A

PROJECT REPORT

ON

"THE INFLUENCE OF LEAN CONSTRUCTION PRINCIPLES ON PROJECT PERFORMANCE"

UNDERTAKEN AT

"WILO ENGINEERS PVT LTD"

IN PARTIAL FULFILMENT OF

POST GRADUATE DIPLOMA IN CONSTRUCTION AND PROJECT MANAGEMENT

MIT SCHOOL OF DISTANCE EDUCATION, PUNE.

GUIDED BY

PROF.DR.JAYANT PANIGRAHI

SUBMITTED BY

MR.PARIMAL SANJAY MURDALE

Student Registration No. : **MIT2022D01923**

MIT SCHOOL OF DISTANCE EDUCATION PUNE - 411 038

YEAR 2022- 2024

<u>CERTIFICATE</u>

This is to certify that **MR.PARIMAL SANJAY MURDALE** has completed the project report withus for his/her project report work on "THE INFLUENCE OF LEAN CONSTRUCTION PRINCIPLES ON PROJECT PERFORMANCE" in fulfillment for the Completion of his Course with MITSDE on "**PGDM in CONSTRUCTION AND PROJECT Management**" asprescribed By MIT School of Distance Education, Pune.

This Project Report is record of authentic work carried out by him with guidanceby our relevant department from Dated **15TH JULY 2024.**

To
The Director
MIT School of Distance Education,

Respected Sir,

This is to request you to kindly exempt me from submitting the certificate from my organization for Project Work due to the reason mentioned below:

Tick the right option

1. As per the Rules of the Organization
2. Self Employed
3. Working in Public Sector
4. Full time Student

Thanking you in anticipation of your approval to my request.

Regards,

(Students' Name and Signature)
MR.PARIMAL SANJAY MURDALE
Student ID: MIT2022D01923

DECLARATION

I hereby declare that this project report entitled “THE INFLUENCE OF LEAN CONSTRUCTION PRINCIPLES ON PROJECT PERFORMANCE” is a bonafide record of the project work carried out by me during the academic year 2022-2024, in fulfilment of the requirements for the award of **POST GRADUATE DIPLOMA IN CONSTRUCTION AND PROJECT MANAGEMENT (PGDM)** of MIT School of Distance Education.

This work has not been undertaken or submitted elsewhere in connection with any other academic course.

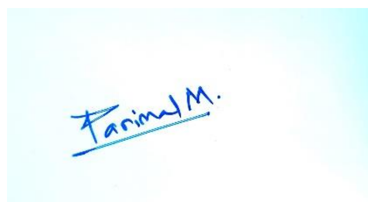
(Students’ Name and Signature)
MR.PARIMAL SANJAY MURDALE
Student ID: MIT2022D01923

ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere thanks and gratitude to Mr. Sameer S of **“WILO ENGINEERS PVT LTD”** for giving me an opportunity to do my project workin your esteemed organization and it has indeed been a great learning and enjoyable experience.

I would like to express my deep sense of gratitude and profound thanks to all staff members of **“ WILO ENGINEERS PVT LTD”** for their kind support and courtesy which helped me in gaining lots of knowledge and experience to do my project work successfully.

At last but not least, I am thankful to my Family and Friends for their moral support, endurance and encouragement during the course of the project.



(Students’ Name and Signature)

MR.PARIMAL SANJAY MURDALE

Student ID: MIT2022D01923

ABSTRACT

India is one of the largest and dynamic emerging markets with vast economic potential. India's GDPin 2012 was USD 1.8 trillion ranking 10th amongst all countries[1]. The objective of the Government ofIndia's, 12th Five-Year Plan (FY2013–17) is to return to GDP growth rates in excess of 8 percent, with strong emphasis on the manufacturing sector. Manufacturing has long been recognized as an essential driver of economic development for most countries, as it has an important economic and employment multiplier effect. The manufacturing sector will have to play an important role to takeIndian economy to a high growth rate trajectory and achieve the planned objectives. Micro Small andMedium Enterprises play an essential role in the overall industrial economy of the country and account for over 45% of India's manufacturing output[2].

Despite strong potential, India's manufacturing performance has not been encouraging. The share of manufacturing in India's GDP has stagnated at around 16 percent[3], compared to more than 30 percent (and growing) in some of the other Asian countries. India's manufacturing sector has been facing challenges, such as low value addition, low productivity, and less-than-desirable up scaling. However, world-class production units that compete in the international market are also present in India.

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

ABOUT THE PROJECTS

India is one of the largest and dynamic emerging markets with vast economic potential. India's GDPin 2012 was USD 1.8 trillion ranking 10th amongst all countries[1]. The objective of the Government ofIndia's, 12th Five-Year Plan (FY2013–17) is to return to GDP growth rates in excess of 8 percent, with strong emphasis on the manufacturing sector. Manufacturing has long been recognized as an essential driver of economic development for most countries, as it has an important economic and employment multiplier effect. The manufacturing sector will have to play an important role to takeIndian economy to a high growth rate trajectory and achieve the planned objectives. Micro Small andMedium Enterprises play an essential role in the overall industrial economy of the country and account for over 45% of India's manufacturing output[2].

Despite strong potential, India's manufacturing performance has not been encouraging. The share of manufacturing in India's GDP has stagnated at around 16 percent[3], compared to more than 30 percent (and growing) in some of the other Asian countries. India's manufacturing sector has been facing challenges, such as low value addition, low productivity, and less-than-desirable up scaling. However, world-class production units that compete in the international market are also present in India.

The major constraints in the growth and competitiveness of India's manufacturing sector are:

- access to finance (especially for MSMEs)
- access to technology and skilled manpower
- access to markets (domestic & export)
- infrastructure deficiencies

These constraints impact the competitiveness of MSMEs operating in both upstream and downstreammanufacturing industries.

Upstream industries, such as the tooling industry, which consists of developing and manufacturing of dies, moulds, casts, as well as testing and prototyping, serves as an interface between product design and product manufacturing. The right tools help increase throughputs, reduce material waste, improve product quality, time to market and thus improve competitiveness. The importance of the tooling industry increases with accelerating technological developments, product sophistication/ innovation/ customization and reducing time to market. Tooling is a specialized but local industry (more than 60 percent of tools in the world are locally produced and consumed – including in India)

---

[1] http://unstats.un.org/unsd/snaama/dnltransfer.asp?fID=2
[2] http://www.dnb.co.in/Nashik2013/PDF/MSMEsInIndia.pdf
[3]The Manufacturing plan - Strategies for accelerating growth of manufacturing in India in the 12th Five Year Plan and beyond, Planning Commission

1.2 Background and project rationale

Dominated by MSMEs (more than 80% of firms in India, Europe, US and Japan). Like other countries,the private tooling industry in India has grown hand in hand with the manufacturing industry. The turnover of the Indian tooling industry is approximately INR 13,000 crores, with more than a thousand firms employing over 120,000 workers (TAGMA 2011). The constraints to the growth and competitiveness of the Indian tooling industry mirror the ones affecting manufacturing as a whole, as articulated above. The scarcity of skilled workers and problems related to their retention, as wellas the lack of access to a high-quality design and prototyping facility has hurt growth.

In downstream industries such as automotive, electronics, fragrance and flavours, glass, leather, toys etc., there is shortage of skilled labour and limited access to advanced technologies. These industries include large numbers of MSMEs, often working as part of supplier networks of larger enterprises and subject to increased international competition.

1.1.1 Demographic overview and challenges

While India stands to benefit from an immense demographic dividend, with the largest youth population in the world (around 66 percent of the total population is under the age of 35), it has anoverall employment rate of 4.7 percent (under usual principal status approach) and an overall labourforce participation rate of 50.9 percent[4]. For the country to gain from this demographic dividend, skilling and up-skilling its youth are key priorities for the Government of India (GoI).

India has a labour force of about 470 million, of which less than 10 percent have received skills training, either through formal or informal means[5]. About 13 million young people enter the labour force annually. Despite the huge expansion of skills training provision during the 11th Five-year plan,the country's skills development system requires massive up scaling. In its 11th and 12th Five-year plans, India recognized that skill development is critical to achieve faster, sustainable and inclusive growth on one hand, and to providing decent employment opportunities to the growing young population, on the other. According to the National Skill Development Policy published in March 2009, India has set a target of skilling 500 million people by 2022[6]. This program will play a bigger role in the country's plan by setting a target of skilling 150 lakh people within the next 6 years.

Global experience shows that a workforce with higher schooling and skill levels leads to higher productivity and personal income. A 2011 study showed that students who attended three-year vocational training courses at ITIs earned 25 percent more than two-year course students, who earned 14 percent more than did one-year course students[7]. These results were also observed in a 2007 study showing that the returns on vocational training in India have been found to be 8 percent,

---

[4] Report on the Third-Annual employment & unemployment survey (2012 – 2013) of the Ministry of Labor, Government of India.

[5] 11th and 12th Five Year Plan

[6] http://labour.nic.in/upload/uploadfiles/files/Policies/NationalSkillDevelopmentPolicyMar09.pdf

[7] Vocational Training in the Private Sector (Goyal 2011)

1.1.2 Country's manufacturing objectives

Development of Indian manufacturing sector calls for deepening and recalibrating of economic reforms that would strengthen the sector and make it grow faster and become an engine of inclusivegrowth. To realize the potential of the manufacturing sector, Government of India has announced National Manufacturing Policy in 2011 with the objective of enhancing the share of manufacturing in GDP to 25% within a decade and creating 100 million jobs. It also seeks to empower rural youth by imparting necessary skill sets to make them employable. Sustainable development is integral to the spirit of the policy and technological value addition in manufacturing has received special focus.

The National Manufacturing Policy has six objectives:

- Increase manufacturing sector growth to 12-14% over the medium term to make it the engineof growth for the economy. The 2 to 4 % differential over the medium term growth rate of the overall economy will enable manufacturing to contribute at least 25% of the National GDPby 2022.
- Increase the rate of job creation in manufacturing to create 100 million additional jobs by 2022.
- Creation of appropriate skill sets among the rural migrant and urban poor to make growth inclusive.
- Increase domestic value addition and technological depth in manufacturing.
- Enhance global competitiveness of Indian manufacturing through appropriate policy support.
- Ensure sustainability of growth, particularly with regard to the environment including energyefficiency, optimal utilization of natural resources and restoration of damaged/ degraded eco-systems.

1.1.3 **Recommendations of XII plan Working group & Parliamentary Standing Committee**

At present, the Office of Development Commissioner [O/o DC (MSME)], Ministry of Micro, Small and Medium Enterprises, operates 10 TRs and 8 TDCs (both hereinafter called as TCs) spread across the country. The TCs have been providing technical and vocational training programmes to more than 1,00,000 trainees annually including AICTE and NCVT approved certification. They also provide

[8] The Knowledge Economy and Education and Training in South Asia (World Bank 2007)

design and manufacturing support to entrepreneurs alongside technical consultancies. The TCs primary focus is to improve access to advanced technologies & provide technical advisory support toentrepreneurs and workers, as well as opportunities for technical skill development to the youth at varying levels.

Considering the performance of existing TCs, the Department related Parliamentary Standing Committee on Industry, in its 235th report submitted to Rajya Sabha on 4 May 2012 have recommended as follows:

i) "The committee is impressed with the performance of the TRs established by the MSME Ministry. These enable the youth to improve their skills and get employment opportunities. The success of such TRs inspires confidence that establishment of more such institutions will equip the young people with necessary ability useful in the expanding market and manufacturing sector".

ii) "The Committee strongly recommends that more money must be allocated for establishmentof TRs across the country. It is understood that MSME Ministry is also approaching the concerned organizations within Government to get loan from International Financial Institutions. If Planning Commission and Finance Ministry cannot allocate more funds for this purpose, the necessary permission to MSME Ministry to get access to borrowings from international banks may be given without delay. However, it is strongly recommended that we must use our own resources for this cause, which is good for the youth of our country andMSME sector".

The evaluation of existing ten TCs was undertaken under GIZ–MSME Umbrella Programme during 2011. The experts have appreciated the performance of the existing TCs and have recommended expansion of skill development activities and introduction of newer technologies in the TCs.

During the budget speech of 2013-14, following announcement was made;

Para 75: "TRs and TDCs set up by the Ministry of MSME have done well in extending technology and design support to small businesses. I propose to provide with World Bank assistance, a sum of Rs2,200 crore during the 12th Five Year Plan period to set up 15 additional Centres".

In pursuance of (i) the announcement made in the Budget (2013-14), (ii) the recommendations of the Department Related Parliamentary Standing Committee on Industry in its 235th Report submitted to Parliament (Rajya Sabha) on 4 May 2012, and (iii) the recommendations of the experts after evaluating the performance of existing TCs, it was proposed to implement "Technology CentreSystems Programme (TCSP)" at an estimated project cost of INR2,200 crore including World Bank

1.1.4 Technology Centres System Program

The Technology Centres Systems Program, a national program, seeks to enhance the technological and skill base of MSMEs in selected manufacturing industries, via upgraded and new TCs (currently called TRs and TDCs). The TCs will have as their mission to improve the competitiveness of MSMEs across India – with a strong emphasis on low income states.

This will be achieved by providing an integrated suite of services to MSMEs on a fee basis, ranging from providing them access to technology, access to skills and access to business advisory services. TCSP will reinforce the technical capability of the TCs as well as their performance, by further increasing the participation of the private sector in key decisions at both the national and local levels.

The TCs will support industry clusters across manufacturing value chains, both upstream (tooling industry) and downstream (key industries exposed to global competition close to the technology frontier, such as the automotive and electronics sectors, as well as industries evolving through indigenous innovations, such as fragrance and flavour, glass, leather, toys etc.).

TCSP's Program Development Objective has been defined to enhance the competitiveness of MSMEsby improving their access to technology and business advisory services as well as skilled workers through systems of financially sustainable TCs. The program seeks to establish 15 new TCs and upgrade capabilities of select existing TCs and develop linkages between MSMEs, Indian andinternational research institutes and leading manufacturers. This would include upgradation in technology, land and building infrastructure and other associated infrastructure of the TC. The program will connect leading practices contributing to advance technology, knowledge, skilling and innovation which can be transferred to MSMEs served by each TC.

The competitiveness of MSMEs is impacted by various factors such as entrepreneurial drive of the leader, market and customer dynamics, their access to technology, finance & business advisory andavailability of skill manpower. The TCs will shape the outcomes of the program by providing MSMEs access to technology, business advisory and skilled manpower. So it would be possible to measure the success of this program by measuring the offtake of these paid services of the TCs by MSMEs. Therefore, the key indicators that will be measured are;

- Number of enterprises paid for services rendered including placement services
- Number of long term trainees employed by industry, including MSMEs, within six monthsafter being trained at TCs
- TCs' gross profit before depreciation (not including land)

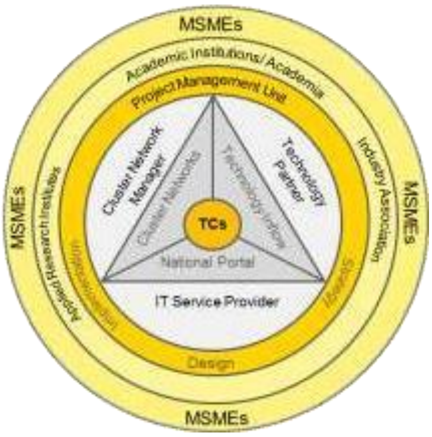
CHAPTER 2

RESEARCH METHODOLOGY

- Access to Technology
  - Revenue of TCs from access to technology activities (production support and consultancy)
  - Capacity utilization of TCs machines
  - Number of technology strategies/roadmaps developed by TPs and endorsed by IndustryAssociations and IC
- Access to Skilled Workers
  - Number of trainees trained (direct program beneficiary)
    - external trainers trained
    - with newly developed contents
    - female
    - from low income states
    - from disadvantaged section of society (SC/ST)
  - Number of skills development contents (e.g. curricula, standards, certification schemes)developed and adopted by industry associations, and/or certifying agencies
- Access to Business Advisory
  - Number of needs assessment and related business plans developed by CNMs andendorsed by Industry Associations
  - Value of TCs' businesses generated with support of Cluster Network Managers

In addition, intermediate result indicators are designed to monitor critical progress towards achievement of the PDO with primary emphasis on market- tested outputs of the TCs supported by Technology Partner and Cluster Network Manager. Examples of such indicators include capacity utilization of machines, number of trainees trained, access to services by MSMEs, number of technologystrategies / roadmaps developed by TPs and endorsed by industry associations and value of TCs' businesses generatedwith support of CNMs.

Figure 1: TCSP eco-system



This program will create an ecosystem to help MSMEs become more competitive by acquiring improved technology and employing better skilled workers. This will be done directly through the services provided to them by the TCs, as well as indirectly through the linkages with larger firms (e.g. as part of the supplier network of an OEM), which will provide access to the services of the TCs under the condition that it benefits their suppliers. The TCs will contribute by providing inputs to MSMEs on manufacturing technology & business advisory and by improving the skills of workers/ skill seekers for better employment opportunities. The program will therefore benefit the Indian MSMEs, students and workers and help establish systems of TCs in the country wherein each centre will gain from the specialisation and experience of the others and improve the competivenessof MSMEs.

1.1.5 Key TCSP stakeholders

TCSP has multiple stakeholders who will need to work together to achieve the objective of enhancing the competitiveness of MSMEs by improving their access to technology and business advisory services as well as skilled workers through systems of financially sustainable TCs. The key players who will participate in the program include:

- MSME Units - Beneficiaries

MSME units will be the prime beneficiaries of the program and the overall objective of the program centres around providing them with access to modern technology, access to business advisory services and access to skilled workforce.

- Skill seekers

Workers, job and skill seekers will also gain from this program with access to short term and long term training/skill development courses that will help job seekers to improve their career prospectsand finding livelihood.

- Office of Development Commissioner, Ministry of MSME (DC-MoMSME)

The program would be designed and implemented under the aegis of the O/o Development Commissioner MSME, Government of India. O/O DCMSME has the mandate to support MSMEs andTCSP will serve this towards this purpose.

- Technology Centres

The TCs will serve MSMEs with integrated suite of services on a fee basis, ranging from providing them access to technology, access to skills and access to business advisory services. The program will focus to upgrade selected existing TCs and development of 15 new TCs that support or will support industry clusters across manufacturing value chains, both upstream (tooling industry) and downstream (key industries exposed to global competition close to technology frontier, such as automotive electronics, as well as industries evolving through indigenous innovations, such as fragrances and flavours, footwear, glassware, toys etc.).

- **Collaborations with Industry associations, academia, applied research institutes and others** Strategic collaborations between TCs and various other organizations will be critical to fosterresearch and development, business incubation and strengthen the TCs with regard to manufacturing services, business advisory and training capabilities. These include:
    - Regional / sectorial industry associations representing MSMEs
    - Regional / national level engineering/ academic / vocational training institutions

- Applied research institutes
- Local regional colleges
- Autonomous institutes such as IISc, CSIR
- Academia

Leading practices from around the world for similar program suggest and underscore the importance of establishing such linkages. In the Indian context, there are many research oriented projects and concepts that can provide competitive advantage to Indian industry once the early state research emanating from applied research institutes and academia can be validated and implemented at the TC through such collaborations. The TCs will provide a unique environment of bringing the country'sleading academics, engineering and industry professionals together to develop and demonstrate new technologies on an industrial scale. This will allow the clients of TCs to develop new manufacturing processes in a safe, neutral setting, reducing the associated financial risks.

► Program Management Unit (PMU)

Role of PMU is to assist the O/o DC MSME in designing and implementing this program. This includes developing framework for identifying sites/sectors for the new TCs, developing detailed project report, support in procurement of services and EPC contracts; developing and implementing environment and social safeguards, monitoring and evaluation, manage the roll out of the national portal, deployment of subject matter expertise and overall program management for TCSP over 6 years. EY LLP has been selected as the PMU for the TCSP by the O/o DC MSME via competitive biddingas per World Bank guidelines.

