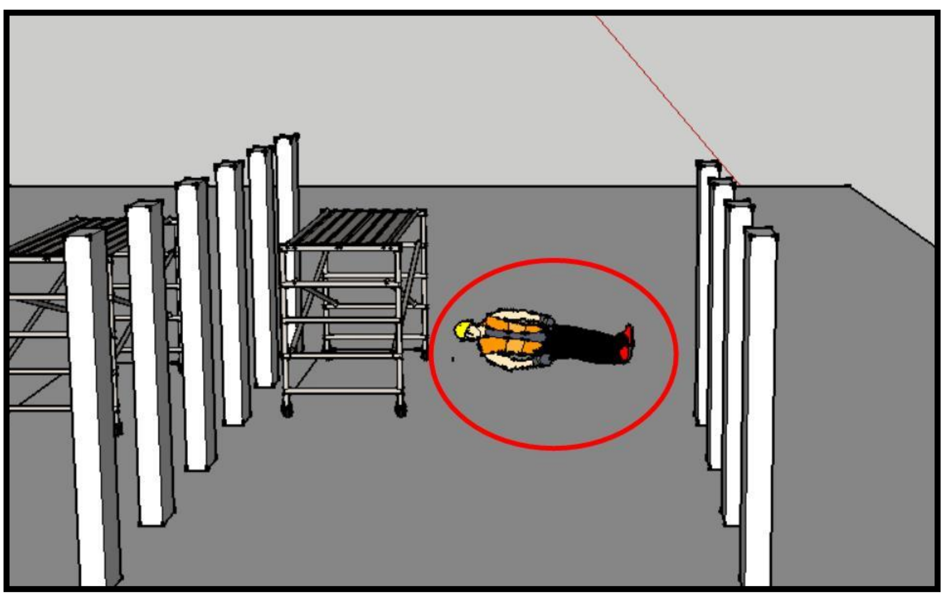


Figure 4.12: Shows the worker falling down due to lack of guard rails and not being tied back.

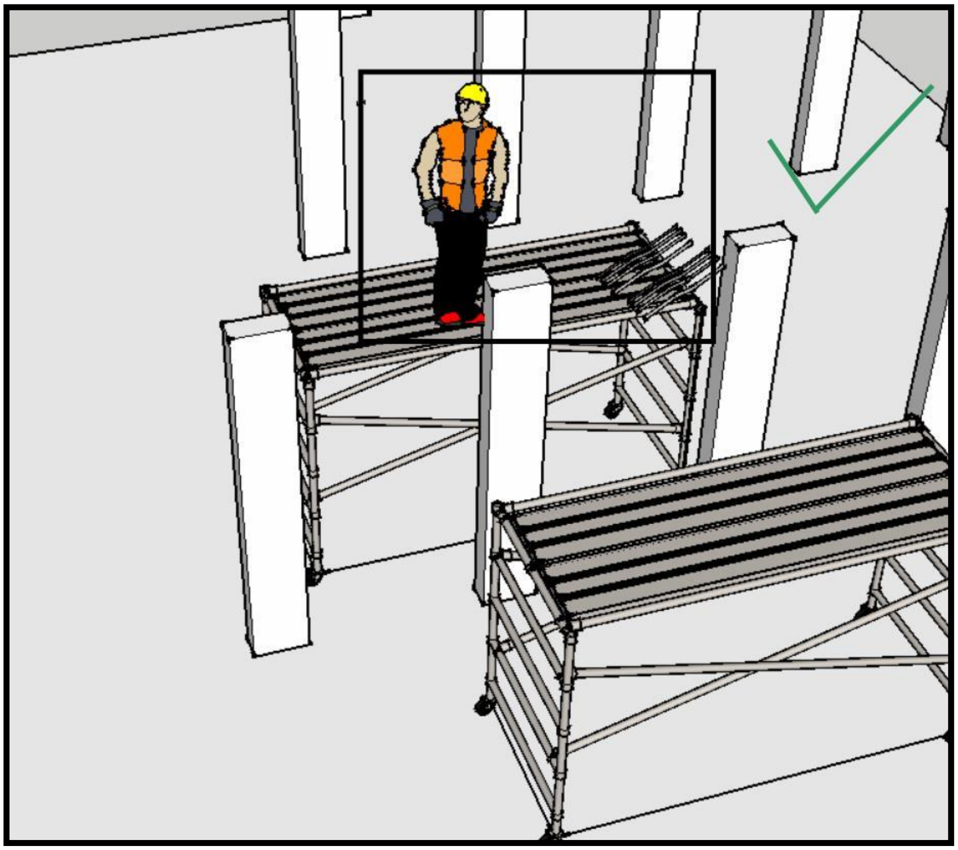


Figure 4.14: Shows the right way of working while scaffolding. Not have a lot of weight on the floor base

CONCLUSION

Along with new sustainability, engineering development for construction, new software for scheduling and budgets, safety is another critical aspect that needs to be prioritized in the construction industry by developing new methods and strategies to implement safety on site.

Based upon on the research, use of BIM for safety purpose would be an effective strategy since visual communication makes one understand a lot better than verbally. The current methods of having safety manual and verbal communication have not been much of an impact for the workforce nor a huge reduction in accident rates in construction. So continuing the use of BIM from pre-construction phase would be an effective strategy making a huge positive impact on safety.

For instance, personally I could not understand much about the safety manual instructions that is provided in the flights. But ever since they started to demonstrate through videos, the content has become easier to understand about the precautions to take while emergency landing or landing in water. This instance is just to show that, for any person visual communication would enhance the knowledge.

We all can understand the impact of current strategies on educating the workers especially workers who are uneducated and cannot understand verbally. So it is important to understand that BIM would abolish the language barrier of trying to communicate safety precautions, educate the workers by successfully communicating virtually.