► Technology Partner (TP)

Role of TP is to help enhance the supply side of the TC by augmenting the technologies at the TCs, assist in their capacity building with respect to the identified technologies and clusters and provide greater support to the services being offered to the MSMEs by the TCs. These services include beingexposed to the potential impact of new and relevant technologies, learning how to use new technologies/equipment, providing access to cutting-edge equipment, developing and testing new products, consultancy, training and deploying efficient techniques and practices that improve the competitiveness of the MSMEs being served.

► Cluster Network Manager (CNM)

CNMs for each System (or sub System) of TCs will specialize on specific geographic cluster(s)/ industry(s). The CNM will build capacity of the TC to enhance economic development cooperation amongst key stakeholders to improve the competitiveness of the cluster. This will include strengthening market linkages of the TCs with the MSMEs in the cluster it serves, trade and industryassociations, academia, educational institutions, applied research institutions, service providers, other government support institutions, workers and skill seekers.

The CNM would seek to increase competitiveness of supply chains of large firms by enhancing quality,reliability and productivity of MSME suppliers by offering services of the TC, thus also helping in meeting revenue targets of the TC. The CNM will enhance the competitiveness of the cluster businessenvironment by establishing a network of service providers which will address the needs of the MSMEs not served by the TC e.g. access to a network of financial services. The CNM will also facilitatecloser cooperation between the TC and MSMEs with key innovation stakeholders such as applied research institutes, autonomous institutions such as IISc, CSIR, academia, skill seekers, and studentsetc. to enhance product and process innovation. TC's capacity will be further enhanced through closer cooperation amongst skills development and labour market stakeholders to increase the number of workers/ trainees from TCs finding long term employment to improve their livelihood.

- National Portal Service Provider (NPSP)

Role of NPSP is to design, develop, set-up, operate and maintain the IT platform for MSMEs. The IT platform will act as a common platform for services that will be required by an MSME from the startof their business, to successful operations and closure e.g. access to regulatory services for entrepreneurs, assistance for financing, access to list of suppliers etc. The platform intends to extendthe reach of the program to its remote beneficiaries well beyond the TCs' physical location throughaccess to e-learning solutions, B2B service and product market place, e-recruitment, assistance for financial services and e-governance services (forum to address grievances, automation of customer facing operations of the O/o DC MSME) on paid basis.

- Construction Management Consultant

The Construction Management Consultant (CMC) shall be responsible for design, supervision of workand final closure of construction works for the TC. CMC will prepare concept plans and subproject appraisal reports, carry out contract planning and detailed engineering designs, prepare schedules of quantities and specifications. It will support the PMU in preparation of procurement packages, biddocuments, invitation, receipt and evaluation of bids etc. CMC will supervise the construction, manage the contract, monitor construction activities and will certify contractor's progress claims, carry out quality control, testing, and prepare progress and monitoring reports, and certify bills.

1.1.6 RFD of TCSP

TCSP's objective is to enhance the competitiveness of MSMEs by improving their access to technology, business advisory services as well as skilled workers through systems of financially sustainable TCs. For monitoring the program outcomes, RFD has been defined; which contains the results indicators at the PDO level and intermediate outcome level together with the baselines and targets over the life of the program. Intermediate results indicators are designed to monitor criticalprogress toward achievement of the PDO with primary emphasis on market-tested outputs of the TCs and other stakeholders of the TCSP (viz. TPs, CNMs and ITP service provider).

Active participation of General Manager of TCs will be essential for steering the operationalization ofTCSP in line with the envisioned mandate. The key success parameters of the General Manager include:

- Revenue earned by respective TC from,
  - Production
  - Training
  - Consultancy and others
  - Business given to private tool rooms
  - Production/training/consultancy with the help of CNM (territory/sectors to be identifiedJointly by CNM and TCs in advance)
- Recovery ratio--Revenue/ recurring expenditure (cash) in percentage
- Profit before depreciation
- Profit after depreciation
- No. of trainees trained in Long term & Short term training programme
- No. of courses identified which are suitable for women employment & courses designed andstarted (CNM to assist the identification of courses and TP to design)
- No. of units assisted , out of which how many are MSMEs
- Present technical papers showing successes delivered and how it has aided industry
- Technical incubation centre to start and the long term trainees to be encouraged to registerfor starting enterprises

The table below depicts the snapshot of result indicators which form a part of the RFD.

Table 1: Result indicators of the RFD

Program development objectiveindicators		Number of enterprises paid for services renderedincluding placement services
		Number of long term trainees employed by industry, including MSMEs, six months after graduating from theTCs
		TCs' gross profit before depreciation (not includingland)
Intermediary Results		
Component 1- Technical assistance to the existing	Access to Technology	TCs revenue from access to technology activities(production support and consultancy)
		Capacity utilization of machines in TCs
		No. of technology strategies/roadmaps developed byTPs and endorsed by industry associations and IC
	Access to Skilled workforce	Number of trainees trained (direct program beneficiary)
		Number of skills development contents (e.g. curricula, standards, certifications) developed and adopted by industry associations, and/or certifying agencies
		Number of needs assessment and business plans developed by CNMs and endorsed by Industry Assocs.

and new TCs

Value of TCs' businesses generated with support of Cluster Network Managers

Number of users of IT Platform

Component 2-Investments to upgrade existing and developnew TCs

Number of new TCs built

Component 3-Technical assistance to MoMSME

Establishment of PMU for program implementation andcapacity building of MoMSME

The program aims to have direct and indirect industrial and economic outcomes to the country, suchas enhanced manufacturing competitiveness, improvement in the overall employment rate and increased GDP growth.

CHAPTER 3
PROJECT HISTORY

PROJECT COST EVALUTION

Schedule Overview
The total project is scheduled to take 528 Days. This does not include pre-design demolition. Substructure is projected to last 164 days, superstructure will take 127 days and the rough-in and finish timeline is 143 days. Building

SN	Name	Focus Sector
1	Central Tool Room & Training Centre (CTTC), Bhubaneswar (Odisha)	General engineering (Precision components)
2	Indo Danish Tool Room (IDTR), Jamshedpur (Jharkhand)	General engineering (Auto components)
3	Central Tool Room & Training Centre (CTTC), Kolkata (West Bengal)	General engineering
4	Tool Room & Training Centre (TRTC), Guwahati (Assam)	General engineering (Training in tool making)
5	Indo German Tool Room (IGTR), Aurangabad (Maharashtra)	General engineering (Auto components)
6	Indo German Tool Room (IGTR), Indore (Madhya Pradesh)	General engineering (Auto& Pharma)
7	Indo German Tool Room (IGTR), Ahmedabad (Gujarat)	General engineering (Auto & Plastic tools)
8	Central Tool Room (CTR), Ludhiana (Punjab)	General engineering
9	Central Institute of Hand Tools (CIHT), Jalandhar (Punjab)	General engineering (Hand tools)
10	Central Institute of Tool Design (CITD), Hyderabad, (Andhra Pradesh)	General engineering & ESDM
11	Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai, (Maharashtra)	ESDM and tool making
12	Electronics Service & Training Centre (ESTC), Ramnagar (Uttarakhand)	ESDM

The total project has a budget of $103 million and building cost of $89 million. The actual building cost per square foot was calculated to be $387. In Table 1, a comparison to the parametric estimate created using D4 Cost Estimating can be seen; the estimates created in my research appear to be low. I feel that the reason for this difference in cost can be justified. The actual building cost considers the many amenities and sport facilities created for VSPL WILO ENGINEERS PVT LTD. In D4 it is strictly looking at square foot and a comparable size building. VSPL is a revolutionary design for focusing on the use of technology and striving for LEED Gold Certification. Also VSPLHS involves the construction of an auditorium, competition gymnasium, auxiliary gymnasium, natatorium and multiple outdoor sports facilities.

The estimate using Cost works (RS Means) has resulted in an estimate of $49.1 million. The revisions made to the base square foot price include: adjusting to appropriate story height and perimeter as well as some additional amenities. The large differences can be accounted for in the differences in the design of the project compared to facilities. RS Means square foot cost data cannot account for the many amenities included in the actual construction costs of VSPL WILO ENGINEERS PVT LTD.

SITE CONDITIONS

Figure 8, below shows the existing site and surrounding building structures prior to demolition. The following two pages are further detailed drawings of the existing site conditions. Figure 10 shows roads, vehicular and pedestrian pathways around the site. More details on the existing utility locations can be found on Figure 11.

SN	Name	Focus Sector
13	Process and Product Development Centre (PPDC), Agra (Uttar Pradesh)	Foundry and forging
14	Process cum Product Development Centre (PPDC), Meerut (Uttar Pradesh)	Sports goods
15	Central Footwear Training Institute (CFTI), Agra (Uttar Pradesh)	Leather & footwear
16	Central Footwear Training Institute (CFTI), Chennai (Tamil Nadu)	Leather & footwear
17	Fragrance and Flavour Development Centre (FFDC), Kannauj (Uttar Pradesh)	Fragrance & flavours
18	Centre for Development of Glass Industries (CDGI), Firozabad (Uttar Pradesh)	Glassware

Figure 2: Location of existing TRs & TCs

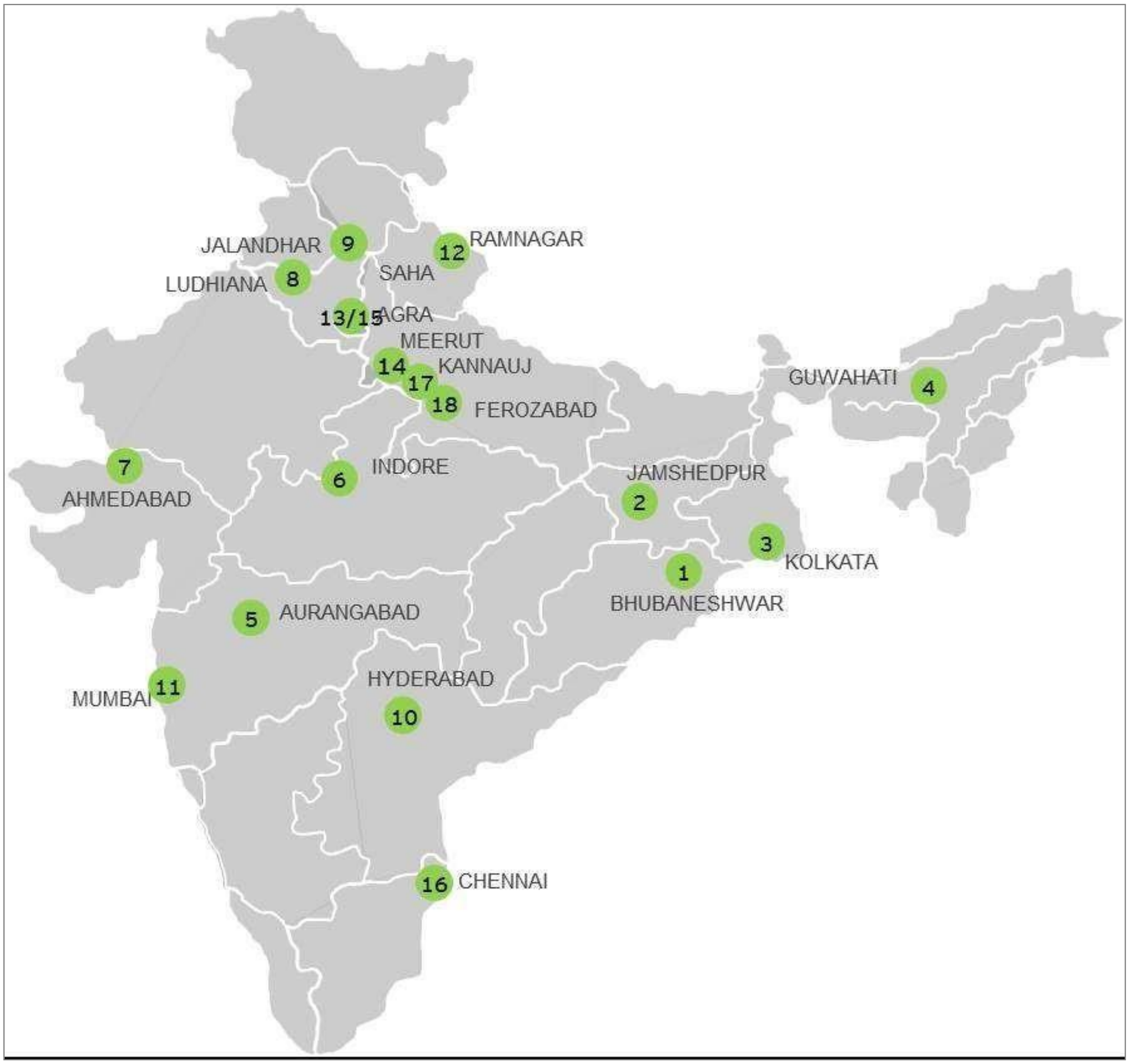


Figure 9: Site plan with ingress/egress and surrounding streets

LOCAL CONDITIONS

Typically in the Washington DC region the preferred method of construction is cast in place concrete. It is interesting that the structural system is mainly ordinary steel construction. With building height not being a design limitation, in respect to maximizing number of floors this may have factored into the method chosen. The site allows limited on-site parking and street parking is available for overflow parking. The surrounding area is mostly residential and street parking will provide sufficient parking spaces during construction.
Many construction recycling companies are available to the DC area, from Aggregate on site recycling to sorting and hauling services. The concrete from the existing facility was recycled during demolition, before the Design-Build Process started.

Subsurface and site conditions from the demolition posed a hazard to the surrounding area due to the groundwater level and large holes on the site. Certain areas ranged from 6 to 14 feet below grade and contained up to 10 feet of water. The soil bearing capacity does not require anything more than the use of geo-piers in certain locations. Spread footings are sufficient in most areas and for detached structures around sports facilities.

LEED CONSIDERATIONS

The WILO ENGINEERS PVT LTD is currently projected to meet LEED Gold under LEED for Schools Program. This rating will be achieved by focusing on Indoor Air Quality and Optimizing Energy Performance. A large portion of the roof (over 40%) will be extensive green roof gardens, while the remaining areas will be a highly reflective EPDM roofing material. The complete LEED Scorecard can be seen in Appendix A, however a summary can be seen below in Table 3.

LEED 2009 for Schools New Construction and Major Renovations			
Category	Points Planned to be Earned		
		Maybe	No
Sustainable Site		3	**5**
Water Efficiency		2	**0**
Energy and Atmosphere		0	**20**
Materials and Resources		1	**6**
Indoor Environmental Quality		0	**1**
Innovation and Design Process		1	**3**
Regional Priority Credits		0	**0**
TOTAL		7	**35**
	GOLD = 60 to 79 points		

CHAPTER 4
DATA ANALYSIS AND INTERPRETATION

Problem Identification

The use of Building Information Modeling, BIM, on VSPL WILO ENGINEERS PVT LTD was an effective way to facilitate trade coordination. The original decision to use BIM was due to the large amount of MEP systems in areas confined by low floor to structure heights and the desire to eliminate field clashes of these components. While this decision was a great way to coordinate MEP Systems there are many uses that could have made the BIM efforts more beneficial and allow for a smoother modeling process.
Building Information Modeling can be much more than a 3-D clash detecting model if the goals and uses are defined early on in a project. This critical industry issue of high initial costs associated with BIM can be justified if the end results and valuable inputs of Building Information Modeling are maximized. This topic was a Critical Industry discussion at the PACE Roundtables

Research Goal

To identify more uses of BIM that were not used and explain how they could have been beneficial to the project team throughout the entire building construction process, using examples within this report to support the opportunities for effective uses

Analysis 1 Introduction

Analyzing the maximization of BIM will be done with the assistance of the Building Information Modeling Execution Planning Guide, or BIM-EX Plan. This plan assists a project teams, identify valuable BIM uses, lay out communication paths, expected deliverables from certain parties at certain times, and establishes programs going to be used. The BIM-EX Plan includes many possible BIM uses; additional uses will be selected from these options. By setting up the BIM Process to allow the maximum amount of BIM uses to be capitalized on, the “low hanging fruit” or the most beneficial uses of BIM will increase. This analysis will also tie in with the Alternative Wall Assemblies and Mechanical Breadth Study, as examples of how specific BIM models can assist a project team when making Value Engineering and Design Development decisions

Building Information Modeling Execution Planning Guide

The Building Information Modeling Execution Planning Guide Defines Building Information Modeling (BIM) as “a digital representation of physical and functional characteristics of a facility.” Currently the implementation of BIM on projects is focused on the representation of physical characteristics and all too often the functional characteristics are not also fully considered. While this is an understandable occurrence due to the high initial costs, project teams are interested in justifying their uses for the model and can tend to dismiss what can be valuable a few years down the road. The owners on many projects are also concerned about high initial cost, but heard about BIM and often require a BIM model, without proper understanding of how and what a true BIM model that provides both functional and physical properties would cost or look like.

The BIM-EX Plan was developed to identify valuable BIM uses throughout the life cycle of the building, design the process of modeling, define deliverables or information exchanges and develop infrastructure to support the BIM process. This analysis will not discuss contracts, but focus more on the additional uses and benefits to the project team and owner.

BIM can provide increased design quality, greater prefabrication possibilities, improved efficiency field construction and added innovation during design and construction phases. Post construction benefits include; asset management, space visualization and maintenance scheduling. All of these benefits and costs to achieve these benefits are possible, when the process is design efficiently and effectively.

Building Information Modeling that takes advantage of all benefits of BIM is unrealistic; however, by designing a proper process and selecting project specific effective uses the initial cost and efforts are justified.

BIM Goals and Uses

In order to define BIM goals and uses the BIM-EX plan provides planning worksheets that define common and valuable uses. BIM Goals are a very essential part of the BIM EX Plan. Defining the main overall goals for implementing BIM the uses can be related back to check relevance and alignment with the project team and owner's goals. Through a series of importance rankings and parties involved the following BIM Goals and uses were recognized as BIM possible BIM uses that could be have been implemented on this project.

Plan- Site Analysis and Cost Estimation
Design- Design Reviews, 3D Coordination, Structural Analysis, Lighting Analysis, Energy Analysis, Mechanical Analysis, Cost Estimation
Construct- Site Utilization Planning, Construction System Design, 3D Coordination, Digital Fabrication, 3D Control and Planning, Record Modeling, Cost Estimation

Operate-

Building Maintenance Scheduling, Building System Analysis, Asset Management, Disaster Planning, Record Modeling, Cost Estimation

The most valuable BIM use implemented on the project would be the 3D Coordination. The ability to run clash detections and visualize three dimensionally field construction conflicts was essential in meeting the demanding schedule with tight constraints on space and the amount of systems in a single area. By setting up proper communication paths and information exchanges the ability to maximize the BIM investment and justify the cost with tangible results to the owner is present.

Streamlining Communication Paths

There are a number of worksheets and exercises clearly laid out in the BIM EX plan. Through experience in

BIM/IPD Studio, these communication paths facilitate the information exchanges well. The ability to specify and select multiple program compatibility prior to construction design work begins allows the total project design and construction team to take full advantage of the desired BIM uses. Without these proper information exchanges and paths, programs separate firms use may not always be compatible with down-stream design and operations teams.

Mapping out this process is essential to any project. Each goal and use identified must be mapped to represent the process of each use working towards a goal. Information exchanges must also be designed for each use to ensure the use can be maximized properly. An information exchange defines the inputs and outputs between each step in the process.

The infrastructure to support BIM is a vital key to success. If language and wording of contracts is not done properly to allow the planning process to work it becomes null and void. Besides contracts there are certain computer and technology resources required to support BIM. VSPL Project Team used an FTP site as an effective means of information exchange.

Adding Value with BIM-EX

Value is a term that can have a loose meaning. Generally value is perceived as dollar signs or a price tag on the building, but value can mean much more than the value on the day of turn over or at the contract signing. Value can be built into a project by providing the owner with a highly efficient building that they actually can know how to maintain and operate complex systems. Part of adding value that a building owner can grasp and take advantage of is Operations and Maintenance Models. The ability to provide a comprehensive Building Model that provides the maintenance and operations teams with valuable physical and functional information could be the most valuable BIM use that will directly impact the owner throughout the life cycle of the building.

Electronic As-built drawings are also very valuable for future renovations or even rearrangements of furniture can be vied three dimensionally prior to and investment. The ability to open one program and Find all required information for any room from paint colors and wall square footage to filter size and maintenance intervals for mechanical systems. The time savings and ability to respond as quickly as possible when issues arise is a very beneficial use of Building Information Modeling.

BIM and Developing Alternative Construction Techniques

As part of Analysis 1 the use of BIM has been demonstrated throughout the rest of this report. Using Autodesk programs and works, with the models provided by the VSPL Project Team, analyzing multiple system alternatives became more viable.

Revit Architecture allowed for quantity take offs for exterior wall construction alternatives estimate. A guide of how this was done can be found in BIM Influences of Analysis 3. Revit MEP was used to determine the Mechanical system load changes with the alternative exterior wall assemblies in the same section is an overview on how that was possible as well. For Alternative Steel Truss Analysis 4 Navisworks was used with the fully coordinated 3-D Building MEP and Structural system to better explore the feasibility of splicing the truss.

Maximizing Building Information Modeling Conclusion

The Building Information Modeling Execution Planning Guide provides a great tool to implement BIM to its fullest potential on a project. The summary of implementation in Analysis 1 provides information of further uses and implementation. Throughout the following analyses evidence to support the further implementation of BIM to maximize building value and quality is present

ANALYSIS 2: OPTIMIZING VALUE ENGINEERING

Problem Identification

Analysis two looks at some possible Value Engineering (VE) Solutions to clear the hurdle of "LEED" elements being excluded from the VE Process. The green roof will be at the center of this analysis and investigation onto the impacts of the green roof on other building systems. Value Engineering that dismisses LEED elements can unknowingly overlook cost effective benefits that can add real value and reduce total project costs and schedule.

Research Goal

To identify the costs and impacts on other systems associated with elimination of the green roof. To develop a way to ensure that the LEED points can still be claimed to achieve LEED Gold at a lower cost and within a shorter duration. Determine the possible missed opportunities that occur when LEED elements are not properly evaluated during the total project Value Engineering Process.

Analysis 2 Introduction

This analysis started with an investigation into the green roof. The properties of the green roof analyzed included: cost, thermal efficiency, storm water storage capacity, weight, and construction duration.
Upon investigation into these properties, the impacts of eliminating the green roof on other systems were considered. The storm water retention of the green roof will affect the greater system sizing and capacity. Weight reduction provides potential for a reduction of the steel framing members, which will be studied as a breadth topic. Thermal properties of the green roof system are very complex and will require careful and creative considerations. Construction duration for the roof system can be reduced dramatically. Finally, cost will be studied with changes and impacts of the other systems to determine the viability of eliminating the green roof. To conclude this analysis taking LEED certification, Value Engineering and Schedule Reduction into consideration will determine the risks and opportunities associated with Optimizing Value Engineering.

				Catchment Area Parameters				Major Firms		Tech Inst.		Presence of state/pvt TR	
		100			30		20		20		10		20
State	Industry	Location	Net Score	Units	Unit Score	ITI/PT	ITI/PT Score	Number	Score	Number	Score	TC of State Govt/ Pvt Tool Room	TC-State Govt/ Pvt Score

LA Index Score= Catchment Score * Presence of TC Score

Green Roof Background VSPL WILO ENGINEERS PVT LTD's design incorporates and extensive green roof as part of the roof system.
Extensive green roof is an innovative use of the thermal and moisture properties associated with soil and plant life material to create a sustainable feature in many modern day construction projects. This particular type of Green roof, extensive, provides
Capacity of only up to 6" of soil

Top of the roof. In Figure 12, a simplified diagram of the extensive green roof utilized at VSPL is shown to allow the visualization of a basic extensive green roof assembly.
The soil medium layer as designed is planned to be four inches and the system selected for use allows the base layer of the assembly to be insulation directly on Concrete, which is not typical for most green roof assemblies. The detailed assembly designed specifically for VSPL WILO ENGINEERS PVT LTD is shown in Figure 13.

Figure 12: Detailed Actual Extensive Green Roof Assembly

Green roofs provide many advantages and disadvantages that must all be considered when deciding if it is a suitable option for a roofing assembly. A few advantages to green roofs are: storm water management properties, acts as a thermal mass, ability to clean the air and possible long term energy savings. Some disadvantages are: high initial costs, increased roof dead loads, maintenance concerns and costly repairs if required. Some of these pros and cons associated with green roofs will be discussed further in the following sections. The green roof designed will cover 45,502 so with an additional 31,648 so draining onto the green roof area. A total of 77,150 so of roof area runoff will be controlled by the green roof. The 31,648 so and the area that drains onto the green roof will be an EPDM reflective roofing materials, 55,904 sf.

Green Roof Estimate

The green roof estimate was generated by first looking at case studies of green roof costs in the DC Region. The use of six case studies resulted in $25.57 per square foot for the green roof installation. Table 4 shows the case studies and the average cost per square foot costs. This cost did not include the waterproofing membrane so an additional $2.50 per square foot will be added in order to account for this cost. The total cost per square foot that will be used to compare the green roof system costs to replacement with reflective EPDM will be $ 28.07 per square foot. The cost used for EPDM price per square foot was researched and the range for installed Reflective EPDM roofing is $ 3.00 to $ 4.50 per square foot. With the green roof being at the higher end of national averages for installation costs, the
$ 4.50 cost per square foot for reflective EPDM roofing will be used.

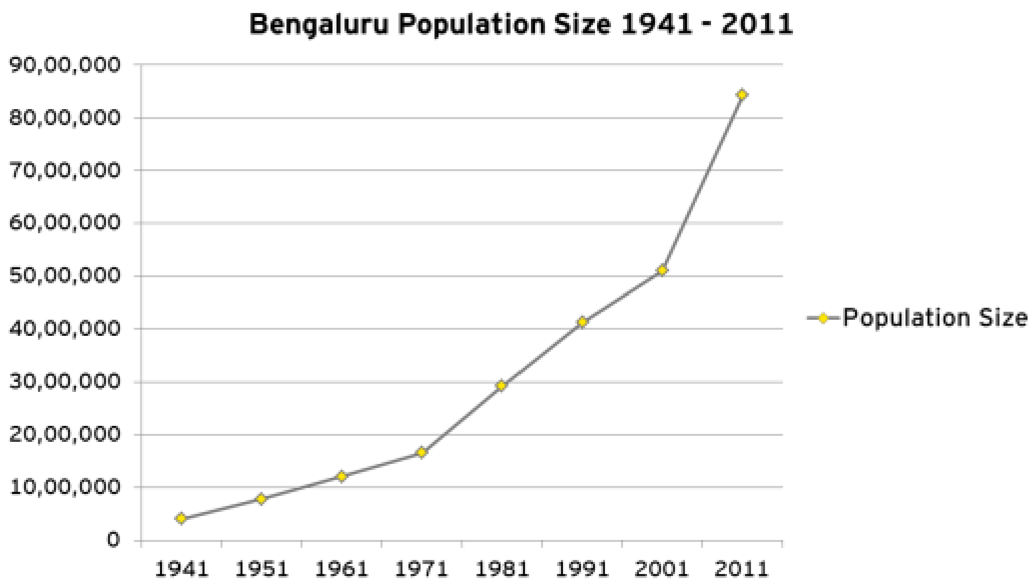
Durations and Schedule Reduction Scenario

The current schedule allowed 60 days for the installation of the green roof on all three bays of the building. 21 for the Center, 20 for the North and 19 for the South, however, the actual green roof, orplant material installation is not on the critical path of the project. The waterproof membrane is the critical portion of the roof enclosure, which will still be the same or a similar process for the EPDM reflective roofing membrane.

Thermal Property Considerations

Thermal properties of a green roof are very complex and difficult to quantify. The R-value of soil can be taken into account, though it is poor, it does not represent accurately all the benefits that the green roofthermally provides. The R-value does not take into account the thermal mass that the soil provides to the construction assembly, creating a longer period of time for heat to transfer to or from the conditioned space. However, this report does not allow the time and depth needed to take this into account while comparing thermal properties; it is an important note to make about the system, but was not accounted for in the alternative design proposal. Equally as important to note about the EPDM roofing membrane is its reflective properties that are not taken into account in this proposal as well.

The as-is design of the green roof has a combined R-value of 43. The alternative assembly being proposed will provide an R-value of 50 and become consistent with the EPDM reflective roofing material. Table 6: R and U value Assembly comparisons. Table 6 breaks down the assembly of the greenroof system and alternative system by R-value. However, when looking into these systems further the Solar Reflectance and Remittance should be taken into account, it was not included in this report.



To determine roughly the amount of BTU/hr. that will be transferred through the 45,502 so of green roof the winter extreme and summer extreme temperatures were used to calculate heat transfer per hour. In order to calculate the heat transferred through the green roof area and potential savings ASHRAE Handbook Fundamentals 2009 was used to determine winter and summer extreme temperatures. These numbers were used to calculate Change in Temperature from one side of the assembly to the other according to the corresponding indoor design temperature. The additional R-value is gained by a proposed Fireproofing system that provides an R of 3.33 per inch and 2.5 inches are required for the 1 hour rating on the underside of the metal decking. The product is Blaze shield II and can be installed for 10 to 15 % less than the typical cementations Spray-on Fireproofing, appendix B Shows the product data sheets.

Greater and Potable Water System Impacts

Another LEED designed element at VSPL WILO ENGINEERS PVT LTD is the Grey water reuse system. The removal of the green roof will have a large impact on this system. One of the benefits to the green roofwas its ability to retain storm water, filtering it and releasing it slowly. However, the Grey water system is another system that assists in Storm Water Management. Part of considering the removal of the green roof was the impacts on other systems. In order to Optimize Value Engineering, redundancy of systems to solve the same problem may not always be the best solution. By expanding the capacity anduses of the grey water system can provide more than assistance in Storm Water Management.

Upon investigation into the total water supply and management, both potable and non-potable as wellas Storm Water, a number of interesting discoveries were made. The first being the redundancy of the green roof and grey water system, secondly the grey water system and conventional plumbing both required for toilet flushing. Toilet flushing also contributes the highest demand for the sizing of the water main coming to the building from the street. The next few sections will explain and justify, in terms of water use, the removal of the green roof, expansion of the grey water system, grey water and trickle tank concept for toilet flushing, as well as downsizing the main water line from the street.

Green Roof Storm Water Storage Capacities

An advantages that will be lost when removing the green roof will be its ability to retain water, filter it and release it slowly. The water storage capacity of the roof is calculated using the Area, Voids ratio of the soil and the thickness. The Total Capacity of the green roof was 6,006 cuff, or 44,928 gallons. Using the short cut routing method an engineer on the project determined that the maximum volume that would be required during either a 2 year or 15 year storm event would be 3,540 cuff and 4,656 cuff respectively. This means that the system had well over the required capacity for a 15 year rain event.

Green Roof Storage Volume Capacity			
Square Footage	Voids Ratio (%)	Thickness of Soil (ft.)	Storage Volume (cubicfeet)
45,502	0.4	0.33	6,006

In addition to the green roof area controlling drainage for 45,502 so, there is also a portion of the roof that drains onto the green roof. 31,648 so of EPDM roof area drains onto the green roof making the total area of roof drainage controlled by green roof 77,150 so, or 76%.

Grey water System Design Considerations

The current grey water system has a capacity of 30,000 gallons, or 4,011 cf. two tanks make up this storage capacity, one a 10,000 gallon tank and the other a 20,000 gallon tank. This is not enough capacity to satisfy the replacement of the green roof entirely. Therefore an additional 20,000 gallon tank will need to be installed, increasing the total system capacity to 50,000 gallons or, 6,685 cf. In addition to the current design of the grey water system tanks and pumps another change can add real value to this project. By adding a main line into the tanks and automatic controls that will never allow the tanks to fall below a minimal level required for all toilet flushing, the redundancy of the plumbing System can be eliminated. The concept of slowly filling the tanks as needed when storm water and grey water re-use systems are not providing enough to make the system usable, the ability to downsize the potable water main becomes possible. By maintaining a minimal level in the tanks and using the system for toilet flushing.

The current design for the water main coming into the building was based on the criteria in Table 9. 5,355 gallons per minute were designed for toilet and urinal flushing, while only 394 gallons per minute make up the rest of the domestic water demand.

Fixture	**GPM/fixture**	**# of Fixtures**	**GPM**

Faucet (kitchen sink)	2.2	56	123
Faucet (lavatory)	1.5	118	177
Shower	2.5	23	58
Faucet (Utility Sink)	4	9	36
Urinal (flush)	35	29	1015
Toilet (flush valve)	35	124	**4340**
TOTAL GPM			**5749**
Total Toilet Flushing			**5,355**

This large portion of water demand will be able to be met entirely by combing the expansion of the grey water/rain storage collection with a smaller water main connection to slowly fill the storage tanks and act as buffers for this large demand. The plumbing engineer would have to study the possibility of downsizing the water main upon proposal of this system. If the water main can be reduced after looking at demand for fire suppression systems and worst case scenarios for the buffer tanks getting minimal rainfall amounts. The location of the tank will be to the right of the current location of the grey water tanks. Figure 13 shows the original design and location of the two water storage tanks under the parking lot at the south of the complex. To the east or right of the tank is where the additional proposed 20,000 gallon tank will also be installed. Table 10 displays a breakdown of estimated additional costs of installing the additional tank.

Additional 20,000 Gallon Storage Tank Costs		
	Impact on Schedule	Cost
Added Excavation	2 Day	$ 15,000
Tank (20,000 gal)		$ 10,000
Additional Plumbing	1 day for connections	$ 1,000 allowance
TOTAL		**$ 26,000**

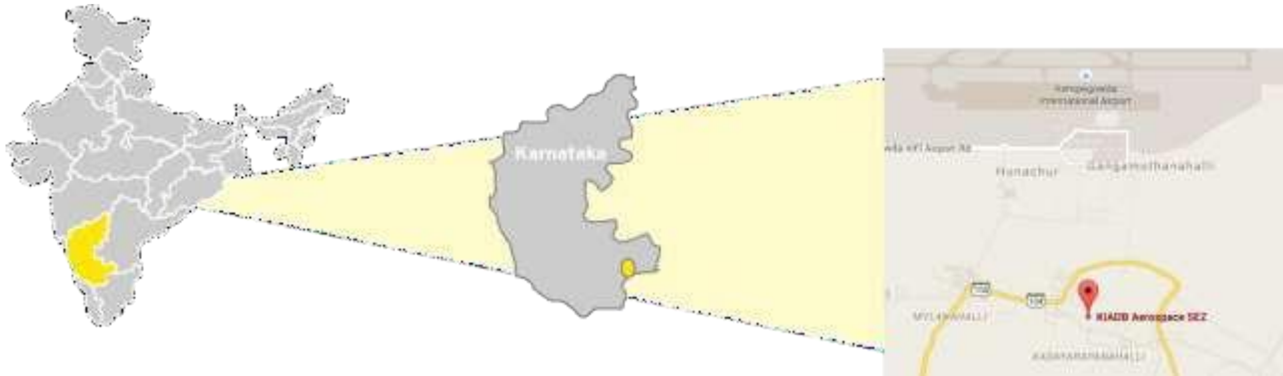


Figure 12: Original Design and Location of Grey water Tanks

Expected Rainfall

Table 11, shows the average monthly rainfall in the DC area. These averages were used to determinehow much rain water can be expected to be collected per month. The rainiest month provides on average 8,049 gallons per day. With a storage capacity increased to 50,000 gallons the ability to significantly reduce the amount of potable water being used for toilet flushing is greatly reduced.

Average Monthly Rainfall from 1971 to 2010 Reagan Airport					
	Inches	Feet	Roof Area	CF	Gallons
January	3.21	0.268	101406	27,126	202,917
February	2.63	0.219	101406	22,225	166,253
March	3.60	0.300	101406	30,422	227,571
April	2.77	0.231	101406	23,408	175,103
May	3.82	0.318	101406	32,281	241,478
June	3.13	0.261	101406	26,450	197,860
July	3.66	0.305	101406	30,929	231,363
August	3.44	0.287	101406	29,070	217,456
September	3.79	0.316	101406	32,027	239,581
October	3.22	0.268	101406	27,211	203,549

Byre moving the green roof the potential to lose thermal efficiency may become difficult

November	3.03	0.253	101406	25,605	191,539
December	3.05	0.254	101406	25,774	192,803
MAX	3.82		MAY	32,281	241,478
MIN	2.63		FEB	22,225	166,253
AVERAGE	3.28			27,711	207,289
TOTAL				332,527	2,487,473

depending on how much the mechanical system designed, relied on the thermal mass of the green roof. In order to combat this issue, the proposal to use a higher R-Value spray on fire proofing is suggested. The impact on cost for this spray on fireproofing is minimal and claims to be at a 10% to 20% reduction of normal cementations spray on fireproofing. If additional insulation for the green roof area, 45,502 so, is needed an additional 2 2” layers for rigid insulation would cost under $80,000. That price can be cut in have if only a single layer is required per the mechanical engineer’s recommendation.

Water efficiency points will also not be affected due to the green roof removal, if the expansion of the grey water system is implemented. The two systems, while quite different, work to combat the same problems of rapid discharged storm water and water use efficiency.

Effects on LEED Criteria

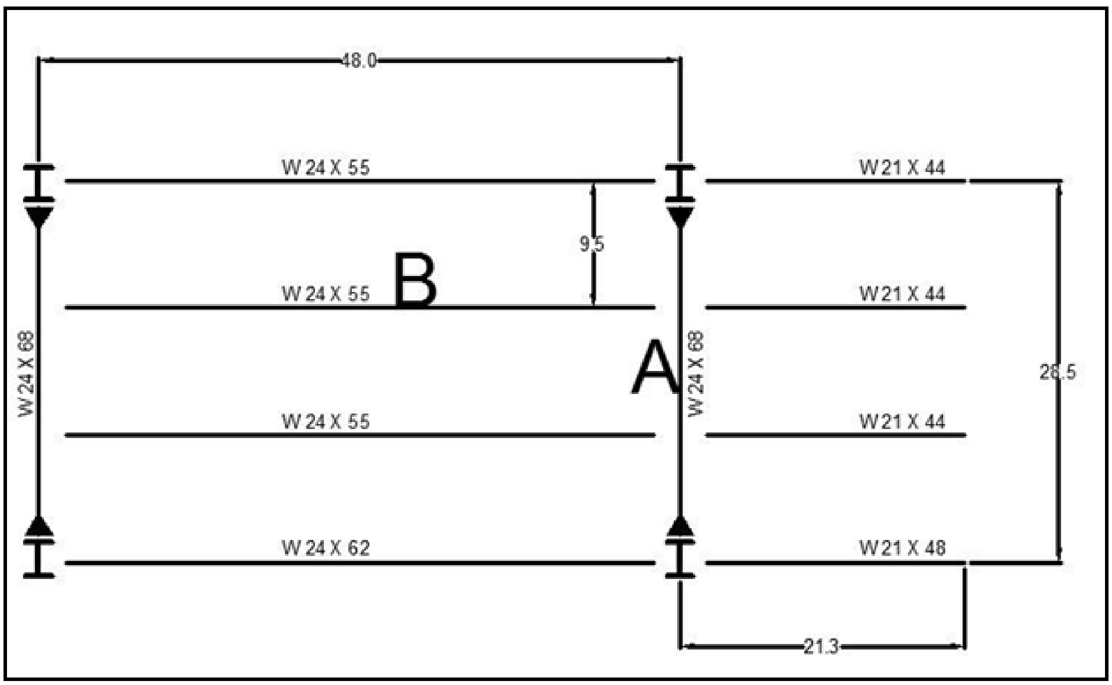
By removing the green roof the potential to lose thermal efficiency may become difficult depending on how much the mechanical system designed, relied on the thermal mass of the green roof. In order to combat this issue, the proposal to use a higher R-Value spray on fire proofing is suggested. The impact on cost for this spray on fireproofing is minimal and claims to be at a 10% to 20% reduction of normal cementations spray on fireproofing. If additional insulation for the green roof area, 45,502 so, is needed an additional 2 2” layers for rigid insulation would cost under $80,000. That price can be cut in have if only a single layer is required per the mechanical engineer’s recommendation.