APPENDIX-A

Metal Stud Catalogue

Product Submittal Sheet

ClarkDietrich BUILDING SYSTEMS

Tech Support: 888-437-3244
Engineering Services: 877-832-3206 | Sales: 800-543-7140
clarkdietrich.com

Product category: S300 (3" Flange Structural Stud)
Product name: **600S300-97 (50ksi, CP60) P - Punched**
97mils (12ga)

Coating: CP60 per ASTM C955
Color coding: Red

Geometric Properties

Web depth	6.000 in		
Flange width	3.000 in	Punchout width	1.50 in
Stiffening lip	0.625 in	Punchout length	4.00 in
Design thickness	0.1017 in	Min. steel thickness	0.0966 in
Yield strength, Fy	50 ksi	Fy with Cold-Work, Fya	50.0 ksi
Ultimate, Fu	65.0 ksi		

Gross Section Properties of Full Section, Strong Axis

Cross sectional area (A)	1.271 in^2
Member weight per foot of length	4.32 lb/ft
Moment of inertia (Ix)	7.383 in^4
Section modulus (Sx)	2.461 in^3
Radius of gyration (Rx)	2.410 in
Gross moment of inertia (Iy)	1.454 in^4
Gross radius of gyration (Ry)	1.070 in

Effective Section Properties, Strong Axis

Effective Area (Ae)	0.870 in^2
Moment of inertia for deflection (Ix)	7.281 in^4
Section modulus (Sx)	2.248 in^3
Allowable bending moment (Ma)	67.29 in-k
Allowable moment based on distortion buckling (Mad)	64.70 in-k
Allowable shear force in web (solid section)	10472 lb
Allowable shear force in web (perforated section)	3806 lb
Unbraced length (Lu)	58.8 in

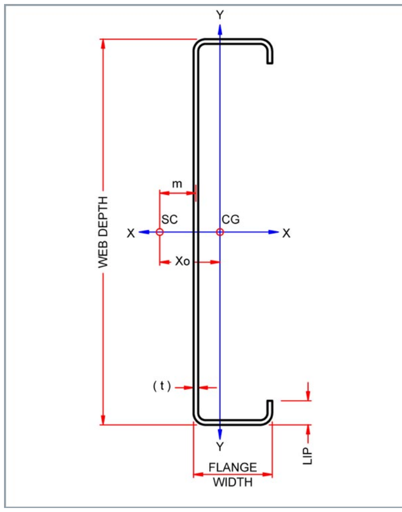
Torsional Properties

St. Venant torsion constant (J x 1000)	4.381 in^4
Warping constant (Cw)	10.776 in^6
Distance from shear center to neutral axis (Xo)	-2.241 in
Distance between shear center and web centerline (m)	1.343 in
Radii of gyration (Ro)	3.461 in
Torsional flexural constant (Beta)	0.581

ASTM & Code Standards:

- AISI North American Specification [NASPEC] S100-07 with 2010 supplement
- * Effective properties incorporate the strength increase from the cold work of forming
- Gross properties are based on the cross section away from the punchouts
- Structural framing is produced to meet or exceed ASTM C955
- Sheet steel meets or exceeds mechanical and chemical requirements of ASTM A1003
- ClarkDietrich's structural and nonstructural framing comply with the SFIA Code Compliance Certification Program, ICC-ES ESR-1166P and ATI CCRR-0206
- For installation & storage information refer to ASTM C1007
- SDS & Product Certification Information is available at itools.clarkdietrich.com

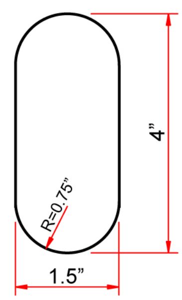
05.40.00 (Cold-Formed Metal Framing)



Structural Stud

Used in framing applications:

- **Load-bearing walls**
- **Curtain walls**
- **Tall interior walls**
- **Floor & ceiling joists**
- **Trusses**



Structural Punchout

East market punchout spacing:
12" from lead end then 24" o.c.

West market punchout spacing:
24" from lead end then 24" o.c.

Sustainability Credits:
For more details and LEED letters contact Technical Services at 888-437-3244 or visit www.clarkdietrich.com/LEED

LEED v4 MR Credit -- Building Product Disclosure and Optimization: EPD (up to 2 points) - Sourcing of Raw Materials (1 point) - Material Ingredients (1 point) - Construction and Demolition Waste Management (up to 2 points) - Innovation Credit (up to 2 points).

LEED 2009 Credit MR 2 & MR 4 -- ClarkDietrich's steel products are 100% recyclable and have a minimum recycled content of 34.2% (19.8% post-consumer and 14.4% pre-consumer). If seeking a higher number to meet Credit MR 5, please contact us at (info@clarkdietrich.com / 888-437-3244)

Project Information	Contractor Information	Architect Information
Name:	Name:	Name:
Address:	Contact:	Contact:
	Phone:	Phone:
	Fax:	Fax:

APPENDIX-B

Brochure of Rain screen panel

Composite & Plate Panel Systems

damsinc.com | 1 888.443.6725

DAMS Incorporated

D. ARCHITECTURAL METAL SOLUTIONS, INC.


LA Live - Plate - Los Angeles, CA


United Therapeutics - Plate - Silver Springs, MA


Argonne Labs - Composite - Lemont, IL

Max Planck - Composite - Multiple Locations

Best Buy - Composite - Multiple Locations

RAINSCREEN SYSTEMS

Our CCRS dry joint system, with its caulk free design, offers the desired crisp, clean, and contemporary look for today's architectural composite cladding design intent.

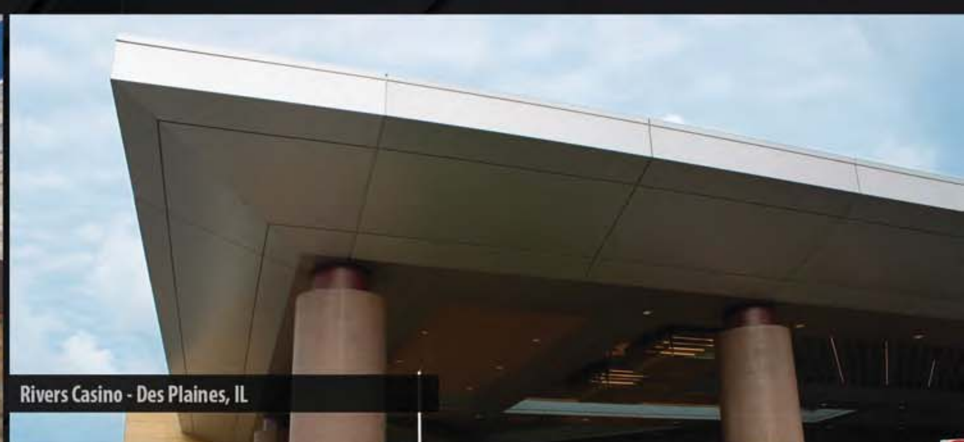
WET JOINT PANEL SYSTEMS

Our CCRWJ system has been in the marketplace for many years. The system utilizes continuous perimeter extrusions which reinforce the panel returns and feature sliding angle clips.

GLAZED-IN SYSTEMS

Glazed-in panels are designed to be used as an alternate for glass in any glazing, curtain wall, spandrel and window application. The panels are available in a variety of thicknesses.

HRT Medical - Woodgrain Composite - Honolulu, HI



Rivers Casino - Des Plaines, IL

Sacramento Intl. Airport - Composite - Sacramento, CA

Oxnard College - Composite - Oxnard, CA

damsinc.com | 1 888.443.6725

Column Covers Facade Cladding Systems

Kaiser Permanente - Sacramento, CA

Bank of America Tower - Charlotte, NC

Recyclable

Sustainable Products for Sustainable Projects.

LEED Credit Potential

Free Design Assist Service

Our team is always available to inform and suggest innovative solutions for your project.

www.damsinc.com

- Downloads
- Specs and Technical Data
- Photos
- Installation Videos

U.S. GREEN BUILDING COUNCIL MEMBER®

INTERTEC | Sunshades Grilles & Louvers
COMPOSITECORE | Architectural Panel Systems
ENTRANCE METAL | Glass Door Systems
DORALCO | Custom Metal Fabrication

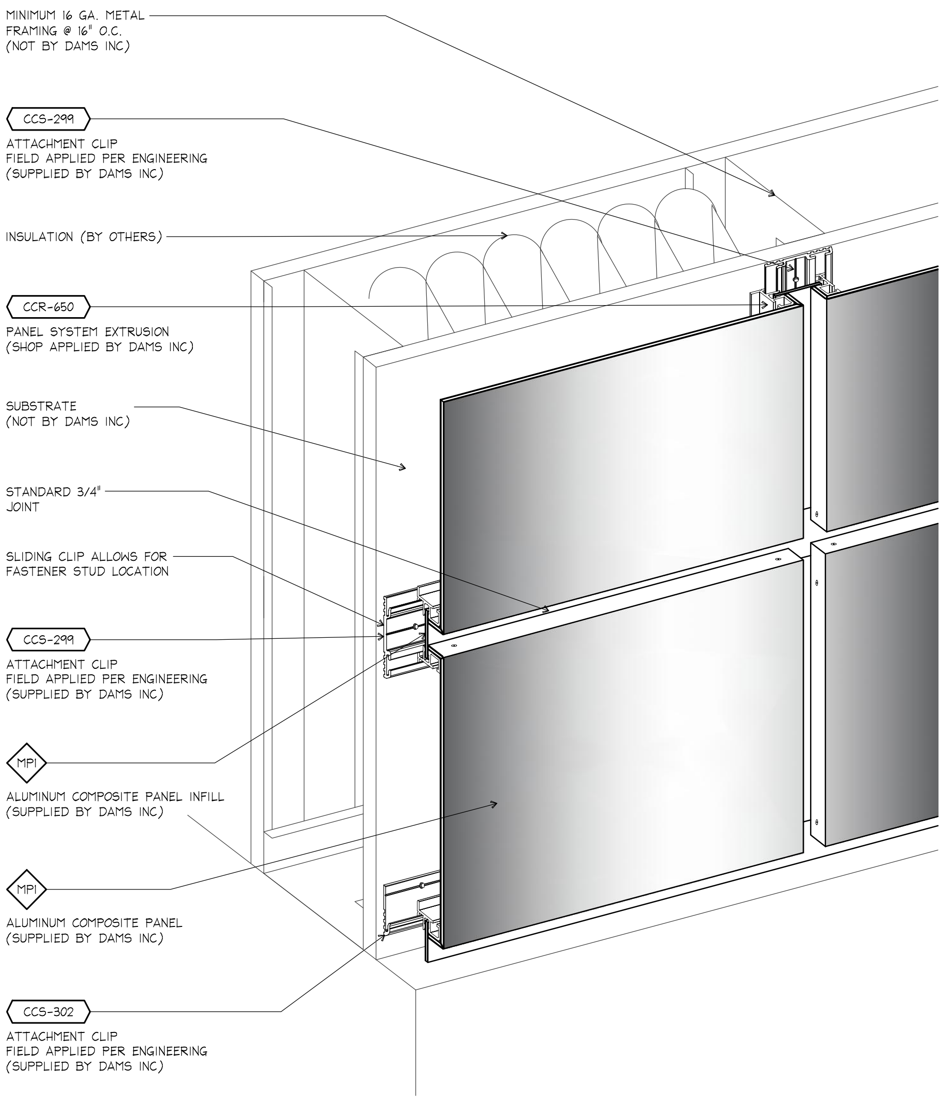
DAMS Incorporated