Water efficiency points will also not be affected due to the green roof removal, if the expansion of the grey water system is implemented. The two systems, while quite different, work to combat the same problems of rapid discharged storm water and water use efficiency.

Structural Breadth- Impacts of Removing Green Roof

By removing the Green Roof the Dead load is significantly decreased on the structural steel roof framing members. This breadth analysis will evaluate the potential to downsize the steel members in a roof section over the south building, above the auditorium between columns K-11 to 15 and H-11 to 15.
Figure 15 below shows the original design of a roof structural bay. Girder A and Beam B will be analyzed for potential reduction due to green roof deletion. The W 21x44 beams are only partially shown to indicate the

tributary area for Girder A.



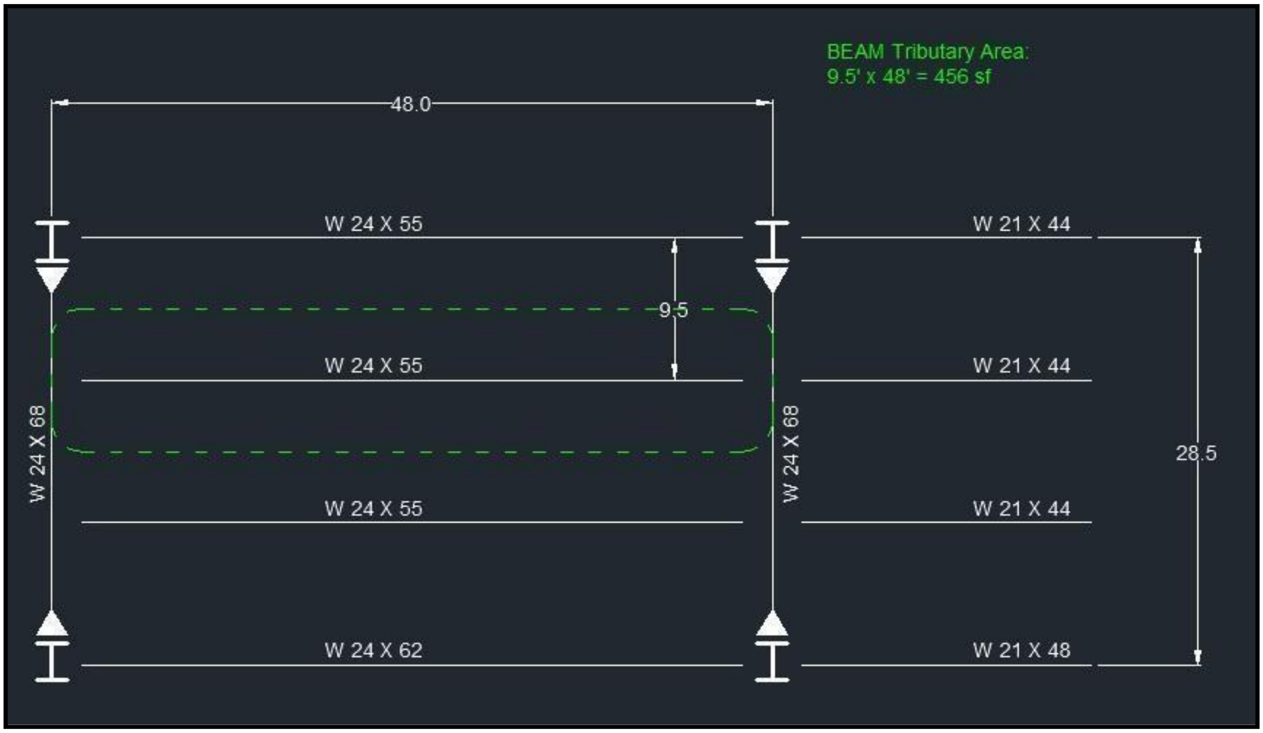


Figure 12: Roof Framing Members Original Design

Figure 13: Beam B Tributary Area and Original Member Sizes

Loading Condition

W 24x55 Loading Calculations
Factored Load: 1.2(30 PSF + 30 PSF) + 1.6(21) = 105.6 PSF
Load (PLF): 105.6 PSF x 9.5' (width of Trib. Area) = 1003.2 PLF (1.003 KLF)
Load per Support: (1.003 KLF x 48') / 2 Supports = 24.072 kips (at each support)Bending Moment: $w_u l^2/8$ = (1.003 KLF) x (48') ^{2}/8 = 288.9 kip-ft.
W 24x55 Max Bending Moment: **503 > 288.9 (57%) OK**

Deflection Calculations
Load: 60 PSF + 21 PSF = 81 PSF, 81 PSF x 9.5' = 769.5 PLF
Deflection: $(5wl^2) / (384EI)$ = 5(769.5 PLF) (48') ^{4}(1728 Conversion) / [(384) (29,000,000) (1350) = 2.34"
Max Allowable Deflection Total Load: L/240 = *48' x (12"/1') +/240 = **2.4">2.34" OK**

Reduced Load Calculations

Factored Load: 1.2(30 PSF) + 1.6(21) = 69.6 PSF
Load (PLF): 69.6 PSF x 9.5' (width of Trib. Area) = 661.2 PLF (.661 KLF)
Load per Support: (.661 KLF x 48') / 2 Supports = 15.87 kips (at each support)Bending Moment: $w_u l^2/8$ = (.661 KLF) x (48') ^{2}/8 = 190.4 kip-ft.
Maintain 57% for unknown factors: 190.4 + 57% = 299 kip-ft.W 21x44 Max Bending Moment: **358 kip-ft. > 299**
W 18x40 Max Bending Moment: **294 kip-ft. «» 299**

Reduced Load Deflection CalculationsW 21x44
Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 9.5' = 484.5 PLF
Deflection: $(5wl^2)$ / (384EI) = 5(484.5 PLF) (48') ^{4}(1728 Conversion) / *(384) (29,000,000) (843) = 2.36"
Max Allowable Deflection Total Load: L/240 = *48' x (12"/1') +/240 = **2.4">2.36" OK**

W 18x40
Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 9.5' = 484.5 PLF
Deflection: $(5wl^2)$ / (384EI) = 5(484.5 PLF) (48') ^{4}(1728 Conversion) / *(384) (29,000,000) (612) = 3.26"
Max Allowable Deflection Total Load: L/240 = *48' x (12"/1') +/240 = **2.4"<3.26" NOT OK**

In the bay studied the W24x55 can be reduced to W21x44 and the W21x44 beams to the right of the bay can be reduced to W18x40s. The calculations for this second reduction can be found in Appendix C.The reason these beams were analyzed was to allow the reduction of the Girder A. The reduced beams are shown in Figure 17 with the possibility to resize the Girder to be investigated in the rest of the Structural Breadth.

Figure 14: Reduced Beam Designations Influencing Girder A

Sectio n	Quantity/Value
Area	
Total geographical area	2196 Sq. km
Administration	
Tehsil	4
Villages	699
Land use pattern	
Total area	2,17,410 Hectares
Total irrigated area	63,800 Hectares
Population (census 2011)	
Total population	**95,88,910**
Men	50,25,498
Women	45,63,412
Literacy	
Total literate	87.67%
Men	91.01%
Women	84.01%
Industries	
Registered MSME units	4,349
Employed persons	48,576

Girder Design Loads and Reduction

In order to re-size Girder A an investigation into the existing design was first done to explore the possibility of downsizing at all. Figure 18 Displays the Tributary Area and design of the steel memberswith the green roof loads accounted for.

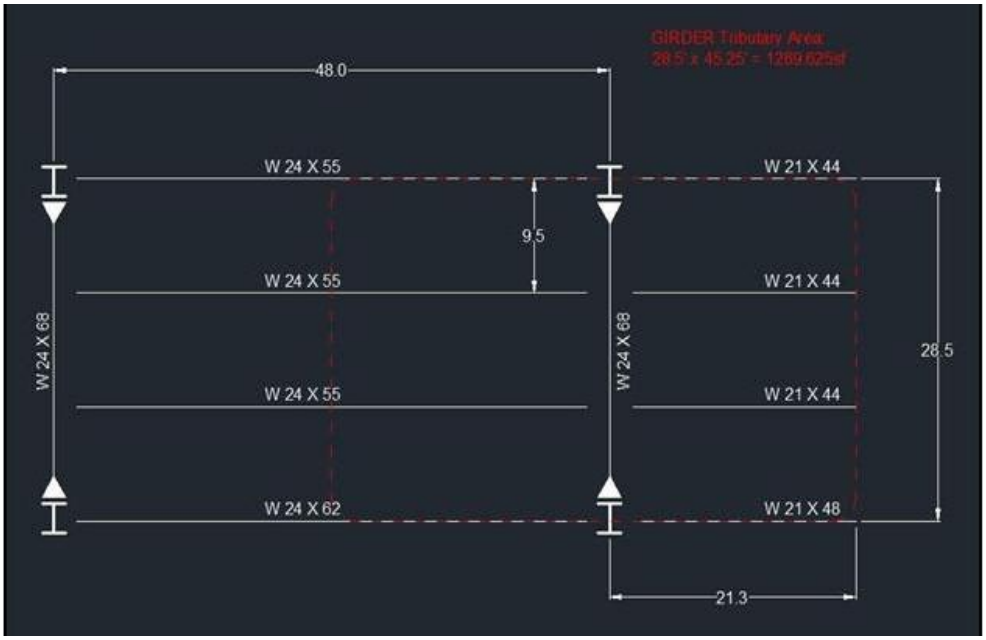


Figure 15: Girder a Tributary Area with Original Member Sizes

W 24x68 Loading Calculations
Factored Load: 1.2(30 PSF + 30 PSF) + 1.6(21) = 105.6 PSF
Additional Self Weight of Connecting Beams: 105.6 + 3.5 PSF = 109.1 PSF
Load (PLF): 109.1 PSF x 45.25' (width of Trib. Area) = 4936.8 PLF (4.94 KLF)
Load per Support: (4.94 KLF x 28.5') / 2 Supports = 70.4 kips (at each support)Bending Moment: $w_u l^2/8$ = (4.94 KLF) x (28.5')^2/8 = 501.6 kip-ft.
W 24x68 Max Bending Moment: **664 kip-ft. > 501.6 kip-ft. OK** (75%)

Deflection Calculations
Load: 60 PSF + 21 PSF = 81 PSF, 81 PSF x 45.25' = 3,665.25 PLF
Deflection: ($5wl^2$) / (384EI) = 5(3665.25 PLF) (28.5')^4(1728 Conversion)/*(384) (29,000,000) (1830) = 1.03"
Max Allowable Deflection Total Load: L/240 = *28.5' x (12"/1') +/240 = **1.43">1.03" OK**

Reduced Load Calculations
Factored Load: 1.2(30 PSF) + 1.6(21) = 69.6 PSF
Additional Self Weight of Connecting Beams: 69.6 + 2.96 PSF = 72.6 PSF Load (PLF): 72.6 PSF x 45.25' (width of Trib. Area) = 3285.2 PLF (3.285 KLF)
Load per Support: (3.285 KLF x 28.5') / 2 Supports = 46.8 kips (at each support)Bending Moment: $w_u l^2/8$ = (3.285 KLF) x (28.5')^2/8 = 333.5 kip-ft.
Maintain 75% for unknown factors: 333.5 + 75% = 416.9 kip-ft.W 21x55 Max Bending Moment: **473 kip-ft. > 416.9 kip-ft.**
W 18x55 Max Bending Moment: **420 kip-ft. > 416.9 kip-ft.**

Reduced Load Deflection CalculationsW 21x55
Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 45.25' = 2307.8 PLF
Deflection: ($5wl^2$) / (384EI) = 5(2307.8 PLF) (28.5')^4(1728 Conversion) / [(384) (29,000,000) (1140) = 1.04"
Max Allowable Deflection Total Load: L/240 = [28.5' x (12"/1') +/240 = **1.43">1.04" OK**

W 18x55
Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 45.25' = 2307.8 PLF
Deflection: ($5wl^2$) / (384EI) = 5(2307.8 PLF) (28.5')^4(1728 Conversion) / *(384) (29,000,000) (890) = 1.34"
Max Allowable Deflection Total Load: L/240 = *28.5' x (12"/1') +/240 = **1.43">1.33" OK**

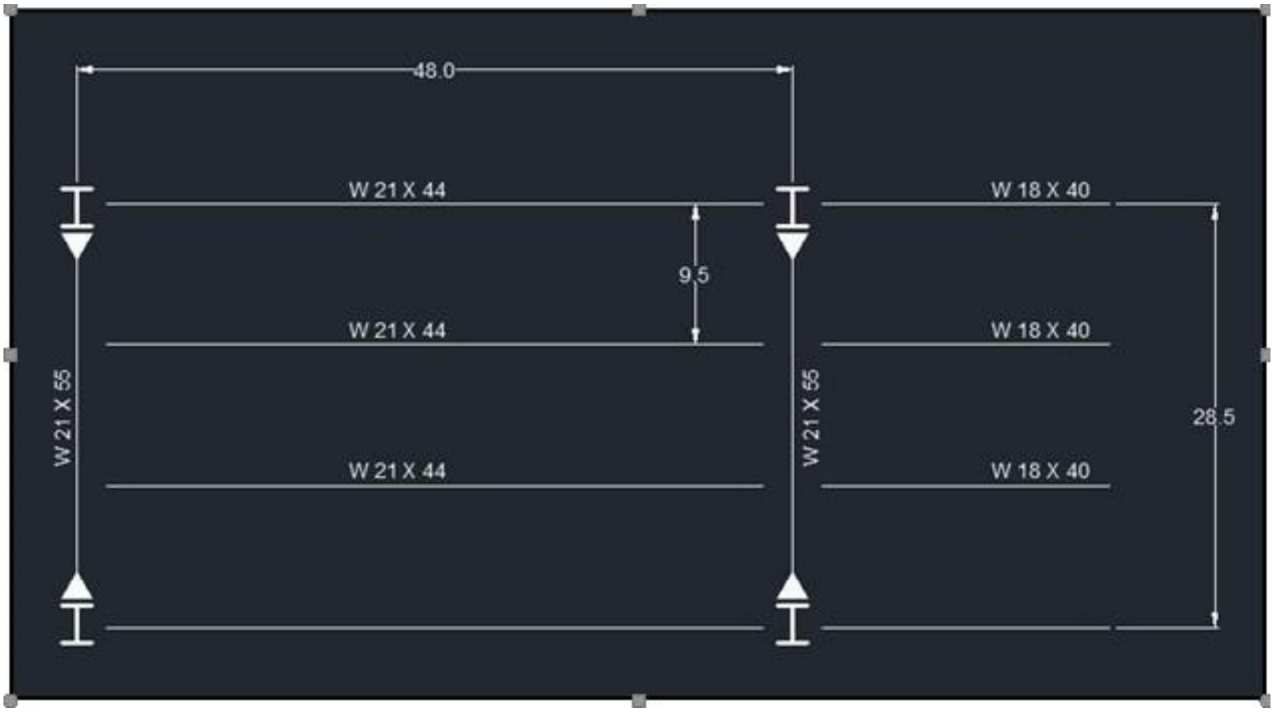


Figure 15: Resized Beams and Girders

Figure 19 shows the reductions able to be made to the structural steel with the deletion of the green roof loads. On average each the beams were able to be reduced by 16%. Upon verification by the structural engineer on the project a reduction of all steel that was originally under green roof area could be reduced by 16% by weight. Removing the green roof would result in the 44% of originally designed roof structure reducing its structural steel member total weight by 16 to 18 tons and saving nearly $50,000.

Optimizing Value Engineering Conclusion

Analyzing and expanding the Value Engineering Process at VSPL WILO ENGINEERS PVT LTD in this analysis yielded three important points. Excluding designated LEED elements from the VE Process poses a risk toimprove the building while reducing costs. Removing a green roof can add benefits that outweigh the advantages it provides. Grey water systems and rainwater harvesting are viable ways to reduce water usage and waste. Overall the VE Options discussed throughout Analysis 2 has the ability to save $1,096,000 while not adding any time to the overall project schedule.

VE Option	Cost
Green Roof Deletion	$ 1,072,480
Additional 20,000 gal. tank	$ 26,000
Reduced Roof Steel Members	$ 50,000
TOTAL	**$ 1,096,000**

Table 12: Value Engineering Cost Summary

ANALYSIS 3: ALTERNATIVE EXTERIOR WALL ASSEMBLIES

Problem Identification

The exterior enclosure is a major schedule risk to the projects timely completion. The current design forthe exterior walls is exterior masonry panels with CMU backing. Issues that come from use of a CMU wall are its duration, weather impacts, cleanliness and ability for changes and acceleration during MEP rough in. The weather is directly related with CMU construction. When the temperatures reach a certain point it must either be completely shut down or costly temporary heat and tents must be used. The process also tends to clutter a site and requires vigilant "house cleaning" efforts. It also makes the MEP rough in cumbersome, especially the in-wall electrical conduits. The path to this topic began with asite visit, during which the masons were laying block and having to lift the blocks over the conduits stubbed up out of the walls.

Research Goal

To develop and chose a more jobsite friendly and efficient exterior enclosure wall assembly, that has potential to accelerate the schedule and eliminate risk of delaying the exterior enclosure construction.The impact of the alternative system must also provide little to no impact to the architecture, while maintaining or improving the material properties and their impact on other building systems.

Analysis 3 Introduction

The analysis of alternative exterior wall assembly options includes comparison of cost, schedule time, thermal properties, through a Mechanical Breadth study, and feasibility. The two alternatives that willbe assessed are an innovative product, Metal Stud Crete, and regular metal stud system. Both these options are only being assessed to replace the CMU Back Up portions of the exterior wall. The square footage of this area is 62,050 square feet. After the two systems are analyzed a summary and recommendation will be made.

Original Design - CMU Back Up

The original design documents call for a regular CMU Wall Back Up with the 4" Precast exterior finish on62,050 square feet of exterior wall at VSPL WILO ENGINEERS PVT LTD. Reasons for proposing to change this element are the schedule risks associated with masonry construction, the need for integrated and simultaneous construction with multiple trades and reduction of on-site congestion.

The project team allowed 90 days for the CMU wall exterior enclosure to be completed. The

begin datestarting in the center bay was September 23, 2010 and end on November 2, 2010. The North Bay was schedule for October 18, 2010 to December 23, 2010 and the south bay from December 16, 2010 to January 21, 2010. The risk with laying CMU walls during the winter can be great. When the ambient temperature drops below 40 degrees F additional precautions must start to be implemented. More drastic measures are required as the temperature drops lower, starting with simply having to heat the mortar to having to heat the CMU Blocks or even to the need to “tent” the areas under construction.
This comes with a large price tag and decreased efficiency.

Laying CMU walls and simultaneously installing conduits and boxes for electrical and other components is not an efficient process. The two crews working together can become frustrated with the other and matching pace with another trade will always require one of the trades to progress slower than typicallyaccepted. This risk of feuding trade contractors, and decreased efficiency make the use of CMU Back Upwalls questioned as the best solution.

CMU Construction processes tend to clutter a site and increase the costs of general cleaning and maintenance of an organized safe site. The use of scaffolding can begin to limit safe site and building access. Safety concerns do not allow workers to be near the base of the scaffold limiting the amount ofwork that can be done in a specific area of the site. The mortar mixing stations along with stockpiles ofmaterial require a sizable area. Cutting masonry units creates dust, and tripping hazards raising safety risks and concerns. Broken and cut-off pieces of the CMU blocks also require continuous clean up.
Storing of CMU on site also can take up a large area.

An excellent solution to reduce or eliminate all or most of these issues is desirable.

Metal Stud Crete

Metal Stud Crete System is a structural, composite wall panel system combining regular hard rock concrete, approximately two inches thick, on exterior side, constructed as a composite with standard light-gauge steel framing on the interior. Metal Stud Crete’s patented structural, composite shear connector bonds these two to create a load bearing, wall designed to carry floor and roof loads and rapidly enclose a building. For VSPL WILO ENGINEERS PVT LTD the Metal Stud Crete is being proposed as an alternative to the exterior CMU Backup walls. Metal Stud Crete can be prefabricated within 500 miles ofany site in the United States. Pricing information was found by contacting Earl Corporation; the company that makes Metal Stud Crete, for the DC Region an average of $ 32 per square foot was given. This price includes Prefabrication, Transportation and Erection. Below, the prefabrication process of theprecast panels is shown, photos and typical details, courtesy of Earl Corporation.

Concrete being poured between stud cavities, leaving stud, (interior) exposed for ease of rough-ins, insulation and gypsum wallboard
Hanging Metal stud framing, welded wire fabric
And shear connectors laid out on casting beds.

Metal Stud Crete and LEED

Metal Stud Crete also qualifies for a number of LEED Credits. They use a large portion of recycled content and regional materials to construct lighter weight pre-cast panels that offer innovation andopportunities to increase building envelope efficiency.

Materials and Resources:

Recycled Content MR
4.0 Regional Materials
MR 5.0

Energy & Atmosphere

Steel Stud Cavities allow for variety of insulations

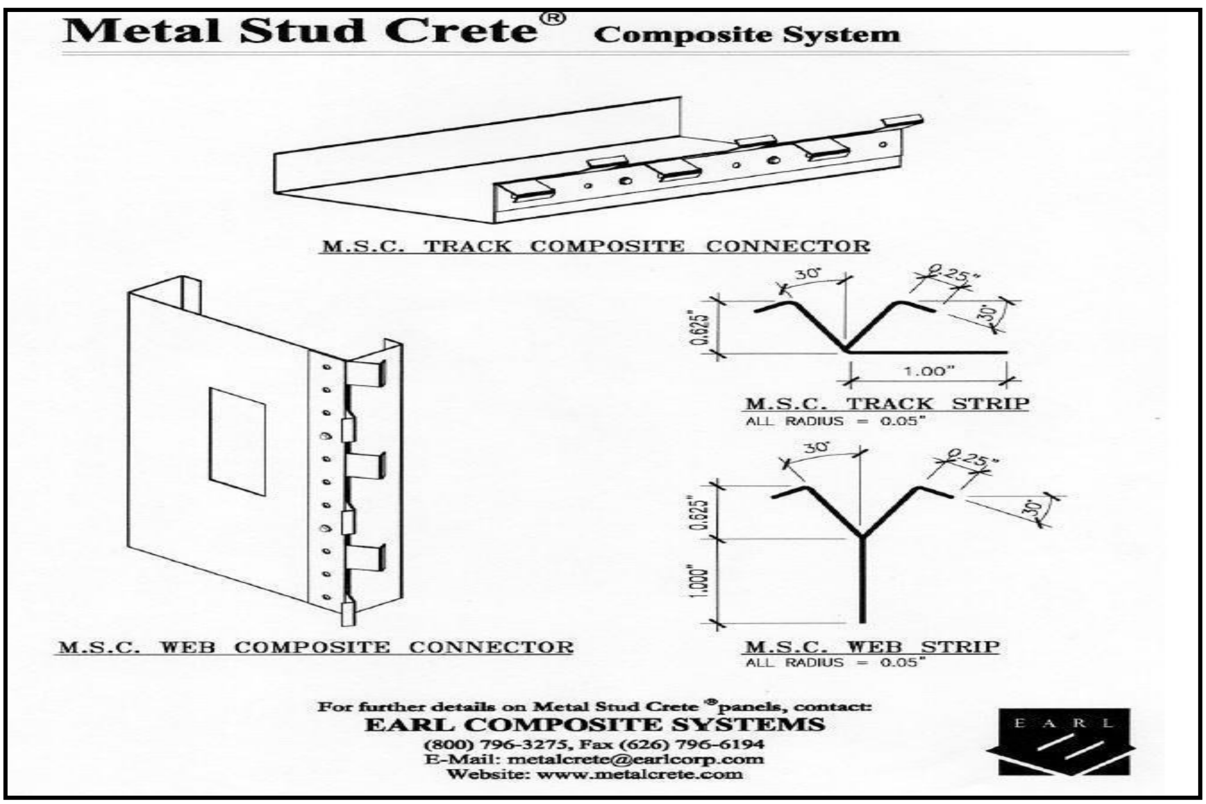
Innovation & Design Process

Exceptional Performance
-Resource Conservation (65% concrete and reinforcing steel
-Conserve resources in Structure (Reduced Dead Load on Foundation)

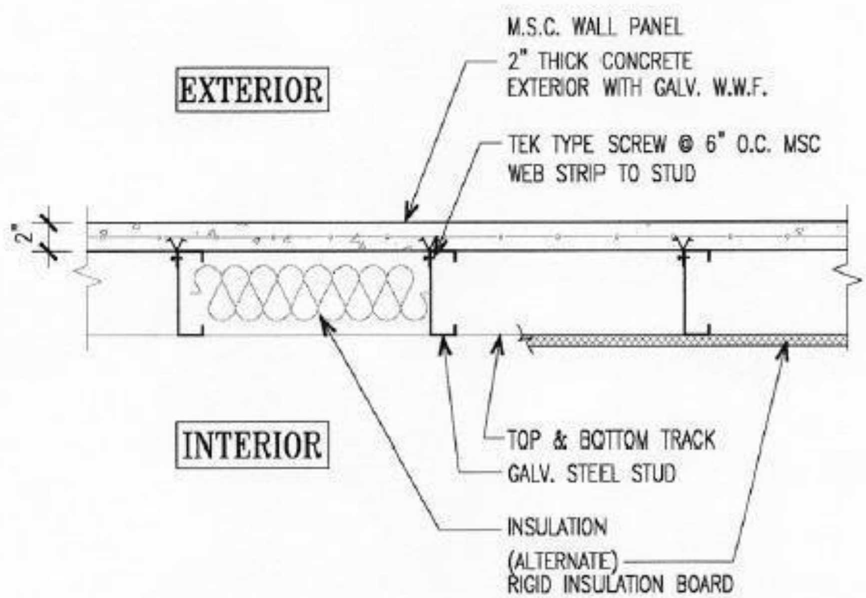
Typical Metal Stud Crete Details

A number of typical details are provided by Earl Corporation to assist in explaining their product functionand design. Two options are shown for attaching the composite connection to the studs, either a face flange is screwed to the stud or a flange is screwed to the slide of the stud. The final design and shop drawings would be done in a collaborative effort with Earl Corporation. The exterior finish would also need to be approved

By the architect on the project, a very similar look to the oversized precast can be achieved.



Metal Stud Crete® Composite System



M.S.C. WALL – PLAN VIEW

1" = 1'-0"

For further details on Metal Stud Crete® panels, contact:

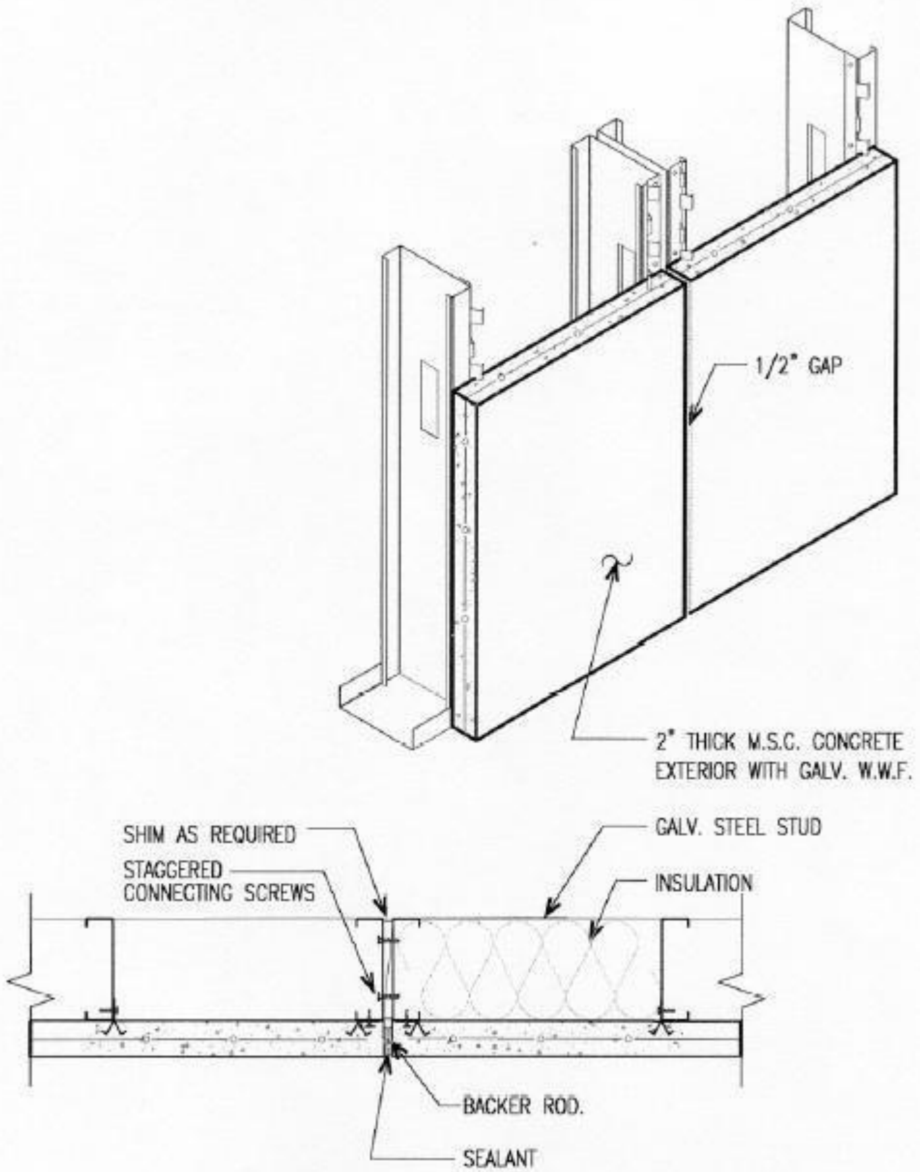
EARL COMPOSITE SYSTEMS

(800) 796-3275, Fax (626) 796-6194

E-Mail: metalcrete@earlcorp.com

Website: www.metalcrete.com

Metal Stud Crete® Composite System



TYPICAL IN-LINE BUTT JOINT

N.T.S.

For further details on Metal Stud Crete ® panels, contact:

EARL COMPOSITE SYSTEMS

(800) 796-3275, Fax (626) 796-6194

E-Mail: metalcrete@earlcorp.com

Website: www.metalcrete.com

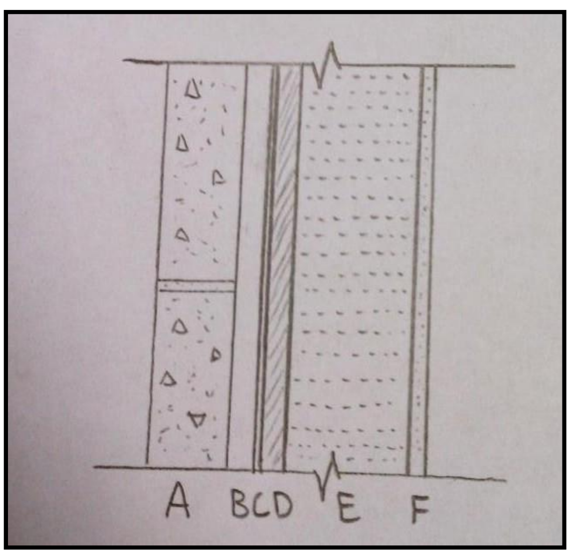
Schedule and Cost of Metal Stud Crete System

To evaluate the cost of the Metal Stud Crete System, a conversation with a representative of Earl Corporation took place. During the conversation a verbal statement, for the DC Region, on average the panels cost $32 per square foot. This price includes pre-casting of concrete walls at one of their locations within 500 miles of the site, transportation to the site and erection of the panels. The price did not include insulation, so an additional phone conversation with NOVA Spray Foam Insulation, LLC, and a DC Metropolitan region spray foam services company was utilized to obtain spray foam information and pricing. And additional $2.40 was added per square foot for open cell foam on the interior, making the total $34.40 per square foot. Total system cost is estimated at $ 2,134,520.

Projected on site erection time for the panels is 17 days. Compared to the original 90 day duration, thisproduct will provide an 80% reduction in this portion of the project. 60 of those original days were on the critical path. There will be an added lead time that can be accounted for that would not exist with the CMU backup system. Besides the direct impact of the affected 62,050 SF of CMU Composite walls other aspects of the building rough-ins and finishes will also be affected. The in-wall electrical rough-inwas originally done in conjunction with the masons laying the block. This is a slower process and increases difficulty of CMU Masonry Construction, ultimately making it less efficient

Regular Metal Stud Back Up

The alternative of using metal stud framing was also identified as a possible option for schedule acceleration and envelope efficiency improvement. An assembly consisting of 25 GA. 6 inch studs, open cell spray foam, 1 inch fiberglass board and the originally designed architectural precast panels.
Advantages of using this system include the ability to increase the speed of enclosing the exterior envelope. Flexibility is increased with possibly changes after installation, prior to precast exterior installation. Also the rough in process for other trades, such as electrical will be increased. The ability to allow trades to follow one another will result in an increased efficiency for both trades and avoid potential conflicts that may arise. Coordination prior to the exterior Back Up walls are installed can be shortened for in wall items, as the metal studs allow increased ability for field adjustments after being enclosed.



Schedule and Cost of Regular Metal Stud Back Up

The estimated cost of the assembly was calculated at $28.00 per square foot, equaling a total of $1,737,400. This cost includes the stud walls, fiberglass board, insulation and precast masonry. It does not include any general conditions costs.
The expected duration for this system will reduce the originally allotted time by 30%. 60 days has been estimated as the duration needed to install this system. The lead times will not be of major concern with this assembly; the materials are typically stocked items at local suppliers.

Alternative Systems Cost Comparisons

Alternative System Cost Comparisons					
	Area (SF)	Assembly $/SF	Estimated Cost	Cost Difference	Duration (days)
CMU Back Up	62050	$ 12.94	$ 802,927	-	90
Metal Stud Crete	62050	$ 34.40	$ 2,134,520	$ 1,331,593	17
Regular Stud Walls	62050	$ 28.00	$ 1,737,400	$ 934,473	60

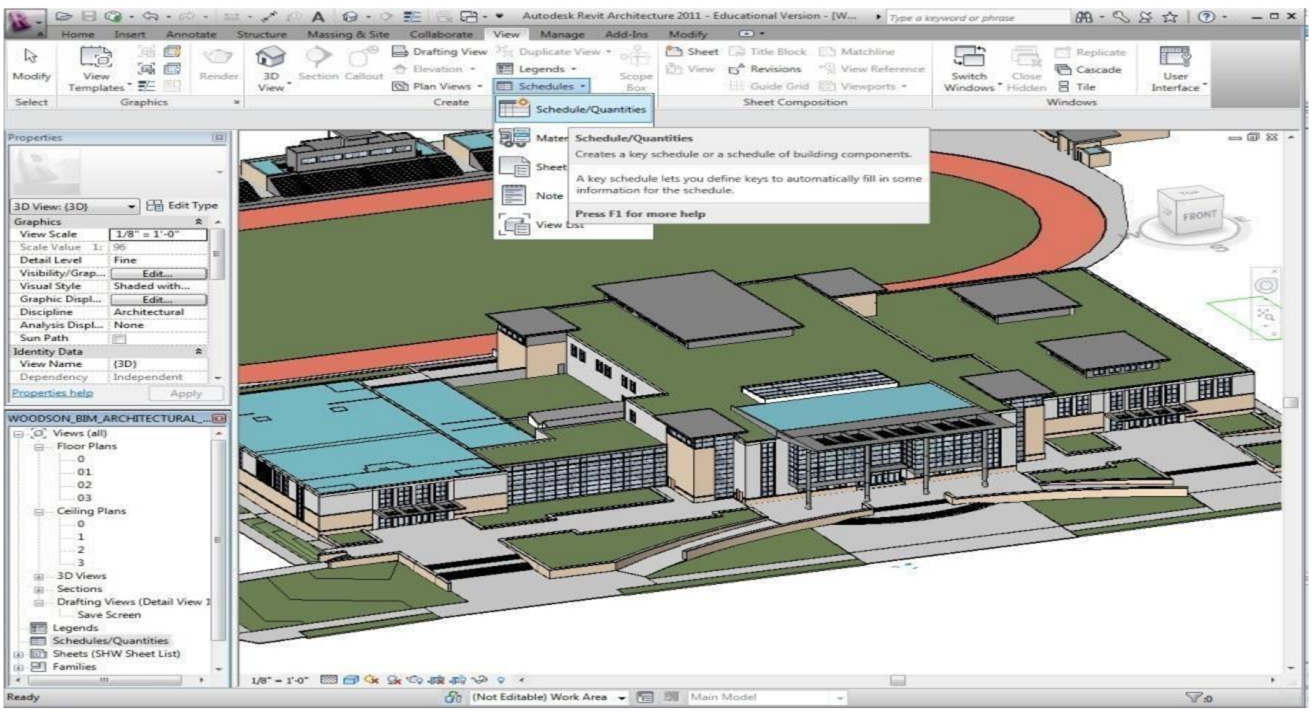
The originally designed CMU assembly was estimated to be the lowest cost version for the wall assemblyitself, but it also has the longest duration. The middle price was $ 1,737,400 with a reduction in schedule time by 30 days. The most expensive assembly is the Metal Stud Crete system that also takes the least amount of time, allowing for the possibility of reducing general conditions cost significantly on the overall project this option begins to be a more realistic figure

BIM Influence on Analysis 3 Alternative Exterior Wall Systems

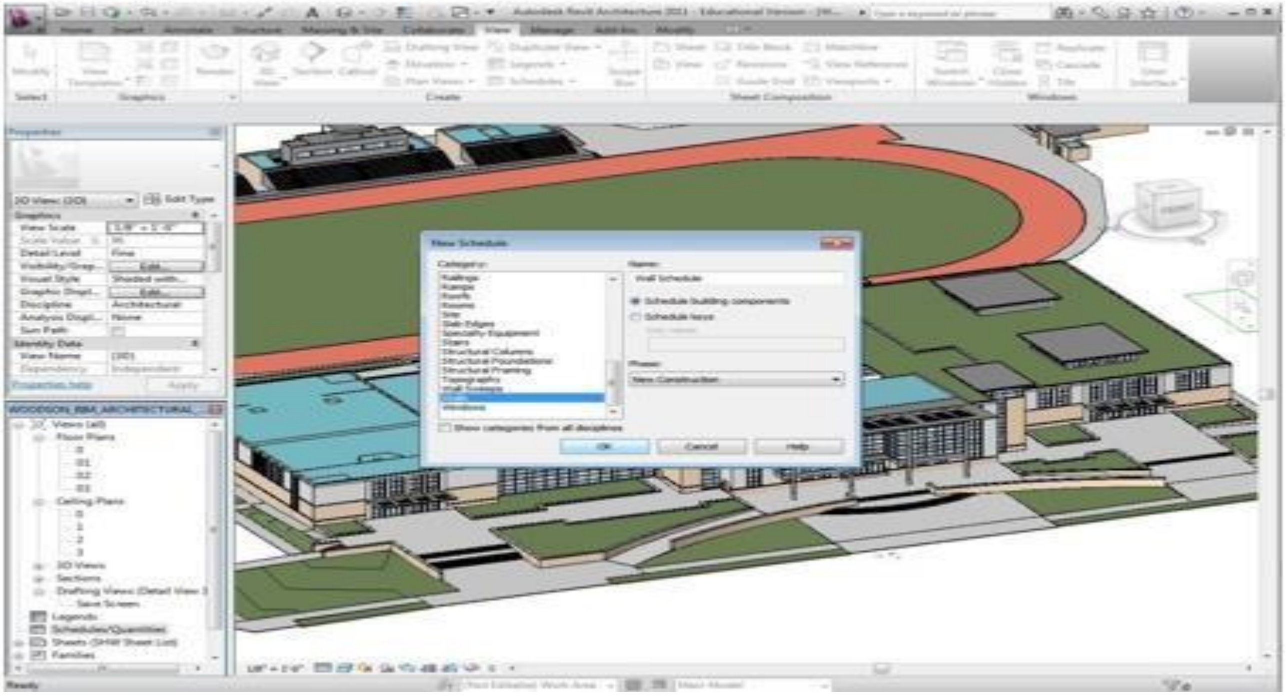
Revit Architectural Model and Revit MEP to analyze alternative wall assemblies could effect on the mechanical systems. Screen shots and descriptions of how the exact CMU exterior composite walls are below. By using the Revit model to calculate electronically the exterior CMU walls many hours of hand takeoffs and calculations were avoided. The ability to quickly have an accurate square footage for estimating allows more time to be focused on selecting viable options and creative problem solving.