D. ARCHITECTURAL METAL SOLUTIONS, INC.

damsinc.com | 1 888.443.6725

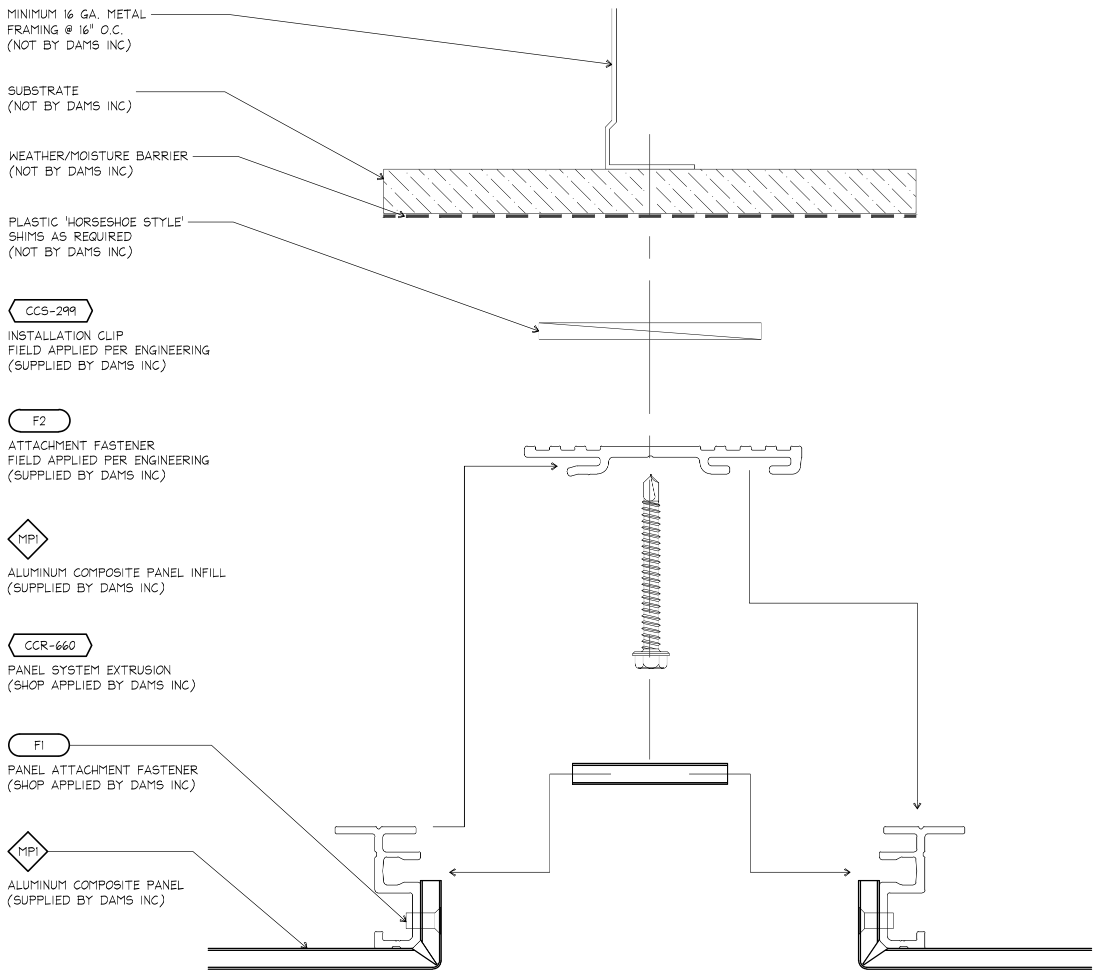
CCRS - DRY JOINT
RAIN SCREEN SYSTEM 1000 SERIES

(3/4" JOINT AT 2" SYSTEM DEPTH - 6MM ACM)



DAMS Incorporated
DORALCO
INTERTEC
COMPOSITEcore
ENTRANCE METAL
5919 W. 118TH STREET ALSIP, IL 60803 P: 708.224.4300 F: 708.388.9392
WWW.DAMSINC.COM

TITLE:	SYSTEM AXONOMETRIC
PROJECT:	CCRS - DRY JOINT RAIN SCREEN SYSTEM 1000 SERIES (3/4" JOINT - 6MM ACM)
DRAWN BY:	-
CHECK BY:	-
JOB No:	-
DATE:	-
PANEL TAG:	CS-01
CRATE #:	-



DAMS Incorporated

DORALCO
INTERTEC
COMPOSITEcore
ENTRANCE METAL

5919 W. 118TH STREET ALSIP, IL 60803 P: 708.224.4300 F: 708.388.9392
WWW.DAMSINC.COM

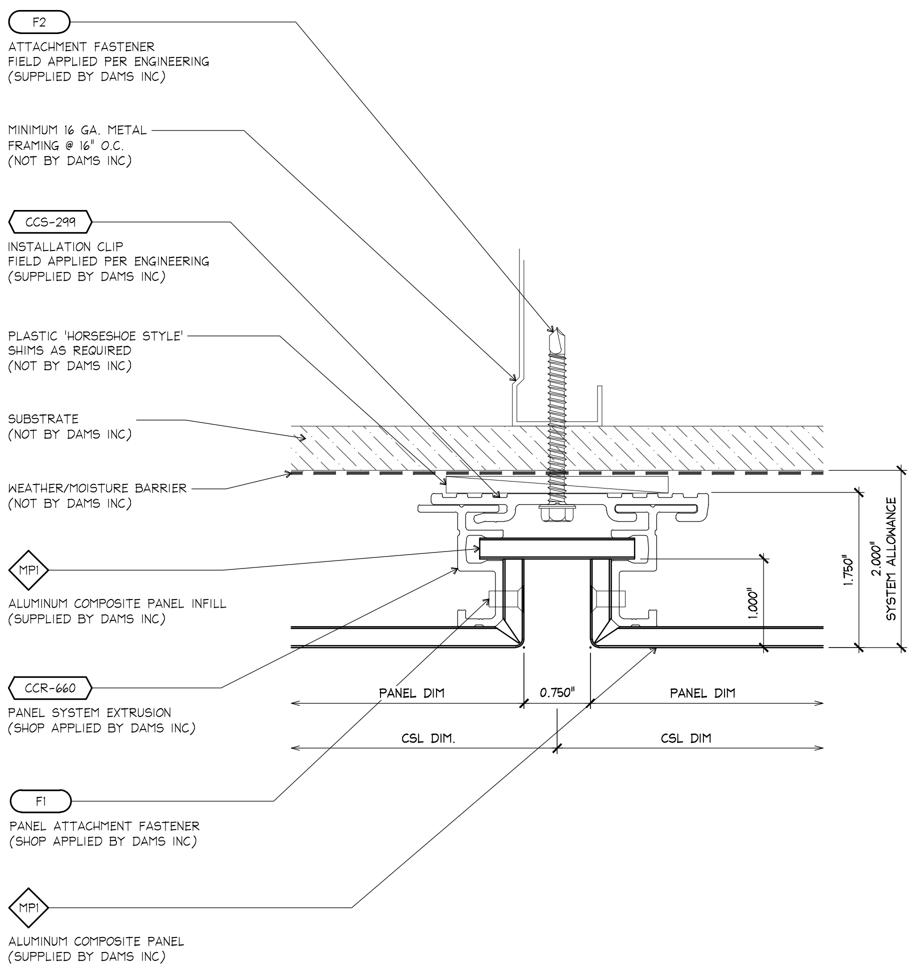
TITLE: ASSEMBLY DETAIL

PROJECT: CCRS - DRY JOINT RAIN SCREEN SYSTEM 1000 SERIES (3/4" JOINT - 6MM ACM)

DRAWN BY:	-
CHECK BY:	-
JOB No:	-
DATE:	-

PANEL TAG: CS-03

CRATE #: -



DAMS Incorporated
DORALCO
INTERTEC
COMPOSITEcore
ENTRANCE METAL
5919 W. 118TH STREET ALSIP, IL 60803 P: 708.224.4300 F: 708.388.9392
WWW.DAMSINC.COM