By using the Revit model to calculate electronically the exterior CMU walls many hours of hand takeoffs and calculations were avoided.

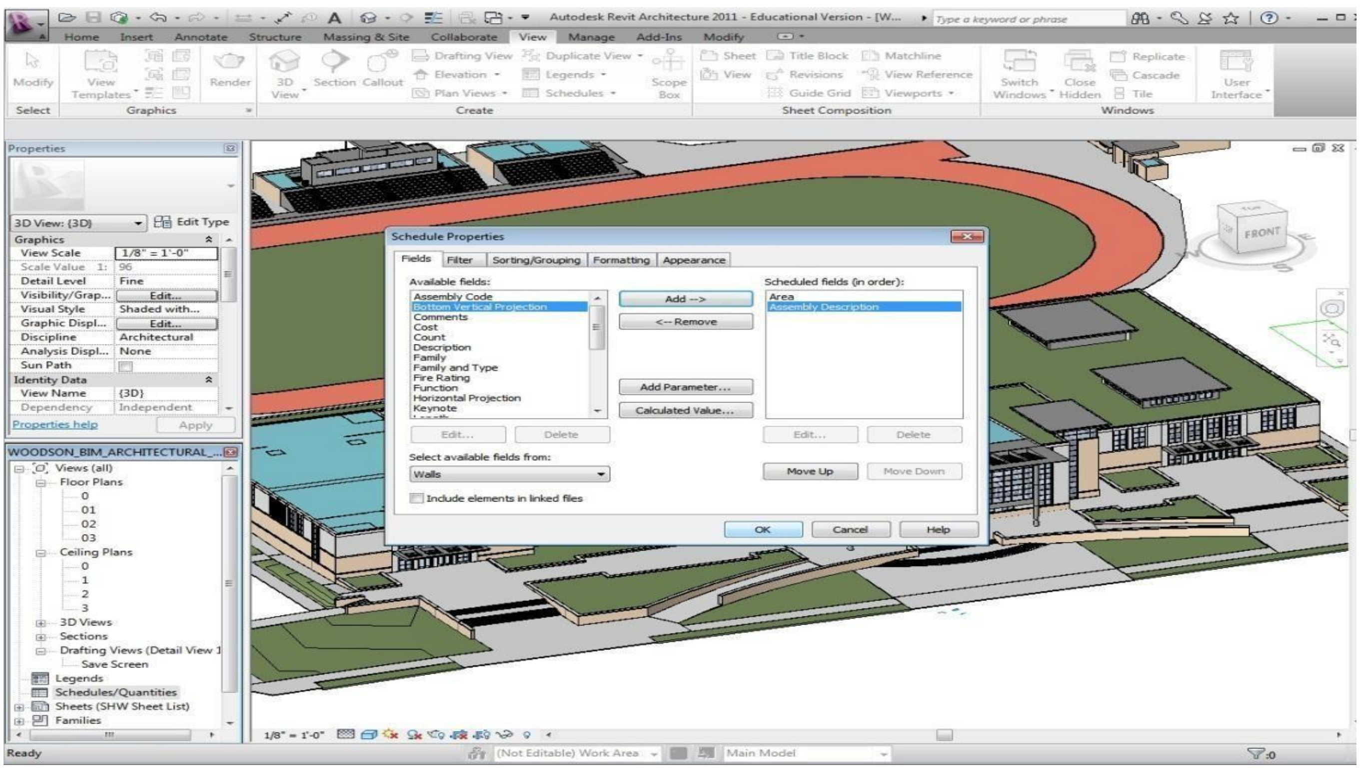
Step 1: Under the View tab the Schedules drop down menu select Schedule/Quantities



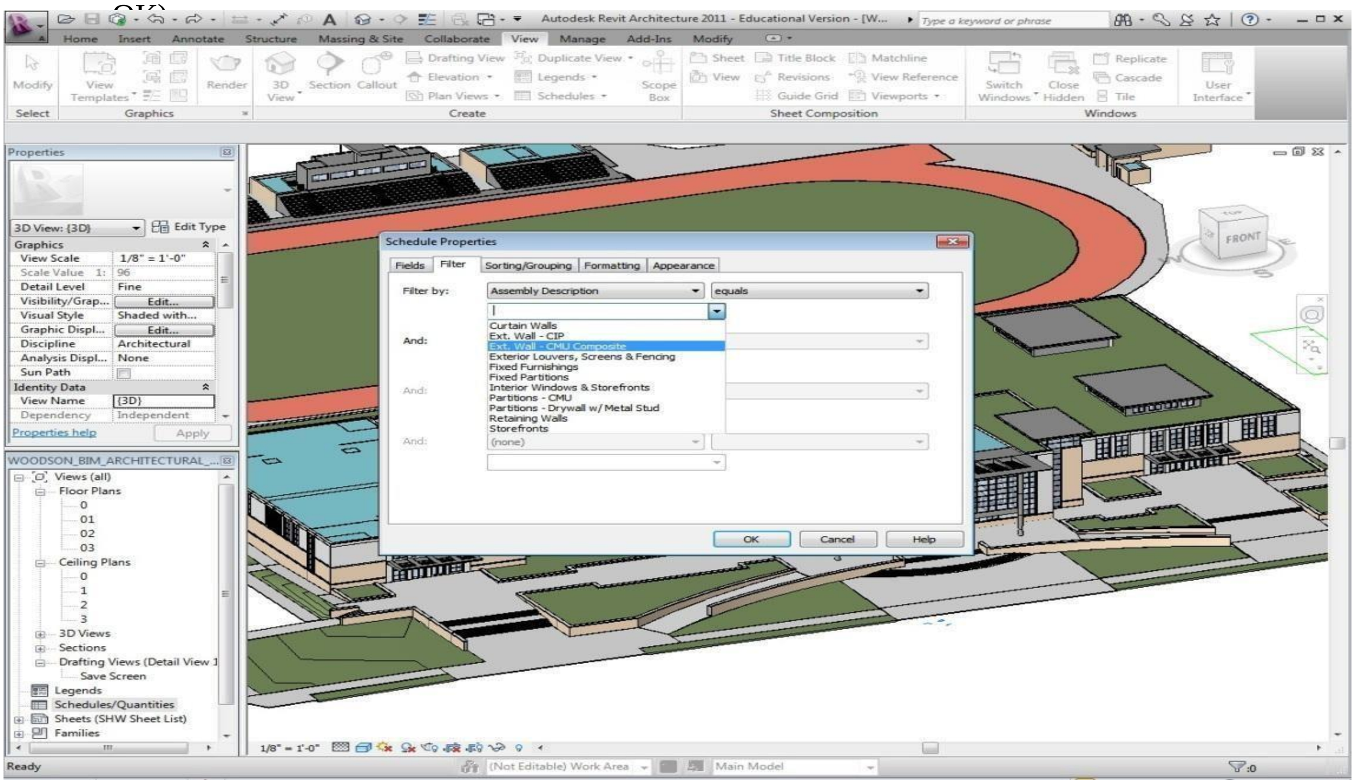
Step 2: On New Schedule pop-up select Walls in left hand menu and Click OK



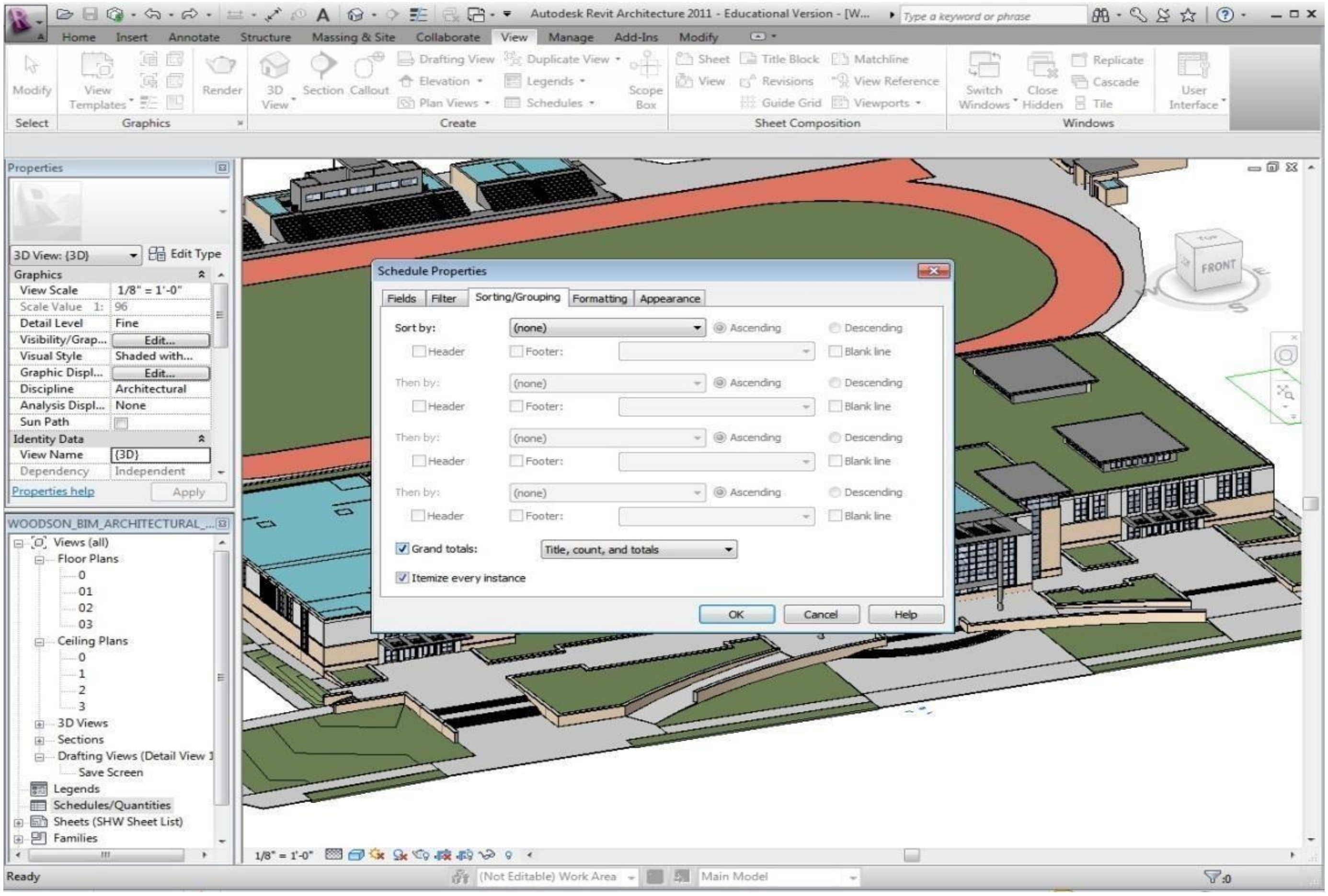
Step 3: Schedule Properties window- Fields Tab- Select, Assembly Description (click Add), Select Area, (click add and do not click OK)



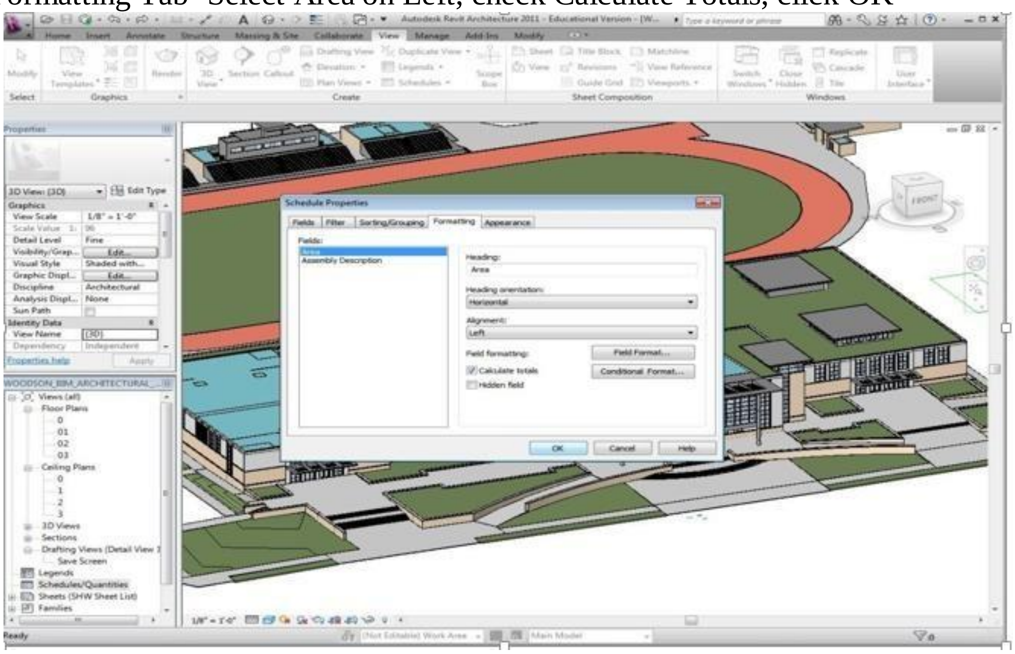
Step 4: Filter Tab- Filter by: Assembly Description- Ext. CMU Composite (do NOT click OK)



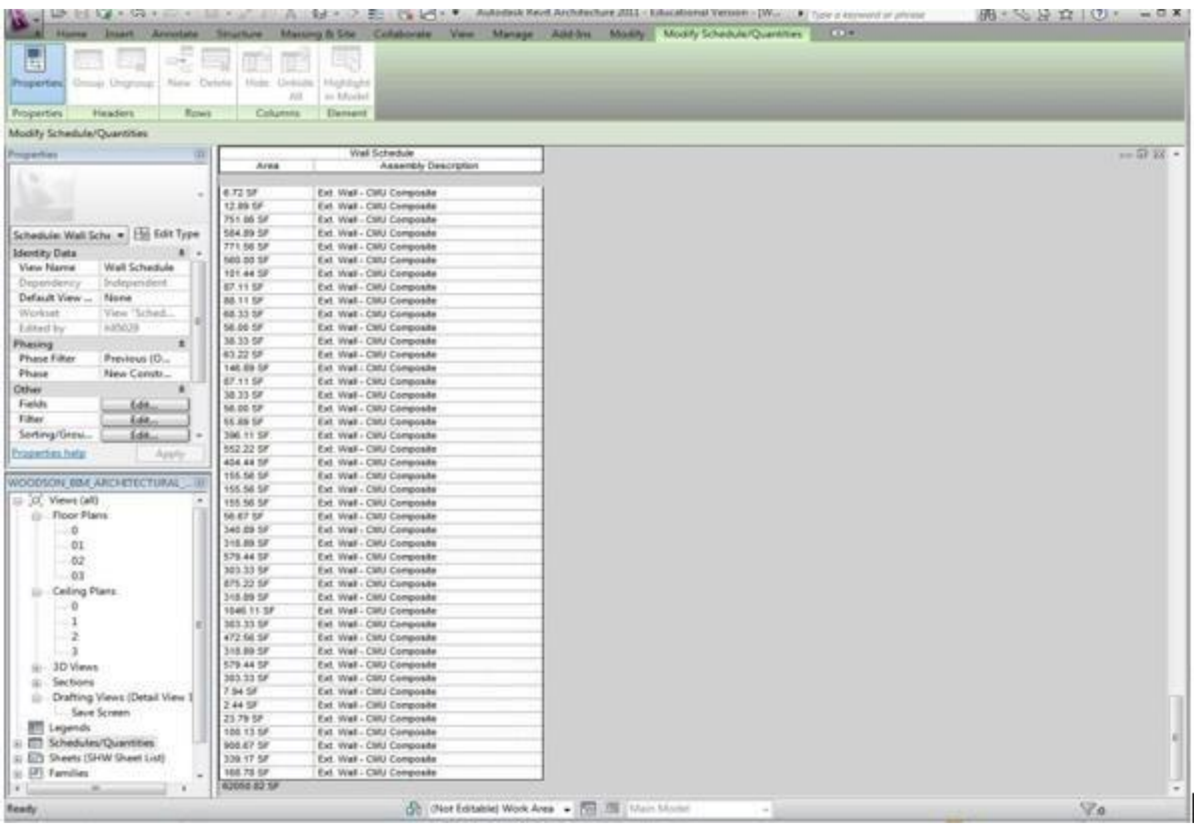
Step 5: Sorting/Grouping- ensure Grand Totals in bottom left is selected (do NOT click OK)



Step 6: Formatting Tab- Select Area on Left, check Calculate Totals, click OK



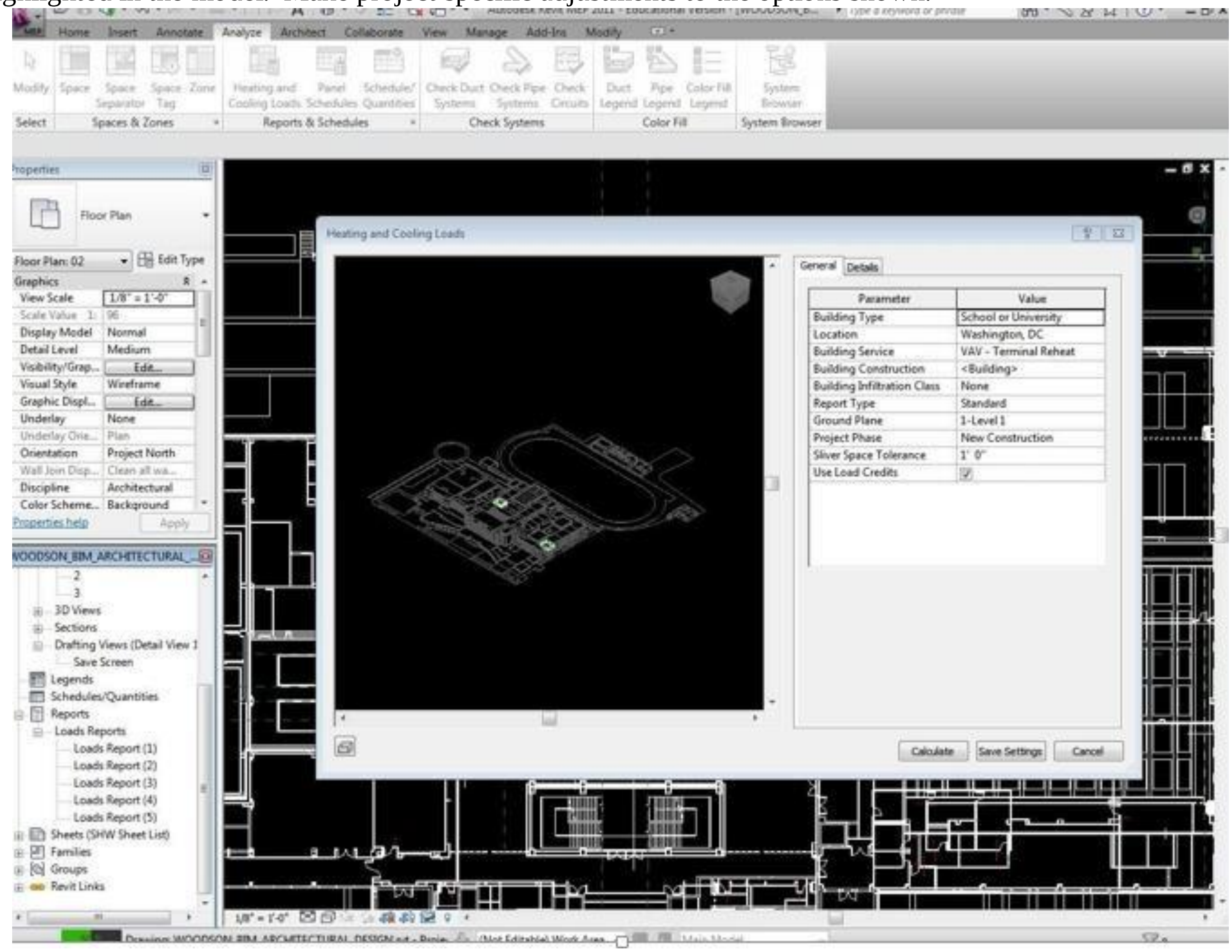
Step 7: Total is displayed at bottom left of table.



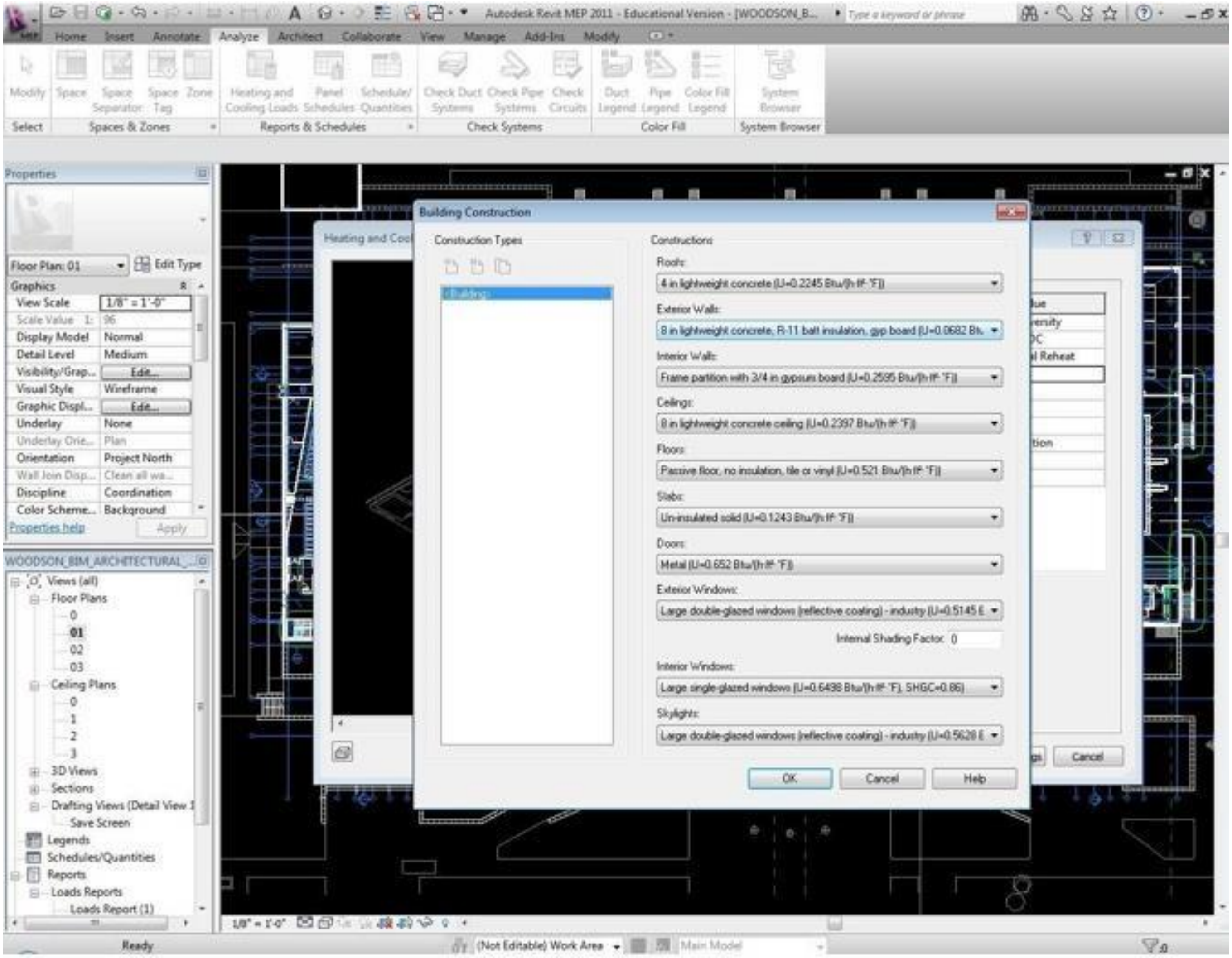
Building Information Modeling also was essential in the Mechanical Breadth Study. By opening the Revit

Architectural Model in Revit MEP the loads in selected spaces were analyzed to determine the effects on the Mechanical System Load when changing the exterior wall construction type. Below is a simplified process that was used for each wall type to allow comparison.

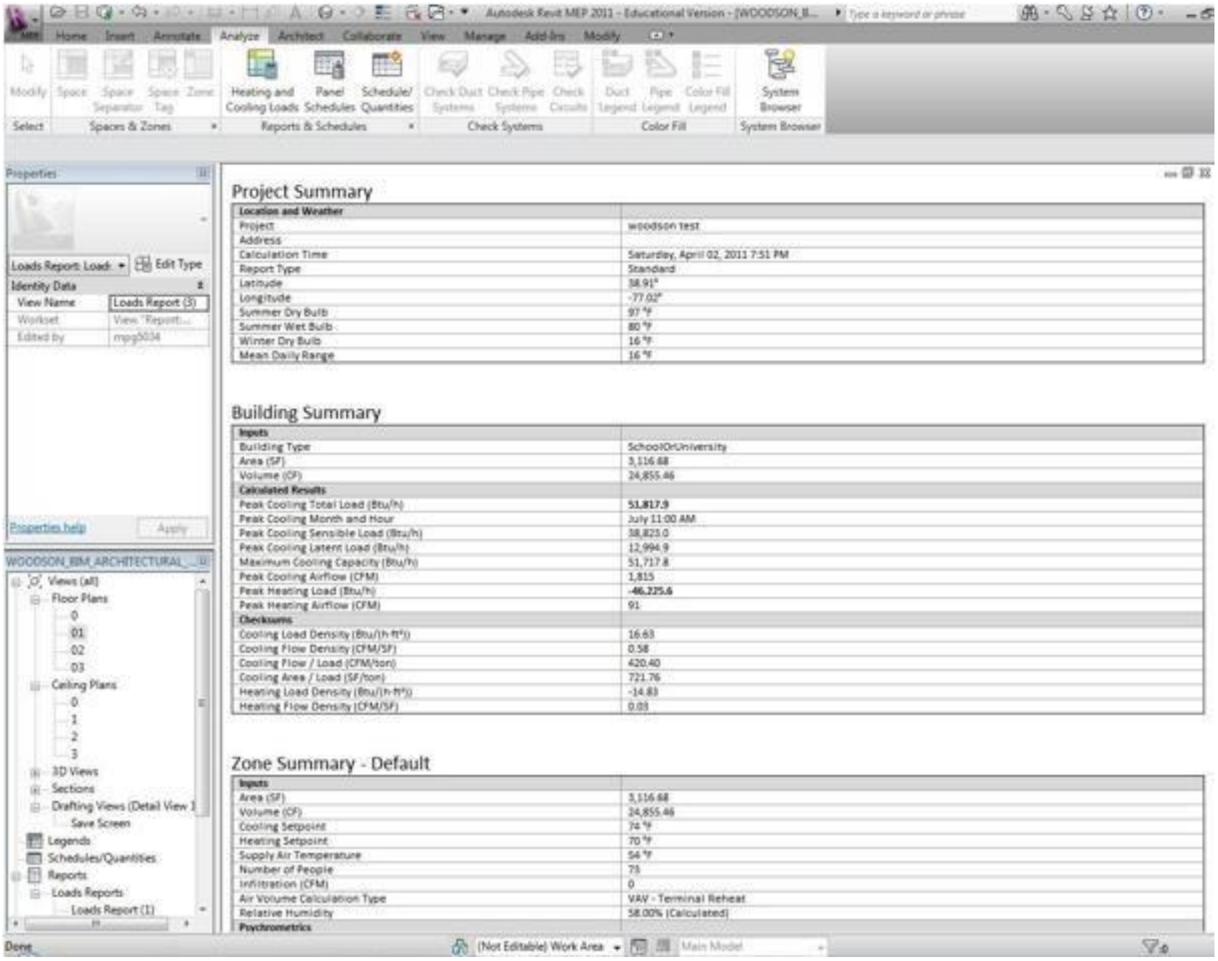
Step 1: After defining the Zones to be calculated on the floor plans, select the Analyze Tab. Under the Analyze tab Select Heating and Cooling Loads. The Window shown below will appear with the two zones highlighted in the model. Make project specific adjustments to the options shown.



Step2: Under the Building Construction Label options select the small box to the right to further define specific system components; this is where the wall types will be changed for each report. In this case the Exterior Walls is what is changed. The exact description is not always an option, so the nearest U value is used for analysis. Select OK when finished defining parameters and select Calculate to generatereport.



Step 3: The Report Summary will appear. At the Bottom of the page the Zones are summarized and specific contributions to the loads are calculated. By repeating this process with the three different exterior wall types a comparison will be able to be made to determine the effects on the mechanical system.



Project Summary

Location and Weather	
Project	woodson test
Address	
Calculation Time	Saturday, April 02, 2011 7:51 PM
Report Type	Standard
Latitude	38.91°
Longitude	-77.02°
Summer Dry Bulb	97 °F
Summer Wet Bulb	80 °F
Winter Dry Bulb	16 °F
Mean Daily Range	16 °F

Building Summary

Inputs	
Building Type	SchoolOrUniversity
Area (SF)	3,116.68
Volume (CF)	24,855.46
Calculated Results	
Peak Cooling Total Load (Btu/h)	**51,817.9**
Peak Cooling Month and Hour	July 11:00 AM
Peak Cooling Sensible Load (Btu/h)	38,823.0
Peak Cooling Latent Load (Btu/h)	12,994.9
Maximum Cooling Capacity (Btu/h)	51,717.8
Peak Cooling Airflow (CFM)	1,815
Peak Heating Load (Btu/h)	**-46,225.6**
Peak Heating Airflow (CFM)	91
Checksums	
Cooling Load Density (Btu/(h·ft²))	16.63
Cooling Flow Density (CFM/SF)	0.58
Cooling Flow / Load (CFM/ton)	420.40
Cooling Area / Load (SF/ton)	721.76
Heating Load Density (Btu/(h·ft²))	-14.83
Heating Flow Density (CFM/SF)	0.03

Zone Summary - Default

Inputs	
Area (SF)	3,116.68
Volume (CF)	24,855.46
Cooling Setpoint	74 °F
Heating Setpoint	70 °F
Supply Air Temperature	54 °F
Number of People	75
Infiltration (CFM)	0
Air Volume Calculation Type	VAV - Terminal Reheat
Relative Humidity	58.00% (Calculated)
Psychrometrics	

Thermal Property Considerations – Mechanical Breadth

In order to demonstrate mechanical breath a comparison of wall assembly effects on the building mechanical system loads was calculated. The R and U values were calculated for the original CMU walls and the two alternatives. The U value was then used to determine the Q (BTU/hr.) through the wall assemblies. This value will then be used to calculate the potential impact on the Mechanical System load using BIM in the form of Revit MEP. Refer to BIM Influences on Analysis 3 for the detail on how the loads were determined for comparison.

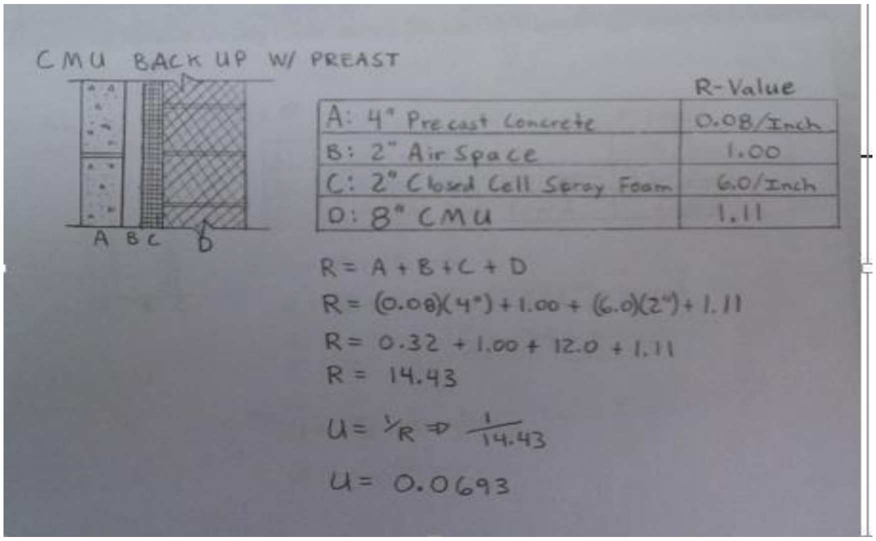
The original system has 2” of closed cell spray foam on the exterior of the CMU wall, between the precast and CMU. The other two assemblies have been selected using open cell spray foam on the interior side between the stud cavities. Open cell and closed cell spray foams have a few differences that are important to know when deciding the location in the assembly and application desired. They both provide very good air sealing and low air infiltration compared to fiberglass bat and cellulose insulation. The reason for selecting the open cell for the alternative systems is the exposure factors and the cost. The closed cell is overkill for the space and the insulation will be well protected in both alternatives. Closed cell can also add a slight increase in wall strength.

Open Cell vs. Closed Cell Spray Foam		
	Open Cell	**Closed Cell**
Cost per Board Foot (1"x12"x12")	$ 0.60	$ 1.50
R-Value per inch	**3.5**	**6.0**
Typical Exposure/Durability	Softer feeling and weaker, air fills voids in tiny cells that aren'tcompletely closed (Usually towards interior side of assembly for protection)	Gas filled tiny cells are able to resist water vapor and moisture infiltration (Can be applied closerto exterior or below grade, and roofing application)
Density	Medium (1.75 - 2.25 lbs./ft^3)	Low (0.4 - 1.2 lbs./ft^3)

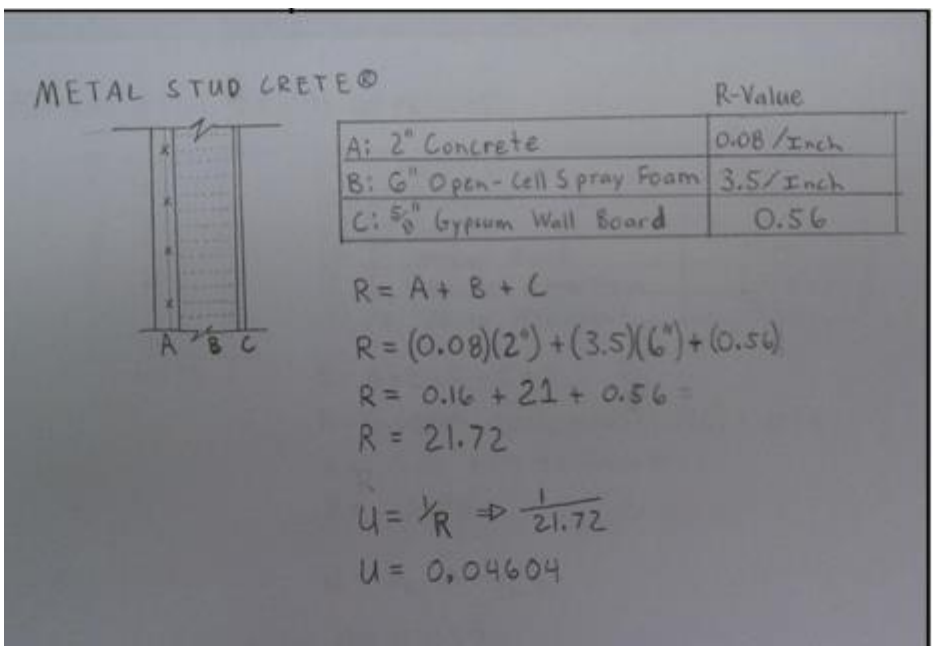
The R and U value are the basis of comparison for the mechanical breadth. These calculations weredone by hand and the results are summarized below as well as the individual calculations.

Original CMU Assembly

Wall Assembly Options R and U Values		
	R	U
Original CMU	14.43	0.0693
Metal Stud Crete	21.72	0.0460 4
Metal Stud Framing	26.88	0.0372



Metal Stud Crete



The two alternate systems proposed for exterior wall assemblies reduce the load on the mechanical system. The load contributed by the exterior walls is reduced. This load differential is not a significant change and will not add cost of upgrading the mechanical system; however it is recommended that theMechanical Engineer be consulted for potential downsizing and verification upon alternative wall assembly selection. The three walls are compared in Table 16 and Table 17.

Space 1 - Heating and Cooling Load Comparisons						
	Cooling			Heating		
	Loads BTU/hr.	% of Total	Cooling Savings	Loads BTU/hr.	% of Total	Heat Savings
Original CMU Back Up	19	0.14%		36.6	0.26%	
Metal Stud Crete	12.5	0.09%	6.5	24.6	0.17%	12
Metal Stud Back Up	10.3	0.08%	8.7	20.3	0.14%	16.3

Overall the exterior wall enclosure accounts for less than 1% of the space load. 90% of the space loadsare contributed by the Occupants, Lighting and Power (computers). However comparisons of the exterior walls are still advantageous. Table 18 shows the Zone Summary for Space 1, a third floor classroom with exterior wall exposure to the South. The total cooling load (BTU/hour) is 19 or 0.14% and heating load (BTU/hour) is 36.6, 0.26%. This report is for the CMU Back Up walls or the basis on which the alternate system would need to improve upon. The other space summaries can be found inAppendix

An important aspect of changing wall types to consider is the electrical in-wall rough-in. There are manydifferences in the rough-in process to analyze. The CMU rough-in process is more time consuming and more expensive for both material and labor. In order to rough-in CMU walls EMT conduit must be used.Typical when EMT is used 10’ sections are able to be installed, however; when used in CMU walls 3’ sections are installed, in the vertical direction, as an assembly working in conjunction with the masons. Wires would then also have to be pulled through the conduits as well. When discussing this topic with the electrical sub-contractor labor and costs were discussed, based on a 10’ section with a single device.The cost of devices will not vary but the CMU assembly is significantly longer time and at a higher cost. The labor rate for rough in is very contingent on the Masons as well. The comparison below shows best case scenario for rough-in.