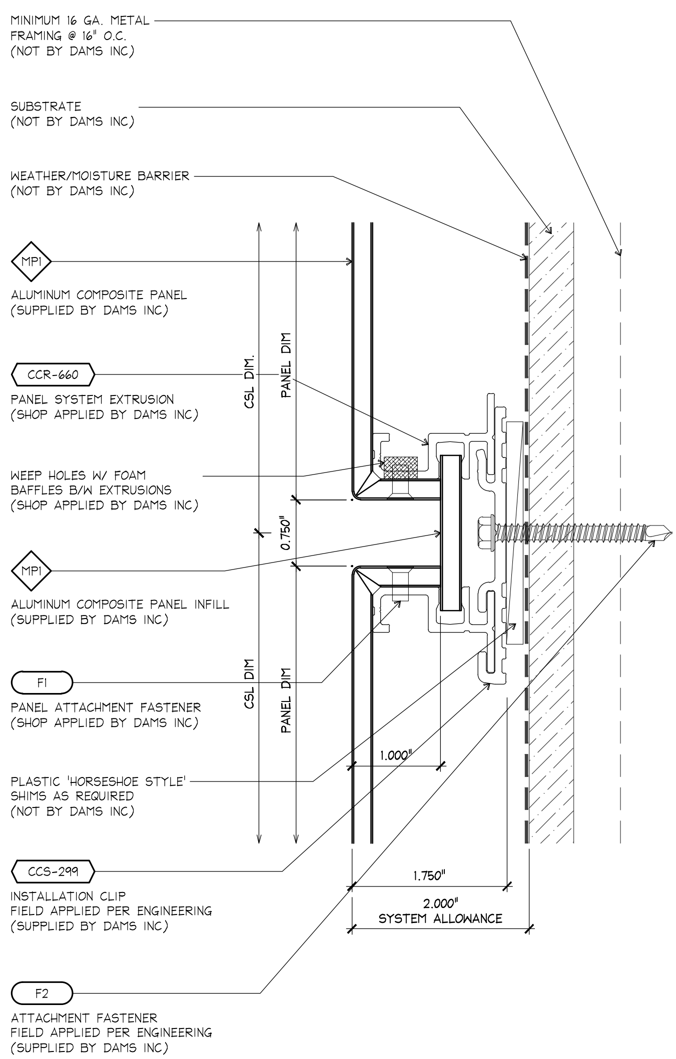
TITLE: VERTICAL JOINT-TYPICAL

PROJECT: CCRS - DRY JOINT RAIN SCREEN SYSTEM
1000 SERIES (3/4" JOINT - 6MM ACM)

DRAWN BY: -
CHECK BY: -
JOB No: -
DATE: -

PANEL TAG: D-01

CRATE #: -



DAMS Incorporated
DORALCO
INTERTEC
COMPOSITEcore
ENTRANCE METAL
5919 W. 118TH STREET ALSIP, IL 60803 P: 708.224.4300 F: 708.388.9392
WWW.DAMSINC.COM

TITLE:	HORIZONTAL JOINT-TYPICAL
PROJECT:	CCRS - DRY JOINT RAIN SCREEN SYSTEM 1000 SERIES (3/4" JOINT - 6MM ACM)
DRAWN BY:	-
CHECK BY:	-
JOB No:	-
DATE:	-
PANEL TAG:	D-02
CRATE #:	-

APPENDIX-C

Checksum calculations of current facade

Zone Checksums

By ACADEMIC

Zone - 001

COOLING COIL PEAK / CLG SPACE PEAK

COOLING COIL PEAK					CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 9 / 16				Mo/Hr: 9 / 11	
Outside Air:	OADB/WB/HR: 89 / 72 / 89				OADB: 82	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	6,280	6,280	2	0	0
Glass Solar	24,955	0	24,955	7	29,092	15
Glass/Door Cond	1,065	0	1,065	0	770	0
Wall Cond	1,105	353	1,458	0	787	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	-291		-291	0	354	0
Sub Total ==>	26,834	6,632	33,466	10	31,002	16
Internal Loads						
Lights	765	191	956	0	765	0
People	313,250	0	313,250	89	156,625	81
Misc	4,474	0	4,474	1	4,474	2
Sub Total ==>	318,489	191	318,680	91	161,864	84
Ceiling Load	393	-393	0	0	202	0
Ventilation Load	0	0	-55	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-101	-101	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	345,716	6,329	351,990	100.00	193,068	100.00

HEATING COIL PEAK

	Mo/Hr: Heating Design		
	OADB: 40		
	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-6,317	30.30
Glass Solar	0	0	0.00
Glass/Door Cond	-5,437	-5,437	26.08
Wall Cond	-662	-872	4.18
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-1,876	-1,876	9.00
Sub Total ==>	-7,976	-14,502	69.55
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-333	0	0.00
Ventilation Load	0	-2,548	12.22
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-3,894	-3,894	18.68
Exhaust Heat		94	-0.45
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-12,203	-20,850	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	71.3
Ra Plenum	75.8	69.4
Return	75.8	69.4
Ret/OA	75.9	69.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	8,759	8,759
Terminal	8,759	8,759
Main Fan	8,759	8,759
Sec Fan	0	0
Nom Vent	77	77
AHU Vent	77	77
Infil	57	57
MinStop/Rh	0	0
Return	8,815	8,815
Exhaust	134	134
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.9	0.9
cfm/ft²	5.30	5.30
cfm/ton	298.59	
ft²/ton	56.29	
Btu/hr·ft²	213.20	-12.63
No. People	627	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	29.3	352.0	196.8	8,759	75.8	67.0	86.6	55.0	54.2	62.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	29.3	352.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,651		
Part	0		
Int Door	0		
ExFlr	0		
Roof	1,366	0	0
Wall	1,010	183	18
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-20.9	8,759	69.1	71.3
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-20.9			

Zone Checksums

By ACADEMIC

Zone - 002

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 9 / 15; Outside Air: OADB/WB/HR: 90 / 71 / 83

Clg Space Peak — Mo/Hr: 12 / 14; OADB: 73

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	867	867	3	0	0
Glass Solar	2,216	0	2,216	7	3,507	19
Glass/Door Cond	231	0	231	1	-43	0
Wall Cond	185	57	242	1	147	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	94		94	0	-10	0
Sub Total ==>	2,727	924	3,650	12	3,600	20
Internal Loads						
Lights	108	27	135	0	108	1
People	24,333	0	24,333	79	12,167	67
Misc	2,372	0	2,372	8	2,372	13
Sub Total ==>	26,813	27	26,840	87	14,646	80
Ceiling Load	46	-46	0	0	1	0
Ventilation Load	0	0	434	1	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-33	-33	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	29,585	872	30,892	100.00	18,247	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-673	29.63
Glass Solar	0	0	0.00
Glass/Door Cond	-520	-520	22.88
Wall Cond	-75	-97	4.29
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-179	-179	7.89
Sub Total ==>	-774	-1,470	64.69
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-33	0	0.00
Ventilation Load	0	-827	36.38
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		24	-1.06
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-807	-2,272	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.9
Ra Plenum	76.0	69.3
Return	76.0	69.3
Ret/OA	76.4	68.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	828	828
Terminal	828	828
Main Fan	828	828
Sec Fan	0	0
Nom Vent	25	25
AHU Vent	25	25
Infil	5	5
MinStop/Rh	0	0
Return	833	833
Exhaust	30	30
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	3.0	3.0
cfm/ft²	5.67	5.67
cfm/ton	321.56	
ft²/ton	56.71	
Btu/hr·ft²	211.59	-15.56
No. People	49	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	2.6	30.9	18.7	828	76.4	66.2	81.4	55.0	54.1	61.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.6	30.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	146		
Part	0		
Int Door	0		
ExFlr	0		
Roof	146	0	0
Wall	110	18	16
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-2.3	828	68.4	70.9
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2.3			

Zone Checksums

By ACADEMIC

Zone - 003

COOLING COIL PEAK / CLG SPACE PEAK

	Cooling Coil Peak				CLG Space Peak	
	Peaked at Time: Mo/Hr: 7 / 17				Mo/Hr: 7 / 18	
	Outside Air: OADB/WB/HR: 87 / 70 / 87				OADB: 85	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	1,309	1,309	2	0	0
Glass Solar	1,836	0	1,836	2	1,957	5
Glass/Door Cond	140	0	140	0	125	0
Wall Cond	358	93	451	1	468	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	39		39	0	41	0
Sub Total ==>	2,373	1,402	3,775	5	2,592	7
Internal Loads						
Lights	119	30	149	0	119	0
People	70,500	0	70,500	93	35,250	93
Misc	0	0	0	0	0	0
Sub Total ==>	70,619	30	70,649	93	35,369	93
Ceiling Load	33	-33	0	0	36	0
Ventilation Load	0	0	1,584	2	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-125	-125	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	73,025	1,275	75,884	100.00	37,997	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-658	10.43
Glass Solar	0	0	0.00
Glass/Door Cond	-356	-356	5.65
Wall Cond	-216	-273	4.32
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-123	-123	1.95
Sub Total ==>	-696	-1,410	22.36
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-16	0	0.00
Ventilation Load	0	-4,960	78.63
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		62	-0.98
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-712	-6,308	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.4
Ra Plenum	75.7	69.6
Return	75.7	69.6
Ret/OA	76.7	67.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,724	1,724
Terminal	1,724	1,724
Main Fan	1,724	1,724
Sec Fan	0	0
Nom Vent	150	150
AHU Vent	150	150
Infil	4	4
MinStop/Rh	0	0
Return	1,727	1,727
Exhaust	154	154
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	8.7	8.7
cfm/ft²	12.22	12.22
cfm/ton	272.58	
ft²/ton	22.30	
Btu/hr·ft²	538.19	-44.74
No. People	141	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter °F	Enter gr/lb	Leave DB/WB/HR °F	Leave °F	Leave gr/lb
Main Clg	6.3	75.9	41.1	1,724	76.7	68.0	90.4	55.0	54.1	61.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.3	75.9								

AREAS

	Gross Total	Glass ft²	(%)
Floor	141		
Part	0		
Int Door	0		
ExFlr	0		
Roof	141	0	0
Wall	270	12	4
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-6.3	1,724	67.1	70.4
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-6.3			

APPENDIX-D

Checksum calculations of new façade

Zone Checksums
By ACADEMIC

Zone - 001

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 17; Outside Air: OADB/WB/HR: 87 / 70 / 87

Clg Space Peak — Mo/Hr: 9 / 12; OADB: 85

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	6,251	6,251	2	0	0
Glass Solar	23,590	0	23,590	7	27,436	14
Glass/Door Cond	1,084	0	1,084	0	614	0
Wall Cond	248	75	323	0	230	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	-266		-266	0	333	0
Sub Total ==>	24,656	6,326	30,981	9	28,612	15
Internal Loads						
Lights	765	191	956	0	765	0
People	313,250	0	313,250	90	156,625	82
Misc	4,474	0	4,474	1	4,474	2
Sub Total ==>	318,489	191	318,680	91	161,864	85
Ceiling Load	374	-374	0	0	206	0
Ventilation Load	0	0	-24	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-96	-96	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	343,518	6,047	349,541	100.00	190,682	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-6,316	30.54
Glass Solar	0	0	0.00
Glass/Door Cond	-5,437	-5,437	26.29
Wall Cond	-488	-642	3.10
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-1,876	-1,876	9.07
Sub Total ==>	-7,801	-14,272	69.01
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-334	0	0.00
Ventilation Load	0	-2,548	12.32
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-3,956	-3,956	19.13
Exhaust Heat		94	-0.46
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-12,092	-20,681	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	71.3
Ra Plenum	75.7	69.4
Return	75.7	69.4
Ret/OA	75.8	69.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	8,650	8,650
Terminal	8,650	8,650
Main Fan	8,650	8,650
Sec Fan	0	0
Nom Vent	77	77
AHU Vent	77	77
Infil	57	57
MinStop/Rh	0	0
Return	8,707	8,707
Exhaust	134	134
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.9	0.9
cfm/ft²	5.24	5.24
cfm/ton	296.97	
ft²/ton	56.68	
Btu/hr·ft²	211.71	-12.53
No. People	627	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	29.1	349.5	194.4	8,650	75.8	67.1	87.0	55.0	54.2	62.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	29.1	349.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,651		
Part	0		
Int Door	0		
ExFlr	0		
Roof	1,366	0	0
Wall	1,010	183	18
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-20.7	8,650	69.1	71.3
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-20.7			