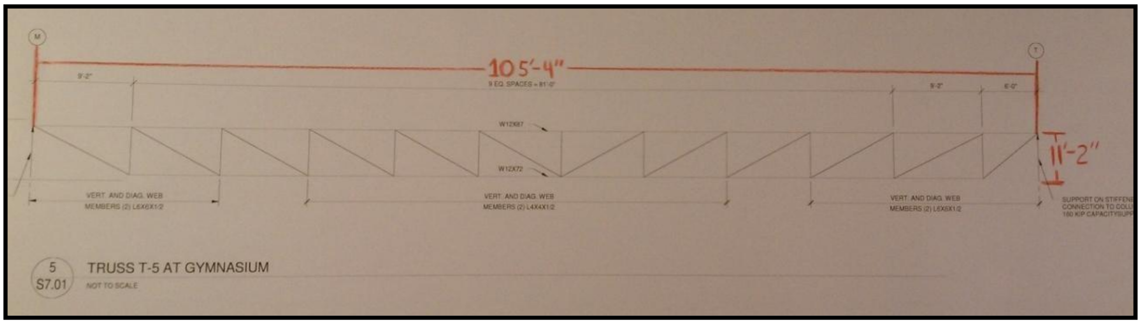
Metal Stud walls and the specifications at VSPL HS allow for the use of MC Cable. MC Cable is aflexible metal conduit with wire already in it. The process is much simpler and allows for a faster rough-in. The cable can be pulled in many directions and snake through much easier, with supports every 4’. Both assembly comparisons include the boxes and box supports. The possibility to save $ 8.50 per 10’ device and rough-in assembly and a labor saving of half an hour exists.

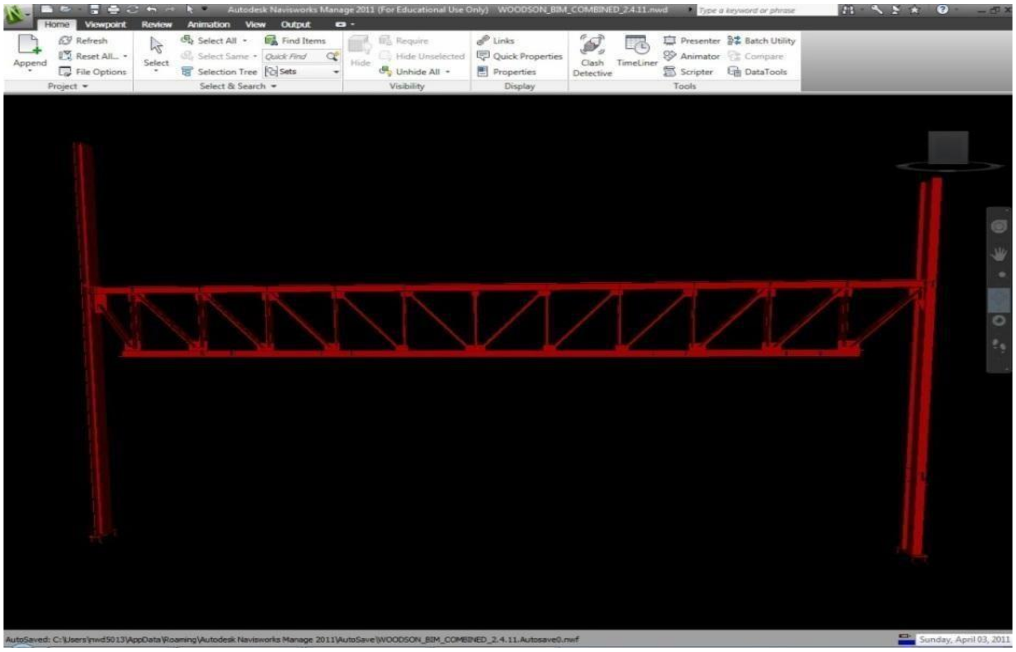
ANALYSIS 4: ALTERNATIVE STEEL TRUSS CONSTRUCTION

Single Piece Truss Discussion

There are a number of advantages and dis advantages to transporting and erecting the truss in a singlepiece. Advantages include single truck for each truss, single pick to erect truss, on site labor and construction is minimized for steel fabrication, low residual stress risk. Disadvantages are the length makes transportation more challenging and at a higher cost due to special load requirements, restrictions and escorts. The risk associated with the transportation of a steel member this large is alsovery high. A viable solution would reduce these risks while maintaining the advantages.

The single member allows for the minimum schedule time and risk to the steel erection sequence. The trusses are supporting two floors above the gymnasium that are supported by the trusses. The location of two columns, on one of trusses is potentially an issue with splicing the truss together in the field. Oneof the single piece trusses, T-5, is shown in Figure 20. The location of the columns supported of one of the trusses is shown in Figure 22. There are two different trusses the T-4 and T-5, the differences are mostly in the length, for this analysis, the principles should still apply.





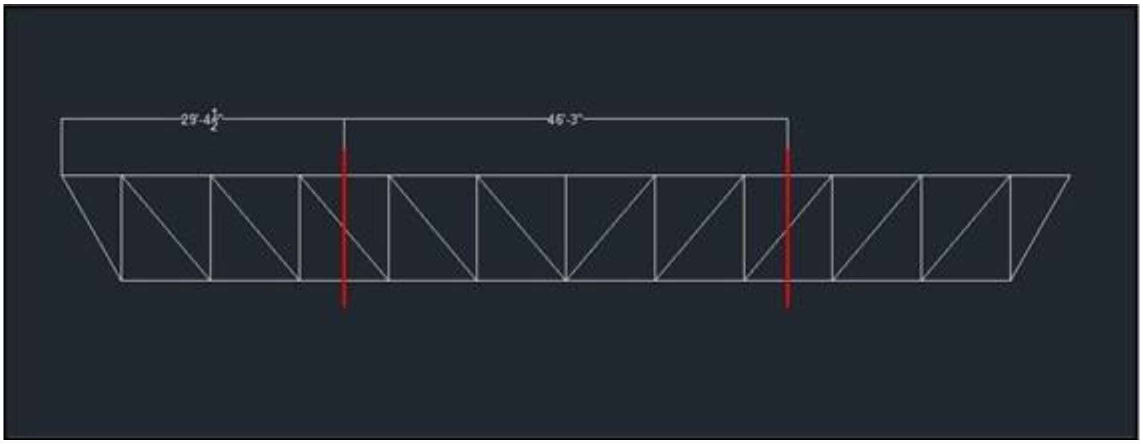
Spliced Truss Options Discussion

In order to splice the truss in an appropriate location and ensure proper design the structural engineerwould have to be consulted. The following discussion would only apply if the design was approved by the proper engineer.

Through a consultation with a fellow AE Structural option student, the suggested locations found in Figure 23. The web members of the truss are welded L Sections or W Section members, and the welds indicate moment resistance in the Webs. The moment is the lowest crossing through the center of the web members. This is why the truss is suggested to be spliced at the locations indicated. An increase inWeb member may be necessary as well as a stiffener plate to transfer the moment. The maximum distance away from the joint is also desired to make the strongest joint possible

Transportation

The costs for transportation are typically priced by ton per mile. The loads even when spliced would stillbe considered an unusual load and prices can typically range from $ 105 to $ 150 a ton per mile. If police escorts are required costs could reach up to $ 175 a ton per mile. The best case scenario would allow shipping to still use the same number of loads as there are trusses and reduce overall length to eliminate police escorts. The main points to consider when determining the transportation of the trusses will be the length, overhang, weight, width and height. Each state has different rules, regulations and permit requirements.



In order to assemble the truss a level and open area will be needed. Gymnasium footprint below wherethe trusses will be going could work for this space. The deliveries can enter the site via EADS St. to the south and driving in a single direction around the building. Figure 24, shows the designated area for thetruss delivery and on site fabrication/assembly area. By assembling the trusses on site, in the area designated with the access road running between the fabrication area and the gymnasium, the crane will be able to swing the trusses into place without having to walk the trusses. The temporary pad will require a level area and temporary supports to allow the trusses to be assembled quickly

Schedule Impacts of On-site Truss Assembly

The erection time of the trusses will increase causing an issue if they were to be delivered as originally scheduled. The trusses would have to be coordinated and approved earlier to allow time for site assembly. Risk is elevated of losing schedule time due to weather factors by fabricating on site. The on-site fabrication time would take up to 2 days for each truss as opposed to delivering the trusses and erecting the same day of arrival. The gym trusses are on the critical path with 5 days allotted beginning August 10, 2010. The added risk of not just delaying the trusses but the remaining steel sequence is a big risk.

Alternative Truss Assembly Conclusion

The proposal to splice the trusses is not recommended. There are a number of reasons why this recommendation is being made. The difficulty of assembling the members on site and schedule risk does not outweigh the little or no cost savings that may have been possible. Removing a process from acontrolled environment, especially steel fabrication increases cost, difficulty and time. The weather poses the risk of losing a day or multiple days on erection time for the gymnasium trusses, which would be unacceptable.

CHAPTER 5
FINAL CONCLUSION

The analyses conducted on VSPL Senior WILO ENGINEERS PVT LTD over the previous year, have developed andconsidered alternative options that improve upon the original design and construction plan. The final report serves as the culmination of these analyses and a source of ideas for future projects. The findingsand investigations are not intended in any way to find flaws or perceived mistakes in the actual project. The suggestions and concepts developed are theoretical and solely for the purpose of the senior thesis capstone course.

Building Information Modeling can be a very valuable tool and process in building construction. Throughthe Building Information Modeling Execution Planning Guide, developed at Penn State, allows the maximum value to be achieved with BIM. The VSPL WILO ENGINEERS PVT LTD Project Team used BIM effectively on the project.

Value Engineering is the process that includes developing and evaluating alternative construction methods and techniques to add value to a project. In Analysis two the suggestion of LEED elements being excluded from the value engineering process explores a potential situation if the green roof was included in the value engineering process. Through removal of the green roof, increasing the R-Value ofthe roof assembly and expanding the greater system, value was theoretically added through a cost savings and reduction of Potable water use in the operation of the building. Additionally the green roofload on the structure will be removed allowing the size and weight of the steel framing members to be reduced.

Alternative Exterior Wall Assemblies were explored and two options were developed to compare to theoriginal system. The recommendation of the Metal Stud Crete system was made. This system, while initially costing less can provide serious schedule acceleration for the exterior enclosure. It will also provide a reduction of loading on the mechanical system from the exterior walls.

Alternative Truss Assembly explored the opportunity to splice the 100+ feet trusses used over the gymnasium. While structurally the trusses would most likely be able to be splice with minor modifications, from a constructability stand point it does not make sense to do this. Splicing wouldsimplify transportation however, the on-site assembly and schedule risk do not provide enough justification to remove a process from a controlled environment and increase risk.

These analyses and breadth topics have allowed a study into how building system assemblies and construction techniques can affect other systems of a building. Through Building information modeling alternative designs and options can be explored quickly and efficiently, allowing more opportunities andoptions to be explored.

<u>CHAPTER 6</u>
BIBLIOGRAPHY

ASI Spray Insulation Professionals. (2011). (Blaze shield II). Retrieved March 2011, Fireproofing + ThermalInsulation=Energy Savings and Protection: http://www.asispray.com.

Border, T. (2011, April 4). Transportation Cost Information. (N. Diehl, Interviewer) Clark, P. (2011, March 29). Metal Stud Crete-Earl Corporation. (N. Diehl, Interviewer)
Computer Integrated Construction Research Program. (2010). (Version 2.0 Guide and Templates).Building Information Modeling Project Execution Planning Guide.

District of Columbia Department of Energy. (2011). (Green Roof Case Studies). Retrieved March 2011,Green Roofs in the District - Showcase Projects: http://ddoe.dc.gov/ddoe.

EPDM Roofing Association. (2011). (Multiple articles and Data). Retrieved March 2011:http://www.edpmroofs.org.

Gambino, T. (2011, April 5). Electrical Rough in Information. (N. Diehl, Interviewer)

Reinsulate. (2011). (Green Roof Diagram and Research). Retrieved March-April 2011, what is a GreenRoof? http://www.greensulate.com.

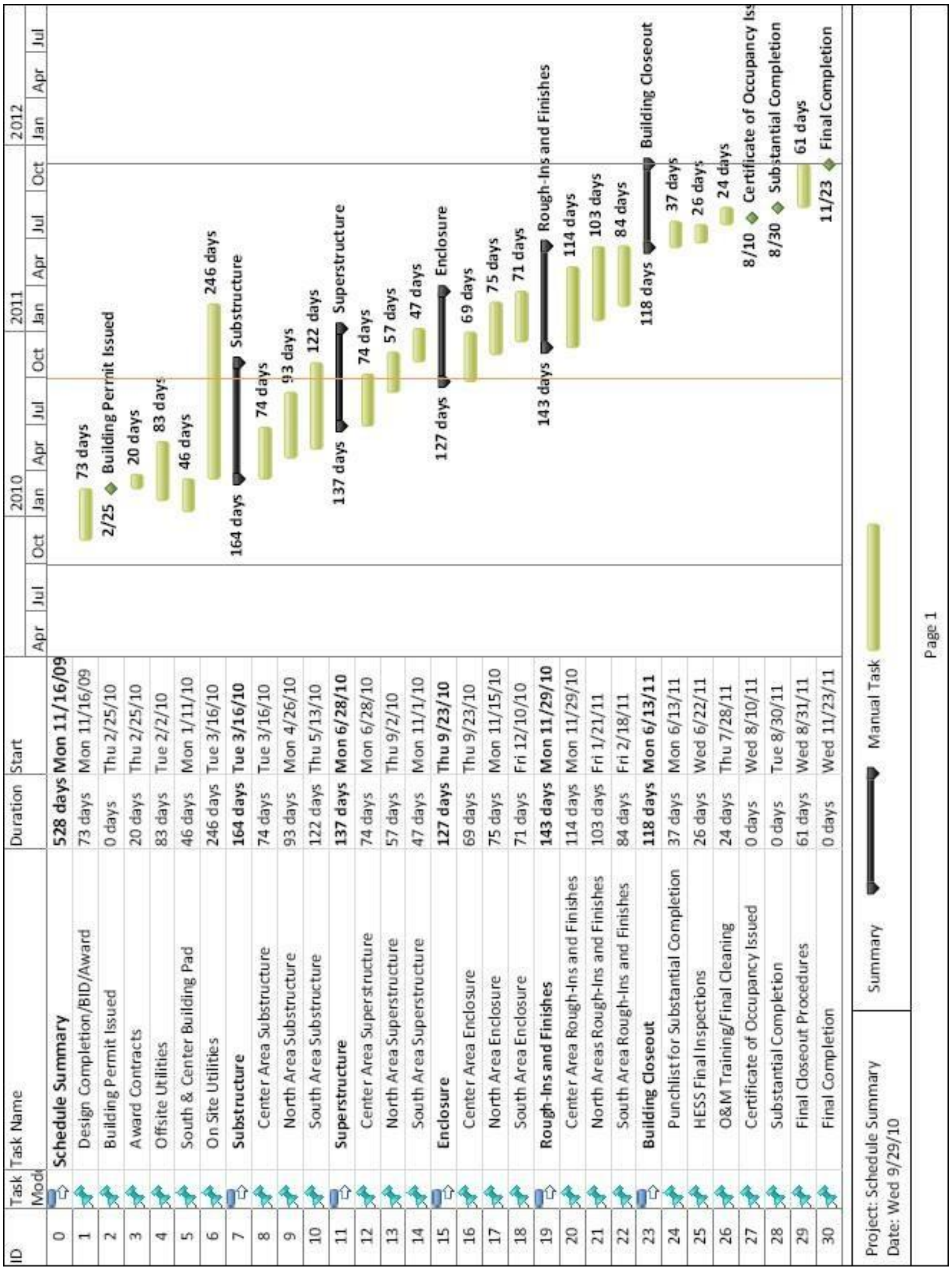
Metal Stud Crete. (2011). (Typical Details and General Information). Retrieved March 2011:http://www.metalcrete.com.

Reinsulate. (2011). (Green Roof Diagram and Research). Retrieved March-April 2011, what is a GreenRoof? http://www.greensulate.com.

Wideloadshipping.com. (2011). (Shipping Restrictions). Retrieved March -April 2011, State Regulations:http://www.wideloadshipping.com.

CHAPTER 7
ANNEXURE –A&B

A. Total Project Schedule Summary Gantt chart



B. LEED Scorecard for Original Design

LEED 2009 for Schools New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N			
16	3	5	**Sustainable Sites**	Possible Points:	24
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Prereq 2	Environmental Site Assessment	
		1	Credit 1	Site Selection	1
4			Credit 2	Development Density and Community Connectivity	4
		1	Credit 3	Brownfield Redevelopment	1
4			Credit 4.1	Alternative Transportation—Public Transportation Access	4
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
	2		Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	2
2			Credit 4.4	Alternative Transportation—Parking Capacity	2
		1	Credit 5.1	Site Development—Protect or Restore Habitat	1
		1	Credit 5.2	Site Development—Maximize Open Space	1
	1		Credit 6.1	Stormwater Design—Quantity Control	1
1			Credit 6.2	Stormwater Design—Quality Control	1
		1	Credit 7.1	Heat Island Effect—Non-roof	1
1			Credit 7.2	Heat Island Effect—Roof	1
1			Credit 8	Light Pollution Reduction	1
1			Credit 9	Site Master Plan	1
1			Credit 10	Joint Use of Facilities	1
9	2		**Water Efficiency**	Possible Points:	11
Y			Prereq 1	Water Use Reduction—20% Reduction	
4			Credit 1	Water Efficient Landscaping	2 to 4
2			Credit 2	Innovative Wastewater Technologies	2
2	2		Credit 3	Water Use Reduction	2 to 4
1			Credit 3	Process Water Use Reduction	1
12		20	**Energy and Atmosphere**	Possible Points:	33
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
7		11	Credit 1	Optimize Energy Performance	1 to 19
		7	Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
1			Credit 4	Enhanced Refrigerant Management	1
2			Credit 5	Measurement and Verification	2
		2	Credit 6	Green Power	2
6	1	6	**Materials and Resources**	Possible Points:	13
Y			Prereq 1	Storage and Collection of Recyclables	
		2	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 2
		1	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
2			Credit 2	Construction Waste Management	1 to 2
			Materials and Resources, Continued		
		2	Credit 3	Materials Reuse	1 to 2
2			Credit 4	Recycled Content	1 to 2
2			Credit 5	Regional Materials	1 to 2
		1	Credit 6	Rapidly Renewable Materials	1
	1		Credit 7	Certified Wood	1
16		1	**Indoor Environmental Quality**	Possible Points:	19
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Minimum Acoustical Performance	
1			Credit 1	Outdoor Air Delivery Monitoring	1
1			Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
4			Credit 4	Low-Emitting Materials	1 to 4
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
1			Credit 8.1	Daylight and Views—Daylight	1 to 3
		1	Credit 8.2	Daylight and Views—Views	1
1			Credit 9	Enhanced Acoustical Performance	1
1			Credit 10	Mold Prevention	1
2	1	3	**Innovation and Design Process**	Possible Points:	6
	1		Credit 1.1	Innovation in Design: Specific Title	1
		1	Credit 1.2	Innovation in Design: Specific Title	1
		1	Credit 1.3	Innovation in Design: Specific Title	1
		1	Credit 1.4	Innovation in Design: Specific Title	1
1			Credit 2	LEED Accredited Professional	1
1			Credit 3	The School as a Teaching Tool	1
			Regional Priority Credits	Possible Points:	4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
61	7	35	**Total**	Possible Points:	110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110