Zone Checksums

By ACADEMIC

Zone - 002

COOLING COIL PEAK / CLG SPACE PEAK

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 9 / 16				Mo/Hr: 11 / 14	
Outside Air:	OADB/WB/HR: 89 / 72 / 89				OADB: 77	
	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	921	921	3	0	0
Glass Solar	2,081	0	2,081	7	3,299	18
Glass/Door Cond	221	0	221	1	-3	0
Wall Cond	32	10	42	0	18	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	113		113	0	14	0
Sub Total ==>	2,447	930	3,377	11	3,327	19
Internal Loads						
Lights	108	27	135	0	108	1
People	24,333	0	24,333	79	12,167	68
Misc	2,372	0	2,372	8	2,372	13
Sub Total ==>	26,813	27	26,840	87	14,646	81
Ceiling Load	47	-47	0	0	3	0
Ventilation Load	0	0	520	2	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-34	-34	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	29,306	877	30,703	100.00	17,977	100.00

HEATING COIL PEAK

	Space Peak Space Sens	Coil Peak Tot Sens	Percent Of Total
Mo/Hr: Heating Design			
OADB: 40			
	Btu/h	Btu/h	(%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-673	29.96
Glass Solar	0	0	0.00
Glass/Door Cond	-520	-520	23.14
Wall Cond	-55	-72	3.19
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-179	-179	7.99
Sub Total ==>	-754	-1,444	64.28
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-34	0	0.00
Ventilation Load	0	-827	36.80
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		24	-1.08
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-788	-2,246	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.9
Ra Plenum	76.0	69.3
Return	76.0	69.3
Ret/OA	76.4	68.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	816	816
Terminal	816	816
Main Fan	816	816
Sec Fan	0	0
Nom Vent	25	25
AHU Vent	25	25
Infil	5	5
MinStop/Rh	0	0
Return	821	821
Exhaust	30	30
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	3.1	3.1
cfm/ft²	5.59	5.59
cfm/ton	318.74	
ft²/ton	57.06	
Btu/hr·ft²	210.29	-15.39
No. People	49	

COOLING COIL SELECTION

	Total Capacity		Sens Cap.	Coil Airflow	Enter DB/WB/HR			Leave DB/WB/HR		
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb
Main Clg	2.6	30.7	18.4	816	76.4	66.3	82.0	55.0	54.2	62.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.6	30.7								

AREAS

	Gross Total	Glass ft²	(%)
Floor	146		
Part	0		
Int Door	0		
ExFlr	0		
Roof	146	0	0
Wall	110	18	16
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°F
Main Htg	-2.3	816	68.4	70.9
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2.3			

Zone Checksums

By ACADEMIC

Zone - 003

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 9 / 16 — CLG Space Peak Mo/Hr: 7 / 18

Outside Air: OADB/WB/HR: 89 / 72 / 89 — OADB: 85

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	724	724	1	0	0
Glass Solar	927	0	927	1	1,319	4
Glass/Door Cond	128	0	128	0	119	0
Wall Cond	76	19	95	0	89	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	52		52	0	41	0
Sub Total ==>	1,183	743	1,926	3	1,569	4
Internal Loads						
Lights	119	30	149	0	119	0
People	70,500	0	70,500	95	35,250	95
Misc	0	0	0	0	0	0
Sub Total ==>	70,619	30	70,649	95	35,369	96
Ceiling Load	18	-18	0	0	29	0
Ventilation Load	0	0	2,092	3	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-69	-69	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	71,820	686	74,599	100.00	36,967	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design

OADB: 40

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-658	10.54
Glass Solar	0	0	0.00
Glass/Door Cond	-356	-356	5.71
Wall Cond	-165	-209	3.34
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-123	-123	1.97
Sub Total ==>	-645	-1,346	21.56
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-17	0	0.00
Ventilation Load	0	-4,960	79.44
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		63	-1.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-661	-6,243	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.4
Ra Plenum	75.4	69.6
Return	75.4	69.6
Ret/OA	76.7	67.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,677	1,677
Terminal	1,677	1,677
Main Fan	1,677	1,677
Sec Fan	0	0
Nom Vent	150	150
AHU Vent	150	150
Infil	4	4
MinStop/Rh	0	0
Return	1,681	1,681
Exhaust	154	154
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	8.9	8.9
cfm/ft²	11.89	11.89
cfm/ton	269.76	
ft²/ton	22.68	
Btu/hr·ft²	529.07	-44.28
No. People	141	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	6.2	74.6	39.6	1,677	76.7	68.2	91.4	55.0	54.2	62.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.2	74.6								

AREAS

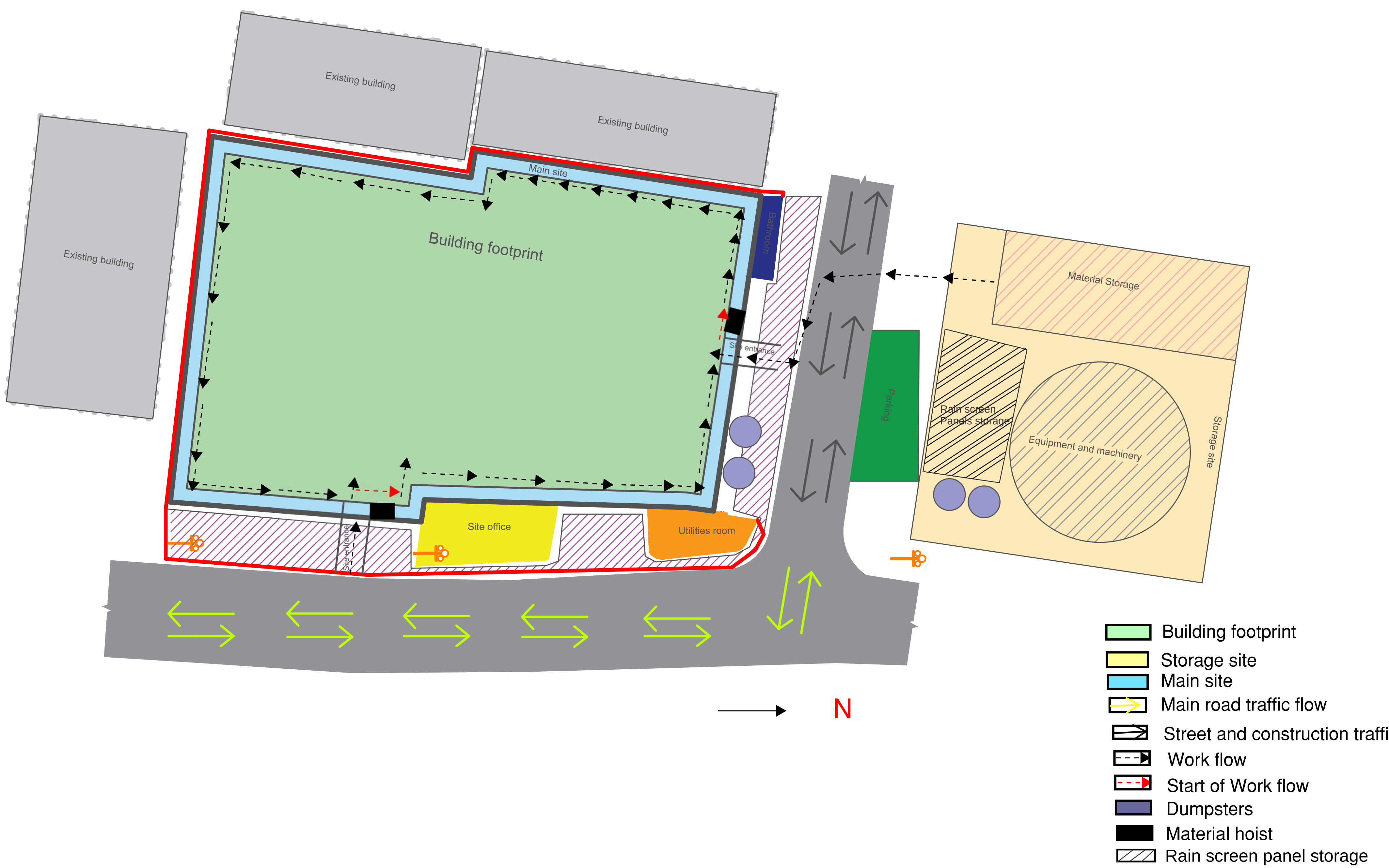
	Gross Total	Glass ft²	Glass (%)
Floor	141		
Part	0		
Int Door	0		
ExFlr	0		
Roof	141	0	0
Wall	280	12	4
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-6.2	1,677	67.0	70.4
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-6.2			

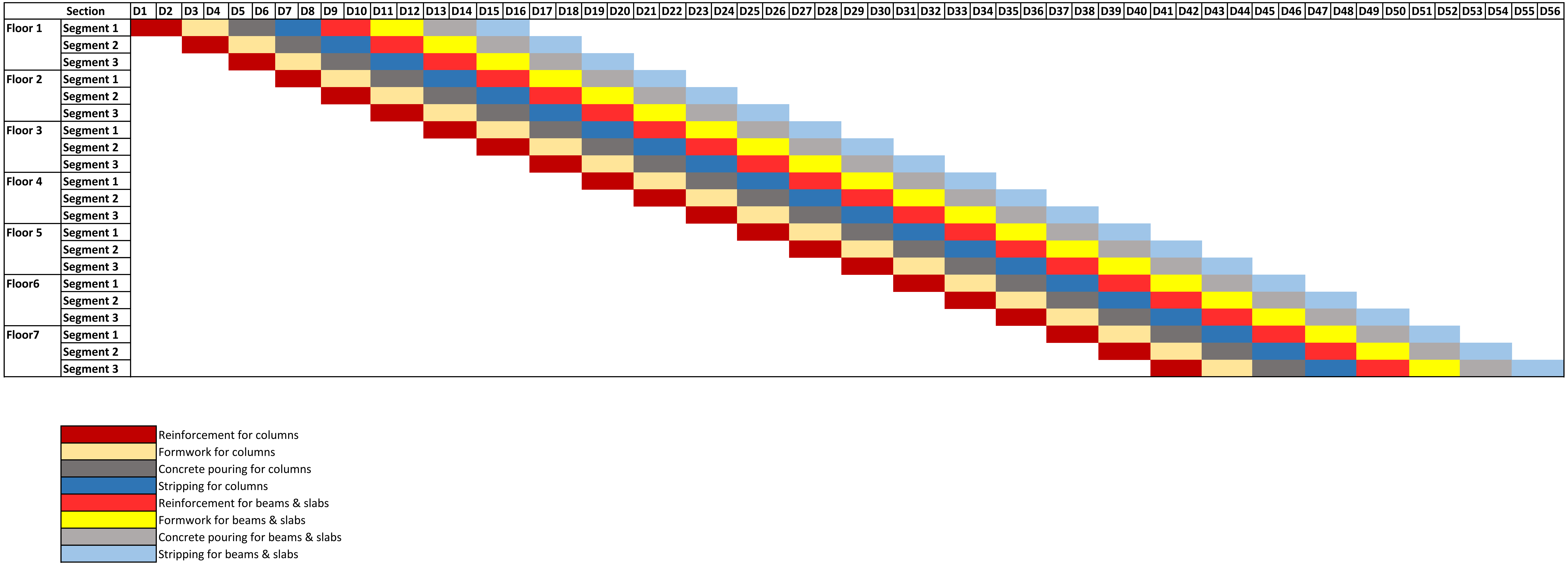
APPENDIX-E

Site Logistics


Existing building
Existing building
Existing building
Main site
Bathroom
Building footprint
Site entrance
Site office
Utilities room
Material Storage
Parking
Rain screen
Panels storage
Equipment and machinery
Storage site
N
Building footprint
Storage site
Main site
Main road traffic flow
Street and construction traffic
Work flow
Start of Work flow
Dumpsters
Material hoist
Rain screen panel storage

APPENDIX-F

Matrix Schedule


Section
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18 D19 D20 D21 D22 D23 D24 D25 D26 D27 D28 D29 D30 D31 D32 D33 D34 D35 D36 D37 D38 D39 D40 D41 D42 D43 D44 D45 D46 D47 D48 D49 D50 D51 D52 D53 D54 D55 D56
Floor 1
Segment 1
Segment 2
Segment 3
Floor 2
Segment 1
Segment 2
Segment 3
Floor 3
Segment 1
Segment 2
Segment 3
Floor 4
Segment 1
Segment 2
Segment 3
Floor 5
Segment 1
Segment 2
Segment 3
Floor6
Segment 1
Segment 2
Segment 3
Floor7
Segment 1
Segment 2
Segment 3
Reinforcement for columns
Formwork for columns
Concrete pouring for columns
Stripping for columns
Reinforcement for beams & slabs
Formwork for beams & slabs
Concrete pouring for beams & slabs
Stripping for beams & slabs